Feeding strategies for Holando Argentino steers aimed at different markets

Estrategias de alimentación de novillos Holando Argentino para diferentes destinos comerciales

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Abstract

The objective was to evaluate the performance and meat quality of Holando Argentino (HA) steers under different feeding strategies. One hundred twenty-eight HA steers (181.4 ± 25.5 kg of live weight [LW]) were allocated to four treatments: FL: feedlot finishing during 98 days; Gr1.25: grazing with 1.25% LW/day maize grain supplementation during 235 days; Gr0.70: grazing with 0.70% LW/day maize grain supplementation during 331 days; and GrFL: 287 days grazing background and 116 days feedlot finishing. Average daily gains (ADG) were 1.14, 1.02, 0.82, and 0.81 kg/day for FL, Gr1.25, Gr0.70, and GrFL, respectively (p<0.01). Adjusted productivity ranged between 710 and 741 kg LW/ha (p>0.05). GrFL and Gr0.70 presented the highest carcass weight (CW; 288.3 ± 5.0 and 267.8 ± 12.2 kg, respectively, p<0.001). Gr0.70 presented the lowest *longissimus thoracis* (LT) *L** (p<0.01) and the highest *a** (p<0.05). Intramuscular fat was the highest for GrFL (4.86 ± 0.93%, p<0.05). In all strategies, LT shear force presented values of tender meat (29.9 ± 3.4 N, p=0.60). HA steers have the flexibility to produce tender meat under different, high-productivity strategies.

Keywords
dairy breeds • grazing steers • supplementation • feedlot steers • shear force • intramuscular fat • meat color • fat color

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Resumen

El objetivo fue evaluar el desempeño y la calidad de la carne de novillos Holando Argentino (HA) alimentados bajo diferentes estrategias. Se utilizaron 128 terneros HA (181,4 ± 25,5 kg de peso vivo [PV]) que se asignaron a cuatro tratamientos: FL: terminación a corral durante 98 días; Gr1,25: invernada pastoril con suplementación con grano de maíz al 1,25% PV/día durante 235 días; Gr0,70: invernada pastoril con suplementación con grano de maíz al 0,70% PV/día durante 331 días; y GrFL: recría pastoril durante 287 días y terminación a corral durante 116 días. Los aumentos medios diarios fueron 1,14, 1,02, 0,82 y 0,81 kg PV/día para FL, Gr1,25, Gr0,70 y GrFL, respectivamente (p<0,01). La productividad ajustada varió entre 710 y 741 kg PV/ha (p>0,05). GrFL y Gr0,70 presentaron el mayor peso de res (288,3 ± 5,0 y 267,8 ± 12,2 kg, respectivamente, p<0,001). Gr0.70 presentó el menor *L** (p<0,01) y el mayor *a** (p<0,05) del *longissimus thoracis* (LT). El mayor contenido de grasa del LT fue producido por GrFL (4,86 ± 0,93%, p<0,05). En todas las estrategias, la resistencia al corte del LT presentó valores que corresponden a carnes tiernas (29,9 ± 3,4 N, p=0,60). Los novillos HA tienen la flexibilidad de producir carne tierna bajo diferentes estrategias de alta productividad.

Palabras clave

razas lecheras • novillos en pastoreo • suplementación en pastoreo • alimentación a corral • resistencia al corte • grasa intramuscular • color de la carne • color de la grasa

Introduction

The availability of Holando Argentino (HA) male steers in the Argentine pampas represents an opportunity for meat production, considering their high growth potential and favorable purchase-to-sale price ratio. Locally, different feeding strategies have been evaluated for HA steers. On one side, intensive grazing systems slaughter between 460 and 540 kg LW, aiming for export markets (19, 21). On the other hand, calf feeding systems with slaughter LW between 300 and 370 kg (20) satisfy local demands characterized by small cuts.

Dairy breeds present higher maintenance requirements and different fat deposition patterns than beef breeds, compromising early slaughter and market acceptability (3). One way to increase local acceptability and market allocation flexibility of meat from HA steers, fed under grazing systems, is to achieve high growth rates, reaching the finishing endpoint at moderate LW (*i.e.* <450 kg). In this sense, using energetic supplements can increase daily gain and fattening rate, reducing the growing and finishing periods (24, 37). Furthermore, new export market opportunities like tax-free meat quota for the European Union, called quota 481, could emerge (23). This quota applies to meat from steers fed with high-concentrate diets for a minimum of 100 days and less than 30 months of age at slaughter.

Concerning meat quality, previous research has shown that meat obtained from dairy breeds has similar overall quality to that obtained from British beef breeds (3). Accordingly, Latimori *et al.* (2008) found that HA steers fed under different strategies presented no differences in tenderness compared with British or crossbred steers, despite having lower marbling scores than meat from Angus steers.

Feeding strategies for finishing steers can vary from pasture-based to concentrated feeding, resulting in different LW gains, age at harvest, final LW, CW, and fatness degree, which can also impact meat quality and market destination (30). Therefore, strategies need to be evaluated taking all these aspects into account. The main objective of this study was to evaluate productivity, animal performance, and meat quality from HA steers fed under contrasting strategies, ranging from grazing with different supplementation levels to feedlot finishing. A second objective was to identify the main traits defining carcass and meat quality of HA steers across diverse feeding strategies and to quantify the relationships among these traits.

Materials and methods

Site and feeding strategies

The study was conducted at the Marcos Juárez Agricultural Experimental Station of the National Institute of Agricultural Technology (INTA). Grazing strategies were evaluated on mixed pastures of alfalfa (*Medicago sativa*) and tall fescue (*Lolium arundinaceum*), established on argiudoll soil with no limitations. The region's climate is temperate, with a mean temperature of 17.9°C and an annual rainfall of 887 mm (14). Live animal management was conducted according to the standards and conditions of the Animal Ethics Committee of INTA.

A total of 128 HA steers with 5 to 7 months of age (181.4 ± 25.5 kg LW) were purchased. Upon arrival at the Experimental Station, animals were treated against internal parasites and vaccinated against Clostridia and respiratory diseases. The animals were then allocated to four feeding strategies. Group FL: *ad libitum* feedlot system for 98 days, targeting the local market (30 steers, 202.9 ± 13.8 kg LW, 10 steers x 3 repetitions); group Gr1.25: grazing with 1.25 %LW/day dry cracked maize supplementation (DM basis) for 235 days, targeting both local and export markets (36 steers, 172.9 ± 19.6 kg LW, 9 steers x 4 repetitions); group Gr0.70: grazing with 0.70% LW/day dry cracked maize supplementation (DM basis) for 331 days, targeting export markets (32 steers, 195.0 ± 11.7 kg LW, 8 steers x 4 repetitions); and group GrFL: grazing background without supplementation for 287 days followed by *ad libitum* feedlot finishing for 116 days, targeting the export quota 481 (30 steers, 156.7 ± 23.8 kg LW, 10 steers x 3 repetitions).

Grazing management and supplementation

Pasture management and supplementation of the grazing strategies are summarized in table 1. Each experimental unit had pasture divided into 6 paddocks grazed rotationally, with independent water troughs (minimum of 16 cm/animal) and group feed bunks providing 0.67 m/animal. Steers grazed rotationally, with paddock occupation and resting periods ranging from 4 to 9 days and from 21 to 60 days, respectively, depending on pasture production. Gr1.25 and Gr0.70 included permanent supplementation with dry cracked maize grain and winter supplementation with alfalfa hay.

Table 1. Grazing management and supplementation.
Tabla 1. Manejo del pastoreo y suplementación.

Feeding strategy	N° EU	N° Steers (steers/EU)	Pasture surface (ha/EU)	Pasture stocking rate (steers/ha)	Pasture allowance (%LW/day)		Supplementation (%LW/day)	
					Autumn-Winter	Spring-Summer	Dry cracked maize	Alfalfa hay - Winter
Gr1.25	4	9	2.4	3.75	3.24 ± 0.14	4.54 ± 0.55	1.25*	0.45
Gr0.70	4	8	2.4	3.33	2.57 ± 0.18	4.78 ± 0.20	0.70	0.60
GrFL	3	10	3.5	2.83	4.59 ± 0.29	6.88 ± 0.05	--	--

Gr1.25: grazing finishing with high supplementation; Gr0.70: grazing finishing with low supplementation; GrFL: grazing background and feedlot finishing; EU: experimental unit; LW: live weight. Pasture allowance and supplements are expressed on a DM basis.* supplementation was delivered in two daily feedings.

Gr1.25: invernada pastoril con alta suplementación; Gr0.70: invernada pastoril con baja suplementación; GrFL: recría pastoril y terminación a corral. EU: unidad experimental; LW: peso vivo. La asignación de pastura y la suplementación están expresadas en materia seca. * suplementación dividida en dos entregas diarias.

Pre-grazing pasture biomass was estimated every two weeks (8 to 18 days depending on the season) by 10 sites of 0.25 m^2 cut at 3 cm height. A subsample (200-400 g) was dried at 60°C for 48 h to determine DM content and milled to 1 mm for subsequent analysis (table 2, page 129). Crude protein (CP) was determined according to Horneck and Miller (1988), while neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest *et al.* (1991). Pasture metabolizable energy was estimated using the digestibility equation McLeod and Minson (1976).

Gr1.25: grazing finishing with high supplementation; Gr0.70: grazing finishing with low supplementation; GrFL: grazing background and feedlot finishing. * Calculated using the equation from McLeod and Minson (1976): Metabolizable energy (Mcal/kg DM) = 3.6 x (92.3 - 0.91 x %ADF) / 100.

Gr1.25: invernada pastoril con alta suplementación; Gr0.70: invernada pastoril con baja suplementación; GrFL: recría pastoril y terminación a corral. * Calculado usando la ecuación de McLeod y Minson (1976): Energía metabolizable (Mcal/kg MS) = 3,6 x (92,3 - 0,91 x %FDA) / 100.

Table 2. Pasture chemical composition.
Tabla 2. Composición química de las pasturas.

Autumn-Winter			
	Gr1.25	Gr0.70	GrFL
Crude protein (%)	21.4 ± 0.4	24.2 ± 1.4	14.5 ± 0.8
Neutral detergent fiber (%)	48.2 ± 0.8	40.6 ± 1.61	50.4 ± 0.9
Acid detergent fiber (%)	31.4 ± 0.4	31.5 ± 1.3	30.9 ± 0.5
Metabolizable energy* (Mcal/kg DM)	2.30 ± 0.1	2.29 ± 0.4	2.31 ± 0.2
Spring-Summer			
	Gr1.25	Gr0.70	GrFL
Crude protein (%)	16.9 ± 0.5	18.9 ± 1.0	12.9 ± 0.8
Neutral detergent fiber (%)	51.8 ± 1.3	44.7 ± 1.1	55.6 ± 0.5
Acid detergent fiber (%)	33.6 ± 0.6	32.8 ± 0.8	35.7 ± 0.3
Metabolizable energy* (Mcal/kg DM)	2.22 ± 0.2	2.25 ± 0.3	2.15 ± 0.1

Feedlot management

The FL and GrFL strategies used six outdoor pens of 250 m^2 for feedlot finishing. Animals assigned to the FL strategy had a 45-day pre-experimental period with *ad libitum* access to alfalfa hay, increasing mean LW from 177.6 to 202.9 kg before entering the feedlot finishing period. The analysis did not include this period. FL strategy used 30 HA steers allocated randomly in three pens for a finishing period of 98 days. Whereas for the finishing phase of the GrFL strategy, 30 HA steers were allocated in three pens for 116 days after the mentioned grazing background phase.

In both strategies, the proportion of grain in the diet was gradually increased during an adaptation period of 21 days. The final diet consisted of a typical finishing diet based on dry cracked maize grain, alfalfa hay, soybean meal, and a mineral supplement (table 3). It was delivered once daily between 8:00 and 9:00, adjusting the amount offered to attain 10% of feed refusal and ensure *ad libitum* access to feed. Each ingredient was sampled monthly, dried at 60°C for 48 h to determine DM content, and milled to 1 mm for the same analysis described for pasture quality. Mean diet metabolizable energy was estimated from metabolizable energy of each component reported by NRC (1996) and their respective proportion in the diet.

[A] supplement composition: Ca, 295 g/kg; mg/kg: Fe 15000, Mn 14889, Zn 13000, Cu 1600, Se 9, I 140, Co 250, monensin 8330; UI/kg: vit. A 3000000, vit. D 1200000, vit. E 100; [B] calculated from composition and energy concentration of individual ingredients (31).

[A] composición del suplemento: Ca, 295 g/kg; mg/kg: Fe 15000, Mn 14889, Zn 13000, Cu 1600, Se 9, I 140, Co 250, monensina 8330; UI/kg: vit. A 3000000, vit. D 1200000, vit. E 100; [B] calculado a partir de la composición y concentración energética de los ingredientes individuales (31).

Table 3. Ingredients and chemical composition of feedlot diet.
Tabla 3. Ingredientes y composición química de las dietas de corral.

Diet ingredients (% in DM)	
Dry cracked maize	84.2
Alfalfa hay	10.1
Soybean expeller	5.3
Mineral supplement [A]	0.4
Chemical composition [B]	
Crude protein (% in diet DM)	12.7
Neutral detergent fiber (% in diet DM)	18
Acid detergent fiber (% in diet DM)	8.7
Metabolizable energy (Mcal/kg DM)	3.12

Animal performance and feeding strategy productivity

Animals were individually weighed without fasting between 8:00 and 9:00, at the beginning, every 4-5 weeks, and at the end of each feeding period. LW was adjusted considering 5% of shrinkage. For feedlot systems (FL and GrFL), mean DM intake (DMI) was estimated per pen of 10 steers (experimental unit) as the difference between offered and refused feed over 5 days, calculated monthly. DMI was used to estimate feed conversion as the ratio of mean DMI to average LW gain.

Productivity, measured as LW production per pasture surface and adjusted surface, was estimated for the Gr1.25, Gr0.70, and GrFL feeding strategies. Surface adjustment considered maize grain equivalents used for Gr1.25 and Gr0.70 supplementation and GrFL pen feeding (16). The maize crop surface needed was calculated considering a mean yield of 12,000 kg/ha for the southeast of Córdoba, Argentina (15).

Carcass characteristics and meat quality

The timing of slaughter for each strategy was based on a visual evaluation of the necessary fatness degree for the aimed market, verified by local cattle buyers for both local and export markets. For GrFL, slaughter timing also required a minimum of 100 days on a high-concentrate diet to target the export quota 481. Three steers per experimental unit from Gr1.25 and Gr0.70, and four steers per experimental unit from FL and GrFL, were randomly selected for carcass and meat determinations, resulting in 12 carcasses per feeding strategy. The slaughter of steers from all feeding strategies was carried out at a commercial abattoir. At 48 h *postmortem*, CW was recorded, and a section containing the 10^{th}, 11^{th}, and 12^{th} ribs was removed from the left side of each carcass. Samples were kept at 4°C until 72 h *postmortem*. Then, ribs were deboned and separated into 2.5 cm thick steaks, vacuum-packed, and stored at -20°C until further analysis. When necessary, samples were thawed at 4°C for 24 h.

Fat thickness (FT) and ribeye area (REA) were measured at the 12^{th} rib using a gauge and digital planimeter, respectively. Intramuscular fat (IMF) content was determined in duplicate by the Soxhlet method (SOXTEC SYSTEM HT 1043 Extraction Unit) using an aliquot of 5 g per steak (10). The results are expressed as a percentage of fresh muscle tissue.

To determine the thawing loss, each steak was placed on a plastic mesh inside a sealed plastic container, preventing the sample from coming into contact with the released liquid, for 24 h at 4°C. The results were calculated as the difference between initial and final weights referring to initial weight and expressed as percentage (28).

Muscle and subcutaneous fat CIE colors parameters were obtained sixfold with a Minolta CR-400 (Konica Minolta, Japan). The colorimeter used illuminant D-65, 8 mm port size, 2° observer, and was calibrated on black and white plates. Measurements followed AMSA (2012) guidelines with 45 min of blooming. Also, pH was recorded on each steak (ThermoOrion 420Aplus; USA).

Water holding capacity (WHC) was determined following the filter paper press methodology described by Coria *et al.* (2020). The WHC was expressed as the percentage of free juice expelled (WHC = meat area / total liquid infiltrated area x 100). Cooking loss was determined by measuring the weight loss of samples after dry heat cooking (oven temperature: 170°C; sample thermal center temperature: 71°C) followed by 20 min of cooling at room temperature (5). The result was reported as a percentage of weight loss relative to the initial sample weight. Warner Bratzler shear force (WBSF) was assessed as described by Coria *et al.* (2020). Steak were cooked on a preheated electric grill (George Foreman, USA) to an internal temperature of 71°C. Eight cores (1.25 cm in diameter, 2.5 cm in height) per steak were removed parallel to the fibers, and WBSF was assessed with a TA-XT Plus® (Surrey, UK). The results were expressed in Newtons (N).

Data analysis

Linear models were adjusted considering feeding strategy as a fixed effect for productive, carcass, and meat quality traits. ANOVA was used to evaluate differences, and means were compared using the LSD test. For WBSF analysis, IMF content was initially included as a covariate. However, since no significant effect was found for the covariate ($p>0.05$), it was excluded from the model. Average daily gains were calculated through linear regression models of LW as a function of days for each feeding strategy. Productivity per pasture surface and adjusted surface was estimated. Then, a linear model with the linear and quadratic components of the stocking rate was fitted to assess productivity as a function of stocking rate.

On the other hand, relationships between productive, carcass, and meat traits were evaluated using stepwise linear regression, including FT, REA, muscle lightness (L^*) and redness (a^*), IMF, and WBSF. The initial regressor variables were: CW, days on feed, total grain intake (TGI), and average daily gain (ADG) for FT and REA; CW, FT, ADG, and pH for muscle L^* and a^*; CW, days on feed, TGI, FT, and ADG for IMF content; and CW, pH, FT, IMF, WHC, and thawing losses for WBSF.

The models and analyses were carried out with the Infostat statistical program (6). All models used each group of steers as the experimental unit.

Results

Animal performance and feeding strategy productivity

The evolution of steers' LW under the different feeding strategies is shown in figure 1. Mean LW gains and final LW were different between treatments (table 4, page 132). FL strategy presented the highest LW gains, followed by Gr1.25, whereas the lowest gains were obtained with Gr0.70 and GrFL strategies. The final LW presented an inversed trend compared with LW gain, with 482.4, 464.9, 413.4, and 314.6 kg LW for GrFL, Gr0.70, Gr1.25, and FL, respectively.

FL: Feedlot system ($y = 198.02 + 1.16$ x, $R^2 = 0.97$, $p<0.001$); Gr1.25: Grazing finishing with 1.25 %LW/day of dry cracked maize supplementation ($y = 163.37 + 1.06$ x, $R^2 = 0.99$, $p<0.001$); Gr0.70: grazing finishing with 0.70 %LW/day of dry cracked maize supplementation ($y = 186.42 + 0.87$ x, $R^2 = 0.98$, $p<0.001$); GrFL: grazing background (GrFLb, $y = 161.26 + 0.76$ x, $R^2 = 0.99$, $p<0.001$) and feedlot finishing (GrFLf, $y = 96.03 + 0.93$ x, $R^2 = 0.89$, $p<0.001$). Values correspond to experimental unit means.

FL: terminación a corral ($y = 198,02 + 1,16$ x, $R^2 = 0,97$, $p<0,001$); Gr1,25: invernada pastoril con suplementación al 1,25 %PV/día con grano de maíz partido seco ($y = 163,37 + 1,06$ x, $R^2 = 0,99$, $p<0,001$); Gr0,70: invernada pastoril con suplementación al 0,70 %PV/día con grano de maíz partido seco ($y = 186,42 + 0,87$ x, $R^2 = 0,98$, $p<0,001$); GrFL: recría pastoril (GrFLb, $y = 161,26 + 0,76$ x, $R^2 = 0.99$, $p<0,001$) y terminación a corral (GrFLf, $y = 96.03 + 0,93$ x, $R^2 = 0,89$, $p<0,001$). Los valores corresponden a las medias de cada unidad experimental.

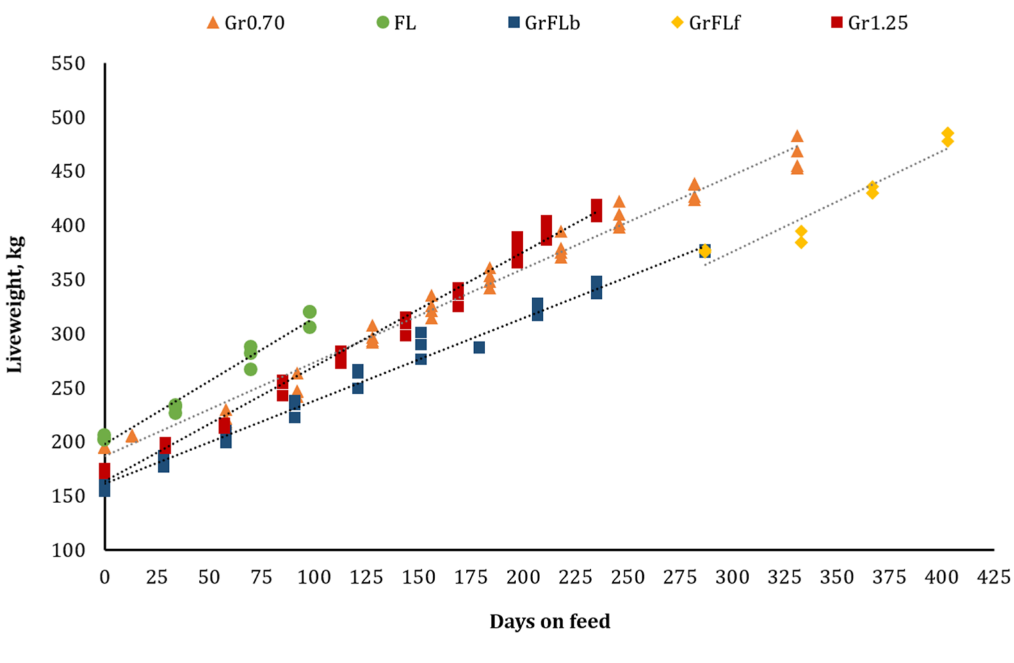

Figure 1. Live weight evolution of Holando Argentino steers under different feeding strategies.

Figura 1. Evolución del peso vivo de novillos Holando Argentino bajo diferentes estrategias de alimentación.

Table 4. Animal performance and productivity.
Tabla 4. Desempeño animal y productividad.

	FL	Gr1.25	Gr0.70	GrFL	*p-value*
Number of animals	30	36	32	30	-
Experimental units	3	4	4	3	-
Initial LW (kg)	202.9 ± 2.3 a	173.0 ± 1.9 c	195.0 ± 0.2 b	156.7 ± 3.2 d	< 0.001
Final LW (kg)	314.6 ± 8.3 d	413.4 ± 5.3 c	464.9 ± 14.0 b	482.4 ± 4.4 a	< 0.001
Days on feed	98	235	331	403	-
Grazing performance					
ADG (kg/day)	-	1.02 ± 0.02 a	0.82 ± 0.04 b	0.76 ± 0.01 c	< 0.001
Feedlot performance					
ADG (kg/day)	1.14 ± 0.07	-	-	0.92 ± 0.03	0.11
DMI (kg DM/day)	7.79 ± 0.35 b	-	-	12.54 ± 0.12 a	< 0.01
Feed conversion	6.85 ± 0.57 b	-	-	13.68 ± 0.33 a	< 0.01
Global performance					
ADG (kg/day)	1.14 ± 0.07 a	1.02 ± 0.02 b	0.82 ± 0.04 c	0.81 ± 0.01 c	< 0.001
Productivity (kg LW/ha pasture)	-	902 ± 20 a	899 ± 47 a	621 ± 6 b	< 0.001
Total grain intake (kg DM/animal)	643 ± 29 d	861 ± 9 b	764 ± 16 c	1224 ± 12 a	< 0.001
Productivity (kg LW/ha adjusted)	-	710 ± 15	741 ± 36	715 ± 4	0.24

Different letters indicate significant differences (p<0.05). FL: feedlot system; Gr1.25: grazing finishing with high supplementation; Gr0.70: grazing finishing with low supplementation; GrFL: grazing background and feedlot finishing; ADG: average daily gain, DMI: dry matter intake, LW: live weight.

Letras diferentes indican diferencias estadísticamente significativas (p<0,05). FL: terminación a corral; Gr1.25: invernada pastoril con alta suplementación; Gr0.70: invernada pastoril con baja suplementación; GrFL: recría pastoril y terminación a corral; ADG: aumento medio diario de peso vivo, DMI: consumo de materia seca, LW: peso vivo.

Grazing LW gain was highest for Gr1.25, followed by Gr0.70, while the grazing background phase of GrFL showed the lowest LW gains. Whereas feedlot finishing LW gain was not different between FL and GrFL (p=0.11). However, DMI was higher in GrFL than in FL (12.54 vs. 7.79 kg DM, p<0.01), as well as feed conversion (13.68 vs. 6.85, p<0.01).

Productivity per pasture surface was higher for supplemented grazing strategies (Gr1.25 and Gr0.70) than the background phase from GrFL. When productivity estimations included feedlot finishing of GrFL (both production and surface needed for feedlot diet ingredients) and the surface needed for Gr1.25 and Gr0.70 supplements supply, no significant differences were obtained (p=0.239). In all cases, adjusted productivity ranged between 710 and 741 kg LW/ha, presenting no response to the increase in stocking rates (figure 2, page 133).

Productivity per pasture surface (kg/ha, oranges triangles, y = -6570.60 + 4228.39 x - 596.22 x^2, R^2 = 0.96, *L*: p<0.001; *Q*: p<0.001) and adjusted productivity (kg/ha, green circles, y = -713.63 + 889.89 x - 136.04 x^2, R^2 = 0.32, *L*: p=0.097; *Q*: p=0.094) as a function of stocking rate. Surface adjustment was done considering maize grain equivalents used for supplementation in Gr1.25 and Gr0.70, and for pen feeding in GrFL. The maize crop surface needed to supply the grain equivalents used was calculated considering a mean yield of 12.000 kg/ha. *L*: significance of the linear component of the model; *Q*: significance of the quadratic component of the model. Values presented correspond to experimental unit means.

Productividad por superficie de pasturas (kg/ha, triángulos naranjas, y = -6570.60 + 4228.39 x - 596.22 x^2, R^2 = 0.96, *L*: p<0.001; *Q*: p<0.001) y productividad por superficie ajustada (kg/ha, círculos verdes, y = -713.63 + 889,89 x - 136,04 x^2, R^2 = 0,32, *L*: p=0,097; *Q*: p=0,094) en función de la carga animal. El ajuste de superficie se realizó considerando equivalentes de grano de maíz utilizados para suplementación en Gr1.25 y Gr0.70, y para la terminación a corral en GrFL. La superficie de cultivo de maíz necesaria para abastecer los equivalentes de grano utilizados se calculó considerando un rendimiento medio de 12.000 kg/ha. *L*: significancia de la componente lineal del modelo; *Q*: significancia del componente cuadrático del modelo. Los valores presentados corresponden a las medias de cada unidad experimental.

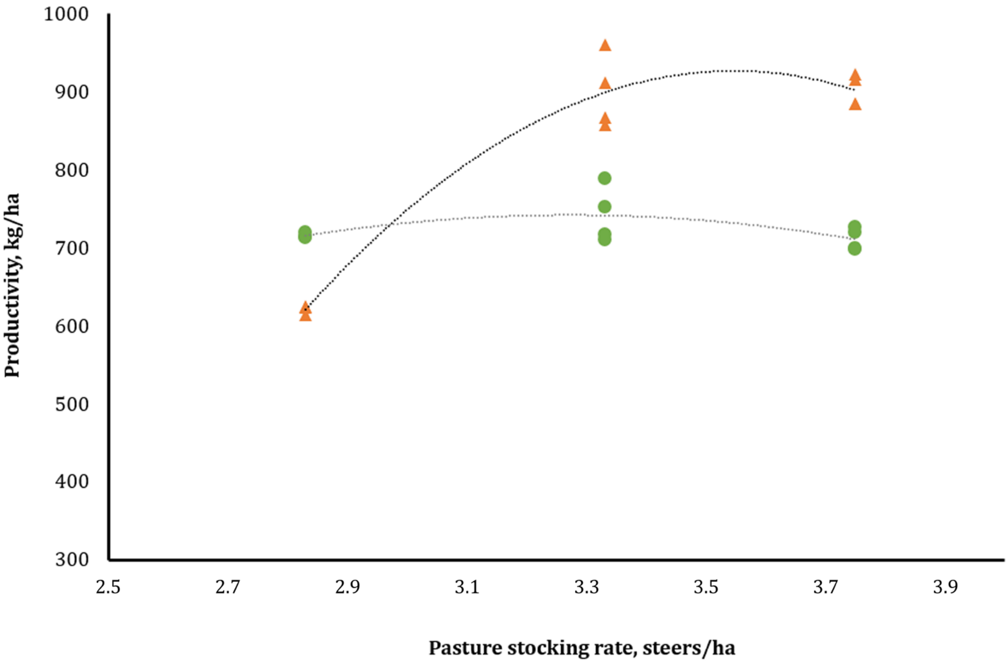

Figure 2. Productivity per pasture surface and adjusted productivity as a function of stocking rate.

Figura 2. Productividad por superficie de pasturas y por superficie ajustada en función de la carga animal.

Carcass and meat quality

Carcass characteristics and meat quality are shown in table 5 (page 134). GrFL and Gr0.70 feeding strategies presented the highest CW, followed by Gr1.25, while FL presented the lowest (p<0.001). FT did not differ between feeding strategies (p>0.05), whereas GrFL REA was larger than that of Gr1.25 and FL (p<0.05).

Regarding color parameters, meat from Gr0.70 was the only one to show differences, with lower *L** (p<0.01) and higher *a** than Gr1.25, GrFL, and FL (p<0.05). No differences were observed for the subcutaneous fat color parameters (p>0.05).

Meat hardness, estimated by *longissimus thoracis* WBSF, presented no differences between feeding strategies, nor for WHC nor losses due to thawing or cooking (p>0.05). IMF content of the *longissimus thoracis* was higher for GrFL than Gr1.25, Gr0.70, and FL (p<0.05).

Relationship between productive, carcass, and meat traits

FT was explained by TGI and ADG (table 6, page 134), whereas REA was explained by CW and days on feed. On the other hand, IMF content of the *longissimus thoracis* was explained by TGI as the only trait retained by the model (R^2 = 0.63).

In relation to muscle color, *L** was explained by FT and CW (R^2 = 0.68), while *a** was explained by ADG and FT (R^2 = 0.68). WBSF was explained by thawing losses, WHC, and FT as variables kept by the model (R^2 = 0.81).

Different letters indicate significant differences (p<0.05). FL: feedlot system; Gr1.25: grazing finishing with high supplementation; Gr0.70: grazing finishing with low supplementation; GrFL: grazing background and feedlot finishing, FT: 12th rib fat thickness, REA: ribeye area, *L**: lightness, from black (0) to white (100), *a**: redness, from green (negative values) to red (positive values), *b**: yellowness, from blue (negative values) to yellow (positive values), WBSF: Warner Bratzler shear force, WHC: water holding capacity.

Letras diferentes indican diferencias estadísticamente significativas (p<0,05). FL: terminación a corral; Gr1.25: invernada pastoril con alta suplementación; Gr0.70: invernada pastoril con baja suplementación; GrFL: recría pastoril y terminación a corral; FT: espesor de grasa dorsal en la 12° costilla, REA: área de ojo de bife, *L**: luminosidad, desde negro (0) a blanco (100), *a**: desde verde (valores negativos) a rojo (valores positivos), *b**: desde azul (valores negativos) a amarillo (valores positivos), WBSF: resistencia al corte de Warner Bratzler, WHC: capacidad de retención de agua.

Table 5. Carcass characteristics and meat quality.
Tabla 5. Características de res y calidad de carne.

	FL	Gr1.25	Gr0.70	GrFL	*p-value*
Number of carcasses	12	12	12	12	-
Experimental units	3	4	4	3	-
Carcass characteristics					
Carcass weight (kg)	197.9 ± 11.5 c	240.4 ± 9.6 b	267.8 ± 12.2 a	288.3 ± 5.0 a	<0.001
FT (mm)	8.3 ± 2.2	10.3 ± 2.6	6.6 ± 3.3	12.3 ± 3.7	0.16
REA (cm^2)	50.5 ± 1.2 b	51.7 ± 1.9 b	54.2 ± 4.0 ab	57.6 ± 2.7 a	0.04
Meat quality					
Thawing losses (%)	2.32 ± 0.55	1.48 ± 0.86	1.20 ± 0.77	1.28 ± 0.79	0.31
pH	5.64 ± 0.07	5.66 ± 0.06	5.66 ± 0.06	5.61 ± 0.03	0.59
Muscle color					
*L**	36.2 ± 0.2 a	36.0 ± 0.6 a	33.7 ± 0.7 b	36.2 ± 0.8 a	<0.01
*a**	18.9 ± 1.1 b	18.6 ± 1.3 b	22.5 ± 2.1 a	19.9 ± 0.3 b	0.02
*b**	11.1 ± 0.5	11.6 ± 0.6	12.3 ± 1.4	11.6 ± 0.6	0.39
Subcutaneous fat color					
*L**	72.6 ± 0.8	71.7 ± 2.1	73.4 ± 1.8	71.4 ± 2.6	0.52
*a**	4.6 ± 1.3	3.0 ± 0.7	5.9 ± 3.5	5.7 ± 2.1	0.33
*b**	11.4 ± 0.5	13.0 ± 1.4	12.1 ± 2.8	12.5 ± 0.3	0.66
Intramuscular fat content (%)	2.52 ± 0.55 b	3.10 ± 0.60 b	3.18 ± 0.66 b	4.86 ± 0.93 a	0.02
WHC (%)	30.9 ± 2.3	31.0 ± 2.7	28.4 ± 0.6	30.1 ± 1.9	0.29
Cooking losses (%)	22.8 ± 3.0	22.0 ± 2.8	22.8 ± 3.5	22.4 ± 2.5	0.97
WBSF (N)	29.1 ± 2.8	31.5 ± 4.2	29.5 ± 3.9	29.2 ± 3.3	0.60

FT: 12th rib fat thickness, REA: ribeye area, *L**: lightness, from black (0) to white (100), *a**: redness, from green (negative values) to red (positive values), WHC: water holding capacity of the *longissimus thoracis*, IMF: intramuscular fat content of the *longissimus thoracis*, ADG: average daily gain, WBSF: Warner Bratzler shear force.

FT: espesor de grasa dorsal en la 12° costilla, REA: área de ojo de bife, *L**: luminosidad, desde negro (0) a blanco (100), *a**: desde verde (valores negativos) a rojo (valores positivos), WHC: capacidad de retención de agua del *longissimus thoracis*, IMF: contenido de grasa intramuscular del *longissimus thoracis*, ADG: aumento medio diario de peso vivo, WBSF: resistencia al corte de Warner Bratzler.

Table 6. Relationship between productive, carcass, and meat traits.
Tabla 6. Relación entre parámetros productivos, de res y de calidad de carne.

Item	Intercept	Explanatory variables	Partial slopes	SE	*p-value*	R^2
FT (mm)	-18.69	Total grain intake, kg	0.01	4.1×10^{-3}	< 0.01	0.52
		ADG, kg/day	15.83	6.52	< 0.05	
REA (cm^2)	15.7	Carcass weight, kg	0.19	0.07	< 0.05	0.62
		Days on feed	-0.03	0.02	< 0.15	
IMF (%)	-3.4×10^{-3}	Total grain intake, kg	3.9×10^{-3}	8.7×10^{-4}	< 0.001	0.63
Muscle *L**	37.71	FT, mm	0.28	0.06	< 0.01	0.68
		Carcass weight, kg	-0.02	0.01	< 0.05	
Muscle *a**	32.92	ADG, kg/day	-10.35	2.75	< 0.01	0.68
		FT, mm	-0.26	0.11	< 0.05	
WBSF (N)	3.08	Thawing Losses, %	-3.02	0.6	< 0.001	0.81
		WHC, %	1.23	0.25	< 0.001	
		FT, mm	-0.59	0.15	< 0.01	

Discussion

Animal performance and feeding strategy productivity

Feeding strategies with higher energy supplementation levels resulted in greater LW gains during grazing. This was expected as pasture allocations were within the range of response to supplementation suggested by Beretta *et al.* (2006).

Comparing grazing strategies (Gr1.25 and Gr0.70), the higher LW gains of Gr1.25 led to faster fattening rates and earlier slaughters at lower LW than Gr0.70. Similarly, Manni *et al.* (2013) reported that increasing concentrate supplementation in 1 kg DM/day improved growth rates by 0.073 kg LW/day and 0.048 kg CW/day in growing dairy bulls. The authors also reported an increase in CW and a slight increase in carcass fatness, suggesting that concentrate supplementation improves growth and carcass fat deposition (25).

In the feedlot finishing phases, the higher DMI and the lower feed efficiency in GrFL compared with FL align with Lancaster *et al.* (2014), who compared calf-fed versus yearling systems. They suggested that lower feed efficiency of steers entering the feedlot older and heavier could result from higher maintenance requirements and higher fat composition in LW gain. This effect could be steeper in dairy breeds due to larger and more metabolically active organs than beef breeds (3). Moreover, GrFL steers were fed beyond the 8.0 mm subcutaneous FT endpoint (12.3 mm), which must have contributed to the decay in feed efficiency as reported by Zurbriggen *et al.* (2022).

In contrast to Lancaster *et al.* (2014), this study found no higher LW gains in backgrounded (GrFL) steers compared to FL steers. This may explain the lack of adjusted productivity advantages for GrFL relative to Gr0.70 and Gr1.25, since the increase in productivity through feedlot finishing relies on the high LW gains expected during this period.

Supplemented grazing strategies (Gr1.25 and Gr0.70) showed higher pasture productivity than not supplemented GrFL background phase, due to higher LW gains and stocking rates. However, pasture productivity was similar between Gr1.25 and Gr0.70, since the higher LW gain and stocking rate of Gr1.25 was offset by the shorter feeding period and the lower LW at slaughter.

When productivity was estimated, including the feedlot finishing period from the GrFL strategy and the adjustments for grain equivalents, no differences were found between GrFL, Gr1.25, and Gr0.70. All strategies achieved adjusted productivities between 700 and 750 kg LW/ha, corresponding with high productivity levels for intensified grazing systems. However, GrFL productivity was below the 1000 kg LW/ha previously reported for grazing background and feedlot finishing systems from the Argentine pampas (17, 22), which may compromise the strategy's viability.

Carcass characteristics and meat quality

Morales Gómez *et al.* (2022) compared feedlot and pasture systems with different LW gain targets (1.50 and 0.90 kg/day for feedlot and 0.90 and 0.60 kg/day for pasture) and found the highest FT in the steers from the feedlot system targeting high LW gains (1.50 kg/day). Furthermore, Morales Gómez *et al.* (2022) reported that pasture systems and feedlots targeting low LW gains (0.90 kg/day) presented FT at slaughter lower than 6 mm, which may have threatened meat quality (33). While grazing systems reported by these authors achieved LW gains above 0.60 kg/day, large variations in gain during the feeding period may have reduced fattening rate and resulted in leaner carcasses.

In the present study, the grazing strategies achieved higher mean LW gains (0.82 and 1.02 kg/day for Gr0.70 and Gr1.25, respectively) with low variations in LW gain through the feeding period (figure 1, page 131). These results explain the proper FT reached at slaughter. Consistent LW gains, supported by strategic supplementation and well-managed forage allowances, are key to achieving proper productivity and meat quality in grazing finishing systems. In this sense, even though FT did not differ between the feeding strategies, FT variations were explained by TGI and LW gain.

The increase in REA with higher CW was also found in previous research with beef steers (4, 8, 43). Gr0.70 and GrFL strategies achieved the highest REA due to the longer feeding periods together with moderate LW gains, which allowed the higher CW and muscle growth.

In this study, TGI mainly explained the IMF content of the *longissimus thoracis*, consistent with previous research showing increased marbling with the inclusion of high-starch diets. Testa (2017) found that marbling score was increased by including high-starch diets during the finishing of beef steers. Garcia *et al.* (2008) also indicated that diet was a determinant for IMF deposition in beef and dairy steers, with no differences between breeds. In addition, Manni *et al.* (2018) found that increasing energy intake and carcass fatness increased the IMF content of the *longissimus lumborum* in dairy bulls.

Despite using the same finishing diet, the difference in IMF between FL and GrFL was expected. Pethick *et al.* (2004) suggested that IMF deposits linearly between a CW of 200 and 400 kg. In the FL strategy, its short duration with no previous background led to lighter carcasses with a mean CW below 200 kg. In contrast, the pasture-based background of the GrFL strategy allowed a higher CW at feedlot entry. This could have allowed coupling the finishing period with high starch diets with the phase of linear increase in IMF proposed by Pethick *et al.* (2004).

In this sense, Lancaster *et al.* (2014) suggested that achieving moderate gains during long stocker phases could improve marbling at constant FT by reaching heavier placement weights at feedlot finishing. However, this could only apply to strategies including feedlot finishing. Whereas for grazing strategies, LW gains need to be high enough to ensure sufficient fat accretion and efficient feeding duration.

Meat color is one of the most important meat attributes since it defines consumers' purchase decisions (39). Subcutaneous FT influences carcass chilling rate and pH drop, and ultimately adequate meat pH, as major factors defining meat color (13). Page *et al.* (2001) proposed a 7.6 mm FT threshold to attain bright meat, which aligns with this study's results. The lower L^* obtained with the Gr0.70 strategy could be attributed to 6.6 mm FT reached, which was below this threshold.

Grass-finished Holando Argentino beef could have acceptable color if steers had enough fatness at slaughter. In this study, the increase in dry cracked maize supplementation from 0.70 to 1.25% LW/day resulted in higher L^* and lower a^*. The use of different feeding strategies can allow for targeting different fat endpoints and attaining the meat characteristics that consumers demand.

Despite all feeding strategies being contrasted in diet, weight, and age, muscle color parameters were within the light and medium meat color range (13). Meat a^* was above the 14.5 threshold for acceptability (11). In all cases, meat pH was within the normal range, suggesting that glycogen levels were enough in all strategies (13, 33).

Although the contrasting differences in feeding strategies, there were no differences in fat color. Fat yellowness (b^* value) is a major trait defining purchase decisions since it is undesirable for most consumers from markets of different countries (9). Fat b^* was between 11.4 and 13.0, lower than the 19.2 mean reported for grazing steers (27) and similar to the 14.1 mean reported for feedlot steers in Argentina (42).

Usually, pasture feeding increases b^* due to the higher carotene content in fresh pastures compared to concentrates. The lack of differences between strategies in this study may be due to the high LW gains of the grazing strategies. In this sense, maintaining high LW gains may have diluted carotenoids with subcutaneous fat accretion (9).

Shear force was explained by thawing losses, water holding capacity, and FT. However, the low change rate in shear force per mm FT was explained by all strategies achieving at least 6.6 mm of mean FT. This fat coverage was above the threshold proposed by Savell *et al.* (2005) and slightly below the 7.6 mm FT threshold proposed by Dolezal *et al.* (1982) to obtain tender meat.

Morales Gómez *et al.* (2022) found differences in meat WBSF between grazing and feedlot-finished steers. These differences were attributable to different muscle pH for feedlot and grazing animals (5.62 and 5.97, respectively) since final muscle pH of grass-fed animals could be associated with dark, firm, and dry meat. This evidences the low FT reached by this feeding system and differs from the FT obtained in the present study for grazing steers, which attained 6.6 mm of mean FT.

Previous research has proposed different WBSF threshold values for consumer unacceptability. Platter *et al.* (2003) suggested 43.12 N, while Miller *et al.* (2001) suggested 55.9 N. In the present study, meat from all strategies could be considered tender since WBSF values were below these thresholds.

The higher IMF content reached under the GrFL strategy did not affect *longissimus thoracis* shear force. According to previous research, IMF content explains only 17% of sensory panel tenderness variation (32). Moreover, Zurbriggen *et al.* (2022) reported that once 8.0 mm FT was reached, the increase in IMF from 2.7 to 7.3% only tended to reduce WBSF in British feedlot steers. However, the increase in marbling must not be belittled since it could improve juiciness and flavor (40) and may be needed to access some export markets.

Conclusion

Grazing finishing strategies for HA steers must achieve and maintain high LW gains to attain the fatness required to guarantee meat tenderness and reduce fat yellowness. Energetic supplementation can be used to achieve this but also to manipulate slaughter LW and IMF to meet different market demands.

Incorporating a grazing rearing phase before feedlot entry to increase the placement weight can increase IMF content, which is relevant for certain export markets. This strategy, however, presented the highest TGI and low feed efficiency, making its viability dependent on pricing conditions in the export market.

Overall, HA steers have the flexibility to produce high-quality meat under different feeding strategies. Production systems can strategically use maize grains as a supplement or in feedlot diets, managing stocking rates, LW gains, and finishing endpoints to achieve high productivity and also manipulating marbling and FT to obtain meat quality that different markets demand.

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