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Effect of corn grain or lupin bean supplementation on performance of growing steers grazing endophyte-infected fescue and on subsequent finishing period

Maria Eugênia Andrighetto Canozzi[1]*, Rodrigo Zarza[1], Georgget Elizabeth Banchero[1], Alejandro La Manna[1], Enrique Fernández[1], Juan Manuel Clariget[1]

[1] Instituto Nacional de Investigación Agropecuaria, Estación Experimental La Estanzuela, Colonia, Uruguay.

***Corresponding author:**
mecanozzi@inia.org.uy

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ABSTRACT - Our objective was to compare performance and carcass characteristics of backgrounding steers grazing poor quality pasture, receiving energy or protein supplements during summer, and on subsequent finishing period. Sixty Hereford steers (14 months; 348±33 kg body weight [BW]) were blocked by BW and randomly assigned to one of three treatments (n = 20 per treatment): control (non-supplemented) and supplemented at 0.8% BW with whole grain of corn (CS) or lupin bean (LS) (phase I; 77 days). Over the following 84 days, none of the steers had access to supplement (phase II). During phases I and II, steers grazed together endophyte-infected tall fescue. In the last phase (phase III; 176 days), and until slaughter, steers grazed lucerne and orchard grass and were supplemented at 0.8% BW with high-moisture sorghum grain. Data were evaluated as a complete block randomized design with three treatments. Intake of supplement in CS and LS groups was 1.9 and 2.4 kg DM/d, respectively. Steers supplemented with lupin showed an improvement in the supplement conversion efficiency (5.7:1 *vs.* 10.0:1). At the end of phase I, BW and average daily gain were different between groups (LS > CS > control). Final body weight in phase II was greater in supplemented steers than in control steers. At slaughter, supplemented groups had greater hot carcass weight than the control group. The advantage obtained by supplementing steers with lupin, compared with corn, was lost in the subsequent phases, as reflected by the absence of differences in carcass weight. Our data illustrate that in similar scenario, energy supplementation is adequate and there is not any extra benefit of adding protein by the use of lupins when considering cattle management and economic factors.

Keywords: beef cattle, supplement intake, self-fed, yearling steer

1. Introduction

In temperate regions, beef is mainly produced under extensive management (Rearte and Pieroni, 2001). In Uruguay, cattle production is based on herds grazing natural or improved forage (MGAP, 2021). During summer, the performance of grazing cattle is limited by forage quality, i.e., low nutritive value (crude protein [CP]: 10.8% and neutral detergent fiber [NDF]: 70%; NASEM, 2016) and digestibility (Smith and Warren, 1986a; Rearte and Pieroni, 2001; Coleman and Moore, 2003). Normally, this low performance is caused not by the quantity of pasture, which is abundant, but by their low quality resulting from its maturity. Indeed, in natural or improved forage, the summer production represents 20-30% of the annual production (Beretta and Bemhaja, 1998; Bemhaja, 2006).

Supplemental sources of energy or protein are often provided to cattle in the warm season, thereby correcting nutrient deficiencies or increasing forage utilization (Rearte, 1998; Poppi and McLennan, 1995; Dixon and Stockdale, 1999; Moore et al., 1999). Corn grain is commonly used as a high-energy, high-starch supplement; however, it can depress forage intake and digestibility (Caton and Dhuyvetter, 1997). For these reasons, lupin can replace corn, as it has similar energy content, but higher protein (typically 32% of CP) and lower starch (Abraham et al., 2019; Petterson, 2000). Furthermore, lupin crop is being grown in increasing amounts in Uruguay.

Previous research evaluated the performance of supplementing low- to moderate-quality forages harvested (Hennessy et al., 1983; Chase Jr. and Hibberd, 1987) or grazed (Smith and Warren, 1986a; Pordomingo et al., 1991; Hess et al., 1996; Nantongo et al., 2021) by cattle. The animal response has been variable between studies due to differences in the environment, individual, pasture, and supplement used (Kunkle et al., 2000). Although fescue is one of the main species of perennial pasture grazed by livestock in temperate regions (Rearte, 1998), research regarding beef cattle performance in response to supplementation on this pasture is not usual in South America countries.

In light of the preceding, we hypothesized that cattle performance during the warm season would be influenced by supplementation feeding and that improvements in growth would be maintained up to slaughter. Our objective was to compare performance and carcass characteristics of steers grazing endophyte-infected fescue supplemented with lupin bean or corn grain during the backgrounding stage in the summer in Uruguay and their residual effect until slaughter.

2. Material and Methods

All procedures involving animals were approved by the Ethics Committee on the Use of Animals (protocol number 2015.52).

The present experiment was conducted from January 20 to December 16th, 2021, at a livestock unit located in Semillero, Uruguay (57°41'39.48" W latitude; 34°20' 23.72" S longitude). The typical climate in this country is humid subtropical with mild winters and hot summers (Cfa = humid subtropical climate, according to the Köppen–Geiger climate classification).

During the experiment, weather and environmental data were provided by an automated weather station (Vantage Vue, Davis Instruments, Hayward, CA), located 2.5 km away from the paddocks, which recorded data at 30-min intervals. Daily average air temperature and daily average relative humidity was used to estimate the temperature-humidity index (THI; Thom, 1959) (Table 1).

Table 1 - Average, minimum, and maximum daily data for climatic measures[1] and temperature-humidity index (THI) summarized for each phase and for previous 10 years

Variable	Phase I	Phase II	Phase III	Previous 10 years
		Daily ambient temperature (°C)		
Average	22.5	14.6	14.2	16.8
Minimum	16.0	5.9	4.6	3.3
Maximum	29.2	21.9	27.7	31.0
		Daily humidity relative (%)		
Average	71.5	80.2	79.6	76.9
Minimum	51.0	46.0	52.0	37.0
Maximum	94.0	99.0	100.0	100.0
		Daily THI		
Average	63.0	50.1	49.6	61.6
Minimum	53.2	39.3	34.8	39.5
Maximum	73.0	62.2	70.4	82.7

[1] Data were recorded from an automated weather station located approximately 2.5 km from the paddocks.

2.1. Location and forage data collection

The experiment was divided into three phases: January 20 to March 30 (77 days; phase I); March 31 to June 23 (84 days; phase II); and June 24 to December 16, 2021 (176 days; phase III) (Figure 1). Two paddocks containing an old tall fescue variety (*Festuca arundinacea* Schreb), totalling 24.2 ha, were used during the first two phases. Microscopic examination of tiller samples from these pastures showed high levels (approximately, 90% of the seed samples) of the fungal endophyte *Epichloë coenophialia* (Casaro et al., 1987). Vegetation was sown in the 1990s and not fertilized during the experiment or within 12 months before the start of the experiment. In the third phase, steers grazed a mixed pasture with lucerne (*Medicago sativa*) and orchard grass (*Dactylis glomerata*) with an average stand age of two to four years (average values during winter and spring for CP = 21.3–23.1%; NDF = 37.9–41.4%; and metabolizable energy (ME): 2.3–2.5 Mcal/kg dry matter [DM]; Mieres et al., 2004; NASEM, 2016). In the last phase, steers were hand-fed with high-moisture sorghum grain at 0.8% BW (average values of CP = 8.2–10.4%; NDF = 9.3–28.3%; and ME = 3.1–3.2 Mcal/kg DM; Mieres et al., 2004; NASEM, 2016).

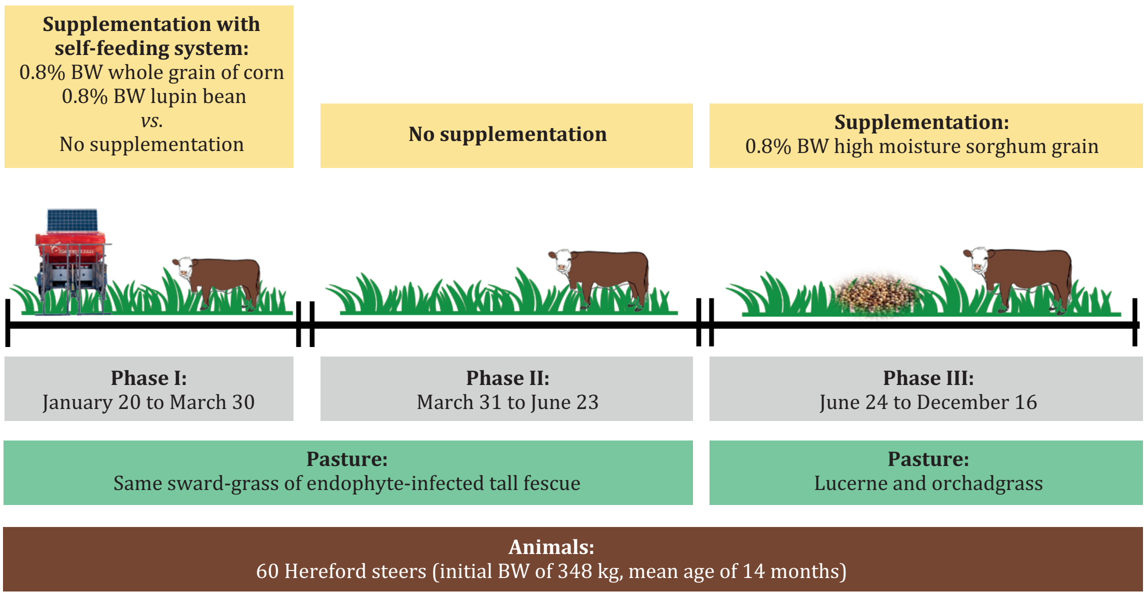


Figure 1 - Characterization of the pasture and supplementation of the three phases of the experiment.

Steers grazed as one herd throughout the experiment and were managed under continuous grazing during phases I and II and under rotational grazing, using the strip-grazing technique of two- or three-day occupation during phase III. Steers had *ad libitum* access to water throughout the experiment.

During the first two phases, forage analyses were conducted in each paddock on a weekly (phase I) or monthly (phase II) basis. Forage mass (kg DM/ha) was determined with 0.5 × 0.5 m^2 exclusion cages in each paddock to limit the steers from grazing the area within. The cages (12 in phase I and nine in phase II) were secured with three galvanized T posts. The paddock was divided into three representative zones by an experienced observer according to a previous observation of pasture, using satellite images of previous summer and winter seasons and a visual observation of forage before the animals' entry into the paddock. The cages were fixed in each paddock before foraging by the animals and removed immediately after the grazing in the area finished. Forage height (cm) was recorded with a ruler at 10 random points inside each cage, and the average of these measurements represented the pasture height for the paddock at the time of sampling. Immediately following sample collection, an estimation (%) of dead herbage and green leaf mass was performed. Samples were dried for DM determination in a forced-air oven at 60 °C until constant weight was achieved (48 to 72 h). Forage allowance (FA; kg DM/kg BW) was calculated as follows (Sollenberger et al., 2005):

$$(\text{Forage mass} \times \text{paddock area})/(\text{Number of animals} \times \text{average animal BW})$$

Forage samples were ground through a 1-mm Wiley mill screen (Thomas-Wiley Lab. Mill Model 4, H. Thomas Co., Swedesboro, NG), pooled per phase (I or II), and sent for forage nutritive analysis.

In phase III, the established FA was 5 kg forage DM/100 kg BW/d which was adjusted to each new paddock. A visual estimation of forage mass was performed by an expert each time a new paddock was accessed by steers.

2.2. Supplement management with automated feeder

A portable, self-contained system (Super SmartFeed; C-Lock Inc., Rapid City, SD) was used to provide supplement and to measure individual animal supplement intake (Husz et al., 2020) during phase I. The device has four feeding stations, and each one was calibrated by removing all orts, taring the scale, and calibrating with a 10-kg certified weight before beginning the experiment.

The feeder was validated two days per week by manually initiating movement of the chain that dispensed supplement. Feed was triggered to dispense a known amount (1 kg) two times for each feeding station, which was weighed on a separate electronic analytical scale. The amount of supplemental feed dispensed in each feeding station was calibrated (1±0.1 kg) after each validation according to the manufacturer's instruction. The validation was also assessed with radio-frequency identification (RFID) tags to check the amount of supplement offered in each feeding station (Husz et al., 2020). The supplement was allotted to each steer throughout the day until animals received the assigned amount, with the allocation reset for all animals at midnight daily. No topographic restriction inhibited the animals' access to the supplementation site.

Supplements were sampled twice per week. Composite samples for each supplement were weighed, placed in a forced-air oven (60 °C for 48 h), weighed for DM determination, and ground to pass through a 1-mm screen (Retsch Cyclon Mill Twister, type ZM 1, Haan, Germany). The samples were sent to the laboratory for chemical composition analysis.

2.3. Animals

Sixty Hereford yearling steers were selected from a herd of 148 animals for agreeable disposition and adaptability to the Super SmartFeed and management. Animals tagged with RFID were allotted to treatments the day before beginning the experiment.

The 60 yearling steers, mean age of 14 months and average BW of 348.2±32.8 kg, were blocked by BW and randomly assigned to one of the three treatments. The three groups of 20 animals were: control (non-supplemented) and supplemented at 0.8% BW with whole grain of corn (CS) or lupin bean (LS). Phase I lasted 77 days. For the next 84 days, the 60 yearling steers only grazed tall fescue (phase II).

At the end of phase III (176 days), when animals had access to a lucerne (*Medicago sativa*) and orchard grass (*Dactylis glomerata*) pasture and a supplementation (0.8% BW of high moisture sorghum grain), they were transported to an abattoir located 15 km from the livestock unit. After unloading, the steers were placed in holding pens for 2 h until slaughter.

2.3.1. Animal measurements

On the first day of the experiment, and every 14 days until the end of phase II, steers were individually weighed (unshrunk) in the morning, always starting at 08:00 h. In the last phase, they were weighed monthly.

During phase I, individual fecal grab samples were collected directly from the rectum of the supplemented steers every 14 days, along with the weighing, to assess grain or bean excretion. Immediately after, the feces were manually separated from the grain or from the bean, and both were weighed, dried at 60 °C in a forced-air oven for a minimum of 72 h, and weighed again for DM estimation. The percentage of grain/bean in the feces was then calculated based on the relation between g DM of grain/bean in feces and g DM of feces.

Average daily weight gain (ADG) was estimated as the linear regression slope of BW (unshrunk) over time for each steer (Crews and Carstens, 2012). Supplement conversion efficiency was obtained for the supplemented groups as supplement intake (kg/d) divided by additional ADG (kg/d) from LS and CS groups over control steers. The compensatory index was obtained for phases II and III based on the ratio of the difference between weight variation at the end of restricted and compensatory growth periods, respectively, relative to the variation at the end of the restricted growth alone index (Wilson and Osbourn, 1960).

Particle size of supplements, fresh and in the feces, was estimated using the 2013 Penn State Particle Separator method (Heinrichs, 2013), with five plastic separator boxes on top of each other (19, 7.9, 4.1, and 1.18 mm and solid holes). The process was repeated five times by the same operator. The proportion of grain/bean remaining in each sieve was calculated considering the ratio between the weight retained and the sum of the weights in all sieves.

At the abattoir, the slaughter live BW (kg) of the steers of each experimental group was recorded. Carcasses were visually graded after slaughter for conformation (scale 1 to 6, I-N-A-C-U-R; from large (I = 1) to lacking (R = 6) of muscle development) and fatness score (scale from 0 to 3; from total absence (0) to excessive covering (3)) (Resolución 65/97; INAC, 1997). Hot carcass weight was individually recorded (HCW; kg). The amount of fat removed during trimming (kg) was estimated before placing the carcass in the chiller, as the difference between the HCW pre- and post-process. Dressing (%) was calculated as the ratio of HCW post-dressing in kg and final BW in phase III in kg multiplied per 100.

2.4. Chemical analysis

Chemical analyses were performed for forage and supplement for phases I and II (Table 2). The percentage of DM of forage and supplement was estimated based on (dry weight/wet weight) × 100. Ash (method 942.05) and ether extract (method 954.02) were determined according to AOAC (1990). The neutral (NDF) and acid detergent fiber (ADF) concentrations, corrected for ash, were determined using an Ankom 2000-I fiber extractor (ANKOM Technology, Macedon NY, United States) according to Van Soest et al. (1991). Lignin and neutral and acid detergent insoluble nitrogen measures were obtained according to Goering and Van Soest (1970). Crude protein concentration was determined by N concentration (Kjeltec 8200; FOSS Analytical, Hillerod, Denmark) multiplied by 6.25 (AOAC, 1990; Method 967.03).

Table 2 - Mean chemical composition of the different dietary components for steers grazing improved natural grass (tall fescue)

Component (% dry matter basis)	Pasture (tall fescue)		Supplementation during phase I	
	Phase I	Phase II	Corn	Lupin
Crude protein (CP)	9.5	10.3	8.3	35.6
Ash	12.2	12.5	1.4	3.9
Neutral detergent fiber	64.6	58.7	10.9	29.7
Acid detergent fiber	41.1	34.3	3.8	22.5
Lignin	7.7	6.7	1.0	0.9
Ether extract	2.2	2.3	1.8	2.3
Acid detergent insoluble CP	0.9	0.6	0.7	0.6
Neutral detergent insoluble CP	2.1	2.4	0.5	0.7

2.5. Statistical analysis

During the last phase, one steer died due to injuries not directly related to treatment, so data from this animal was not used in this period. The Shapiro-Wilk test was used to check the normality of data. Data were analyzed as a randomized complete block design, using the MIXED procedure, applying the following equation:

$$Y_{ij} = \mu + B_i + S_j + e_{ij},$$

in which μ = overall mean, B_i = random effect of block (i = 1 to 20), S_j = fixed effect of treatment (j = corn grain, lupin bean, or unsupplemented), and e_{ij} = residual error.

Comparison of least square means (LSMeans) were performed by Tukey's test and significance was set as $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and $P \leq 0.10$. Individual supplemental intake in a common pasture allowed each steer to be used as an experimental unit (Adams et al., 2000). Results are presented as LSMeans ± standard error of the mean (SEM). No significant differences ($P \geq 0.05$) in initial BW were observed between treatments; however, this variable was included in the BW model as covariate to correct possible differences in gut fill among treatments. Statistical analyses were performed using SAS statistical software (Statistical Analysis System, version 9.4).

3. Results

3.1. Forage characteristics and utilization

During phases I and II, respectively, mean forage mass was 3,414±1,801 and 4,591±2,431 kg DM/ha; sward height was 11.8±4.8 and 15.6±7.5 cm; green leaf was 64 and 74%; and FA was 1.9 and 2.7 kg DM/kg BW. Both NDF and ADF of tall fescue were lower in the second than in the first phase (Table 2).

3.2. Grain and bean characteristics

The percentage of supplement excreted in feces by steers was lower for those that received lupin bean than for those that received corn grain (9.2 *vs.* 17.2±2.7 for LS and CS, respectively; $P \leq 0.05$).

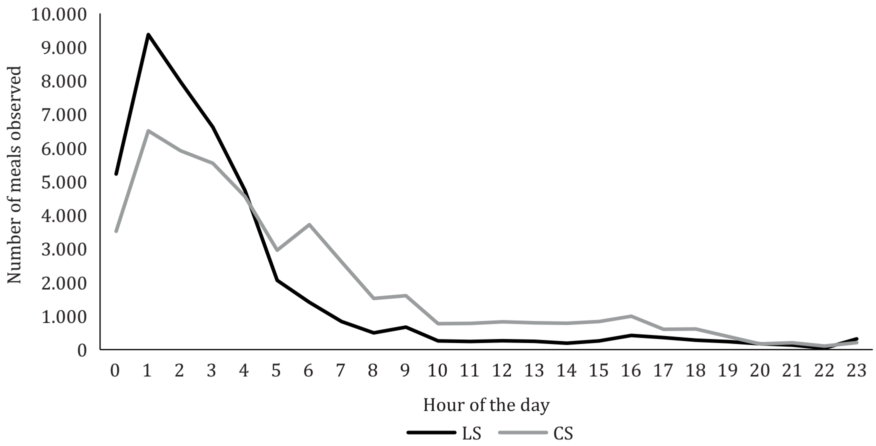
Most of the fresh and feces lupin beans was retained on sieve with a particle size of 8–4.1 mm, and corn grain on sieve of 19–8 mm particle size (Table 3).

Table 3 - Relative particle size (%) of each supplement measured by Penn State Particle Size Separator

Particle size (mm)	Fresh grain		Grain in feces	
	Corn	Lupin	Corn	Lupin
> 19	0	0	0	0
19–8	64.7	1.1	59.4	8.4
8–4.1	35.0	97.4	39.6	84.7
4.1–1.18	0.3	1.5	0.7	6.6
Bottom residue (< 1.18)	0.02	0.01	0.3	0.3

3.3. Animal performance

The animal visits to the feeder were distributed throughout every hour of the day, with a peak at 01:00 h (Figure 2). The intake of supplement ranged from 1.4 to 2.7 kg DM/d for LS steers and from 0.06 to 2.6 kg DM/d for CS steers (CV = 18 and 51% for LS and CS, respectively). Twenty percent (n = 4) of CS steers consumed less than 0.2 kg/d. The average supplement intake tended to be different between treatments (P = 0.08; LS: 2.4 and CS: 1.9 kg DM/d).



LS - lupin supplementation at 0.8% BW; CS - corn supplementation at 0.8% BW.

Figure 2 - Visitation of steers to the automated supplement feeder in each evaluated treatment during phase I.

On the first day of the experiment, the initial weight of steers was similar among treatments (Table 4). Following day 77 of phase I, weight and ADG were different between groups (LS > CS > control), with control steers losing weight. Supplement conversion efficiency was improved when lupin was supplemented. At the end of phase II, supplemented animals weighed more (> 20 kg) than the group without supplementation, and the compensatory index for CS was superior for control steers (36% *vs*. 8%). During the last phase, no differences were observed in performance variables, with a total (100%) and partial (63%) compensatory growth achieved by CS and control steers, respectively, in relation to LS.

Slaughter live BW was 511.0, 524.5, and 524.7 kg for control, LS, and CS groups, respectively. Supplemented cattle had greater HCW and trimming than unsupplemented steers. Conformation, fatness score, and dressing percentage did not differ between treatments (Table 5).

Table 4 - Least-square means ± SEM for performance variables of steers grazing tall fescue (phases I and II) or mixed pasture (phase III) according to group supplementation in phase I

Variable	Supplement during phase I			P-value
	Control	LS	CS	
Initial body weight (kg)	346.9±7.2	347.3±7.2	350.3±7.2	0.37
		Phase I		
Final body weight (kg)	344.9±3.0c	372.2±3.0a	356.7±3.0b	<0.0001
Average daily gain (kg/d)	−0.05±0.04c	0.37±0.04a	0.14±0.04b	<0.0001
Supplement conversion efficiency[1]	-	5.7:1	10.0:1	
		Phase II		
Final body weight (kg)	350.2±10.1b	375.5±10.0a	365.3±9.6a	<0.0001
Average daily gain (kg/d)	0.21±0.04	0.21±0.04	0.28±0.04	0.13
		Phase III		
Final body weight (kg)	531.9±5.2	541.7±5.2	542.5±5.4	0.30
Average daily gain (kg/d)	1.07±0.04	0.97±0.04	1.02±0.04	0.15

Control - unsupplemented; LS - lupin supplementation at 0.8% BW; CS - corn supplementation at 0.8% BW.
[1] Calculated as grain intake (kg/d) per unit body weight response (kg/d) to supplementation.
Means in a column followed by different letters are significantly different by Tukey's test (at P≤0.05).

Table 5 - Least-square means ± SEM for slaughter data of steers grazing tall fescue (phases I and II) or mixed pasture (phase III) according to group supplementation in phase I

Variable	Supplement during phase I			P-value
	Control	LS	CS	
Hot carcass weight (kg) pre-trimming	289.1±5.4b	300.9±5.4a	300.3±5.5a	0.02
Trimming (kg)	20.1±0.6b	22.4±0.7a	23.3±0.7a	0.0007
Carcass conformation[1]	2.9±0.04	2.9±0.04	3.0±0.04	0.62
Fatness score[2]	1.7±0.1	1.8±0.1	1.6±0.1	0.27
Dressing (%)	50.8±0.4	51.6±0.4	50.8±0.4	0.26

Control - unsupplemented; LS - lupin supplementation at 0.8% BW; CS - corn supplementation at 0.8% BW.
[1] Carcass conformation: scale 1 to 6, from large muscle (1) to lack of muscle development (6).
[2] Carcass fatness: scale 0 to 3, from total absence (0) to excessive covering (3).
Means in a column followed by different letters are significantly different by Tukey's test (at P≤0.05).

4. Discussion

The response to supplementation by yearling steers during the warm season was different depending on the type of supplement consumed, with an effect on subsequent performance. At the end of phase I, supplementation with lupin increased live weight gain of steers by 0.37 kg/day, but this difference in weight gain was not retained until slaughter. Alternatively, despite the fact that steers that received corn gained less weight (0.14 kg/day of ADG), they had an improvement in growth until the end of phase III. The unsupplemented steers did not maintain their live weight during the 77 days of phase I (−0.05 kg/day) when they were offered only poor-quality pasture (CP, 9.5%; NDF, 64.6%). The performance of control animals was very low and did not seem to be solely related to forage allowance or feed quality. The presence of endophyte in fescue, which has been reported as responsible for a series of animal health disorders (Rouquette Jr., 2015), might be contributing for the poor animal response.

A high proportion of the variation in performance is explained by forage quantity, i.e., forage mass and/or forage allowance (Sollenberger and Vanzant, 2011). According to Rouquette Jr. (2015), animal performance may increase to a maximum at some level of abundant forage mass. From the standpoint of steer growth, the forage mass during phases I and II might not have limited the herbage ingested per grazing bite since it was above 2,000 kg DM/ha (Hodgson, 1984; Minson, 1990). On the other hand, the intake may have been compromised by the limited forage offered to the steers (~2% of live weight), mainly to unsupplemented steers, as the intake normally approaches maximum at allowances three to four times greater than the amount consumed (Hodgson, 1984; Sollenberger et al., 2005), giving the animals opportunity for selection and *ad libitum* intake (Sollenberger and Vanzant, 2011). Moreover, as expected for temperate pasture, the forage became more mature in the summer (Minson, 1990; Rearte, 1998), with fescue showing lower quality from January to March (phase I) than from April to June (phase II; autumn season), with similar CP concentrations and lower NDF levels than those reported by NASEM (2016) for the species.

It has been reported that diets with CP below 8% (Poppi and McLennan, 1995; Moore et al., 1999) and high content of fibrous cell walls (NDF > 40%; Mertens, 1987) could decrease the rate of passage and extend digestion (Coleman and Moore, 2003), influencing total DM intake in steers. In addition to the low forage allowance and nutritive values, variables responsible for achieving maximum performance from pastures (Hodgson, 1984; Poppi and McLennan, 1995; Rouquette, 2015), the continuous stocking might compromise the potential productivity of fescue. As mentioned by Hodgson (1984) and Rouquette Jr. (2015), cattle are selective grazers, and when on continuous grazing, they choose the more immature forage from previously grazed areas. Therefore, chemical composition of forage, presence of endophyte, and stocking method may have limited steer performance in phases I and II.

Forage intake is the one of the main responses associated to protein supplementation (McCollum and Horn, 1990), with the largest effect in daily gain occurring when supplemental CP intake is greater than

0.05% BW (Moore et al., 1999). As we demonstrated, supplementing growing steers with lupin and corn increased daily live weight gain, with advantage for those fed protein. Non- supplemented steers lost weight, similarly to that reported before for steers grazing tall fescue (Elizalde et al., 1998), unimproved natural pastures (Nantongo et al., 2021), oat stubble or dry, annual pasture (Smith and Warren, 1986a), and low-quality hay (Hennessy et al., 1983; Sanson et al., 1990; Bodine et al., 2001).

When medium-to-low digestible forage (organic matter digestibility < 60%, Poppi and McLennan, 1995; > 50% NDF, Rearte, 1998) is consumed, as in this experiment, digestion process is diminished due to the complexity of the fiber structure, and grains could modify the amount of undigested residues accommodated in the reticulorumen (Rearte and Pieroni, 2001). Probably, during phase I, the concentration of the main substrates for the microbial growth (ammonia requirements) was met, reflecting a better utilization of dietary N (McCollum and Horn, 1990; Beever and Mould, 2000; Rearte and Pieroni, 2001), enhancing digestion and rate of passage (Stafford et al., 1996; Poppi and McLennan, 1995). Therefore, an improvement in animal performance is achieved (Pordomingo et al., 1991; Nantongo et al., 2021), e.g., LS and CS groups over unsupplemented steers.

The better conversion ratio for LS (5.7:1) than for CS (10.0:1) steers can be explained by the protein status, which appears to be a primary factor influencing energy intake and utilization (McCollum and Horn, 1990; Coleman and Moore, 2003). Alternatively, the short-term forage intake, which is affected by the ruminal fill (Decruyenaere et al., 2009), could have compromised the performance of control steers. In our experiment, a source of protein of high degradability (lupin bean) enhanced animal performance more than corn when supplemented to cattle grazing low-protein forage (fescue, < 7% CP; Caton and Dhuyvetter, 1997), increasing nutrient and total dietary intake.

The presence of endophyte in the fescue and the variability in supplement intake among steers can help us better understand our results. Within the factors limiting supplement intake, competition for the supplements seems not be part of the problem. Husz et al. (2020) observed, in a similar feeder, a small effect on supplement intake when stocked with at least 20 animals in each feeding station. Moreover, the animal visits to the feeder were distributed throughout every hour of the day, with a peak at 01:00 h (Figure 1). Reuter et al. (2017) mentioned appetite or variation in nutrient requirement as animal-level factors influencing the behavior of supplemental intake when offered by automated feeder. Furthermore, to achieve an acceptable level of ADG (0.7 kg/day) during rearing at low forage allowance and with energy supplementation, as observed during phase I, a better quality of pasture (13% CP, < 50% NDF) (Clariget et al., 2021) is necessary than that observed in the tall fescue.

The type of supplement offered to cattle influences the supplement consumed by individual animals (Bowman and Sowell, 1997). The Penn State Particle Separator showed that both fresh and in feces lupin beans had a greater proportion of particle size between 8 and 4.1 mm, while that of corn grain was between 19 and 8 mm. In addition, the percentage of supplement excreted in feces was also different, with a lower percentage of lupin bean than of corn grain. These results could be associated with the performance, mainly with supplement conversion efficiency. The greater percentage of larger particles of fresh corn leads to the idea that these particles have a lower probability of escape from reticulo-omasal orifice, increasing the particle turnover (Okine et al., 1998) and animal performance. For unknown reasons, we observed a higher percentage of corn, not lupin, in the feces of steers, and this finding could explain the lower conversion efficiency for CS treatment. According to Okine et al. (1998), the outflow of digesta is not only based on the physical nature of the feed, but also considers the individual response to the feed, the physiological and metabolic demand, and the environment.

At the end of phase III, supplemented animals weighed more than those of the group without supplementation, and the compensatory index was superior for CS than for control steers. Steers that received lupin gained 24 kg during phase I, and over the next 84 days, those steers previously supplemented with corn made a partial compensatory gain as they grew numerically faster and showed a final body weight like those from LS group. During the last phase, no differences were observed in performance variables: steers supplemented with lupin in phase I gained numerically less weight (151 kg) than those supplemented with corn (165 kg) or unsupplemented (167 kg). Smith and Warren (1986a) observed a significant, inverse, linear relationship between live weight gained in yearling grazing steers supplemented with cottonseed and without supplementation the following 90 days. In agreement with our results, Smith and Warren (1986b) also observed, at the end of finishing, an incomplete compensation for unsupplemented steers, i.e., 63% for control compared with LS steers.

In Uruguay, beef cattle are generally finished directly on pasture; however, supplementation has increased due to the growth of the agricultural area and greater availability of grain and byproducts (Clariget et al., 2021). During the 176 days before slaughter, previous supplementary feeding had no significant effects on performance. However, the HCW and fat removed during the trimming process were greater for supplemented groups than for control steers. Conformation, fatness score, and dressing percentage did not differ between treatments. Similarly, a tendency to greater HCW and dressing percentage with minimal effects on carcass measurements were observed in rearing steers supplemented with different energy sources in endophyte-infected tall fescue pasture and finished in feedlot (Elizalde et al., 1998).

5. Conclusions

This research evidences the requirement of protein by yearling steers grazing endophyte-infected tall fescue in the warm season in the subtropics, due to their faster growth. However, considering subsequent refeeding under grazing conditions, both supplemented groups achieved a similar hot carcass weight at slaughter. These results allow us to think about the applicability of lupin instead of corn in beef cattle production in Uruguay, since the economic cost per ton of feed is higher for the protein supplement than for the energy one. The challenges on this subject are to identify the causes of the low performance of the supplemented cattle, considering rumen physiology and forage intake, as well as identify alternative supplements, mainly those that do not compete with human feeding, to offer to backgrounding steers in pasture in temperate regions.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Canozzi, M. E. A.; Zarza, R.; Banchero, G. E.; La Manna, A.; Fernández, E. and Clariget, J. M. **Data curation:** Canozzi, M. E. A. and Zarza, R. **Formal analysis:** Canozzi, M. E. A. and Clariget, J. M. **Funding acquisition:** Banchero, G. E. **Investigation:** Canozzi, M. E. A. and Zarza, R. **Methodology:** Canozzi, M. E. A.; Zarza, R.; La Manna, A.; Fernández, E. and Clariget, J. M. **Project administration:** Banchero, G. E. **Resources:** Banchero, G. E. **Supervision:** Clariget, J. M. **Writing – original draft:** Canozzi, M. E. A. **Writing – review & editing:** Canozzi, M. E. A.; Zarza, R.; Banchero, G. E.; La Manna, A.; Fernández, E. and Clariget, J. M.

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