Rev Colombiana Cienc Anim. Recia.
2023 julio-diciembre; 15(2):e978
https://doi.org/10.24188/recia.v15.n2.2023.978

Original

Performance of beef animals after different corn harvest strategies in a crop-livestock integrated system

Comportamiento de ganado vacuno de carne después de diferentes estrategias de cosecha de maíz en un sistema integrado agropecuario

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Recepción: 18 febrero 2023 | Aprobación: 18 Junio 2023 | Publicación: 1 agosto 2023

ABSTRACT

Corn can be used in several ways as an animal feed in crop-livestock integrated systems. The objective of this experiment was to evaluate three harvest strategies of corn intercropped with pigeon pea + Palisade grass on weight gain since grazing through finishing. A triple intercropping of corn + pigeon pea + Palisade grass was established in nine hectares (ha) during the 2016/17 season. Treatments were determined according to each corn harvest strategy: whole crop silage (WCS), high moisture corn (HMC) or corn grain (CG). The latter was not harvested due to a low yield and difficulties to hire a combine harvester for only three ha. After harvest, the 9-ha area was divided in six 1.5-ha pens for the grazing phase of the experiment with 30 non-castrated Nelore steers. The same animals were fed feedlot diets based on three sources of corn following the same harvest strategy (treatments): WCS, HMC or CG (bought from a feed industry). During the grazing phase the area that was supposed to be harvested for CG resulted in the greatest ($p \leq 0.05$) stocking rate (3.02 LU/ha) and weight gain per area (210 kg of BW/ha) compared with WCS and HMC. There was no response ($p \geq 0.05$) of corn source (according to each harvest strategy) on feed conversion ratio (FCR), body weith (BW) growth, subcutaneous fat thickness (SFT), pre-slaughter BW, hot carcass weight (HCW) and dressing percentage (DP) during the finishing phase. The data reported here may be a valuable guideline for decision making according to the beef production system and economic scenario.

Keywords: Body weight; energy; feedlot; forage; grain; grazing; Nelore; silage.

RESUMEN

El maíz es un cultivo que puede ser utilizado de varias formas como alimento animal en sistemas integrados cultivo-ganadería. El objetivo de este estudio fue evaluar tres estrategias de cosecha de maíz intercalado con guandú y pasto Palisade sobre el desempeño animal desde el pastoreo hasta la finalización en un confinamiento. Se estableció un triple intercalado de maíz + guandú + pasto Palisade en nueve hectáreas durante la temporada 2016/17. Los tratamientos se determinaron de acuerdo a cada estrategia de cosecha de maíz: ensilaje integral, maíz de alta humedad o maíz en grano. Este último no se cosechó por el bajo rendimiento y las dificultades para alquilar una cosechadora para solo tres ha. Después de la cosecha, el área de 9 hectáreas se dividió en seis corrales de 1,5 hectáreas para la fase de pastoreo del

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Ligoski CB, do Prado PT, Moreira AE, Ferreira GL, Martins OL, Silva RM, et al. Performance of beef animals after different corn harvest strategies in a crop-livestock integrated system. Rev Colombiana Cienc Anim. Recia. 2023; 15(2):e978. https://doi.org/10.24188/recia.v15.n2.2023.978

ISSN: 2027-4297

experimento con 30 novillos Nelore no castrados. Los mismos animales fueron alimentados con dietas de confinamiento a base de tres fuentes de maíz siguiendo la misma estrategia de cosecha (tratamientos): ensilaje integral, maíz de alta humedad o maíz en grano (el último fue comprado a una industria de alimentos). Durante la fase de pastoreo, el área que se suponía que sería cosechada para maíz en grano resultó en la mayor (p≤0.05) carga animal (3.02 unidad ganadera/ hectárea) y ganancia de peso por área (210 kg de peso corporal/ hectárea) en comparación con ensilaje integral y maíz de alta humedad. No hubo efecto (p≥0.05) de la fuente de maíz (según cada estrategia de cosecha) sobre la tasa de conversión alimenticia, el crecimiento del peso corporal, el grosor de la grasa subcutánea, el peso corporal antes del sacrificio, el peso de la canal caliente y rendimiento de la canal durante la fase de confinamiento. Los datos aquí reportados pueden ser una guía útil para la toma de decisiones según el sistema de producción de carne y el escenario económico.

Palabras clave: Confinamiento; energía; ensilaje; forrage; grano; Nelore; pastoreo; peso corporal.

INTRODUCTION

Brazil has reached the second beef production (only behind the United States) and the first beef exporter position of the world at the end of the first decade of the 21st century (1). Reasons for such an increase go from land extension, favorable soil and climate conditions, water supply, low productions costs, and government actions to control and eradicate diseases, which have enabled the continuous supply of high quality beef meat at competitive prices (2).

However, due to growing pressures to reduce deforestation and increase pasture productivity, beef production based on grass has undergone several changes to establish sustainable systems with low environmental impact (3,4).

The integration of crops with livestock may represent a favorable alternative for more efficient production systems (5). Crop-livestock integrated systems (CLIS) are defined by the rotation between crops and pastures in the same area with the aim to maximize land use, infrastructure, labor, as well as minimize costs (6,7). In addition, CLIS seem to be promising to recover degraded pastures and eliminate the necessity to deforest new areas for agricultural and livestock production (8).

The intercropping of annual crops with forages (especially Palisade grasses) has become more frequent in the Brazilian Savannah (9) with the objective to increase feed supply to livestock throughout the dry season (9) and also improve the physical, chemical, and biological properties of the soil as a result of the increased biomass production (8).

Corn is a crop that can be harvested and processed in several ways to be used as an animal feed, such as silage (10), high moisture corn (11) or corn grain (10). However, to the best of our knowledge, there is not a previous report about how corn harvest strategy may affect the performance of animals raised on grass and finished in a feedlot. For instance, corn silage has been widely used as a forage source for beef animals finished in feedlot due to its high dry matter (DM) yield, energy content, and great palatability (12). Conversely, cutting and chopping intercropped forage species on a ground level for whole crop silage (WCS) production may compromise forage regrowth and postpone animal grazing.

Alternatively, corn can be harvested soon after physiological maturity when moisture content ranges between 28 to 32% (11), which may anticipate harvest from two to three weeks compared with corn grain (CG) harvest; therefore animals would be able to graze earlier.

Dried corn kernels, even when finely ground, are protected by the pericarp, which is resistant to microbial and enzymatic digestion in the rumen and small intestine, respectively. Alternatively, ensiling CG with high moisture content will alter physical and chemical properties in the starch molecule and facilitate the action of amylolytic enzymes in the rumen digestion and pancreatic enzymes in the small intestine digestion (13). Moreover, high moisture corn (HMC) has been reported to have a greater digestibility than CG due to the anaerobic ensiling process (14), although there is the demand for silos and a roller or a hammer mill as a disadvantage.

The objetive of this work was to evaluate three harvest strategies of corn intercropped with pigeon pea and Palisade grass on the animal performance since grazing until finishing in a feedlot.

MATERIALS AND METHODS

Location and general information. The present experiment was conducted at the School Farm of the Goiano Federal Institute of Education, Science, and Technology (IF Goiano), Iporá (16º25’29’’S and 51º09’04’’W, 602 meters of altitude), Goiás State, Brazil, during the 2016/17 season. According to Köppen's characterization, the predominant climate is Aw (tropical climate with a dry winter and a hot and rainy summer with mean temperature of 24.4 ºC and mean yearly rainfall of 1,613 mm (15).

Intercropping design. A triple intercropping of corn (Biomatrix hybrid - BM 840®) + pigeon pea (*Cajanus cajan* cv. Super N) + Palisade grass (*Urochloa brizantha* cv. BRS Xaraés) was established in the 2016/17 season in nine hectares. On November 23 of 2016, corn was drilled 0.8 meters within rows at a seeding rate of 60,000 seeds/ha. Simultaneously, pigeon pea was also drilled 0.8 meters within rows (alternated with corn rows) at a seeding rate of 180,000 seeds/ha, whereas Palisade grass was broadcasted at the rate of 360,000 seeds/ha (4 kg of seeds/ha). For a better comprehension, the intercropping scheme used in the present study is described in Figure 1.

An amount of 310 kg/ha of Phospohorus fertilizer (18% P_2O_5) was applied at drilling and a nitrogen fertilization with 250 kg/ha of urea (45% N) was broadcasted when corn reached four mature leaves (V4 stage). There was no application of post-emergent herbicide or insecticide on the corn field, as well as there was no necessity to suppress the initial growth of Palisade grass due to the time elapsed between the emergence of corn and grass.

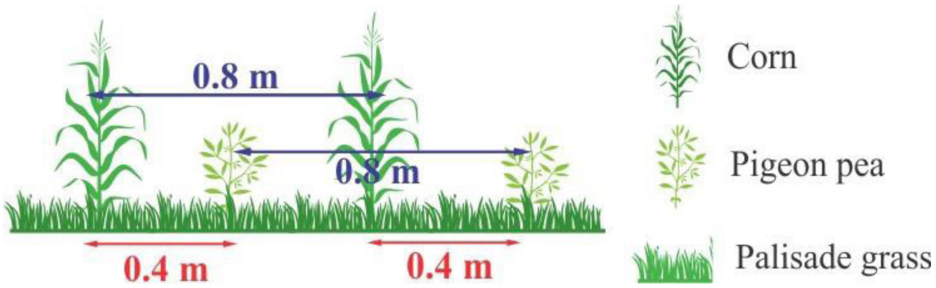

Figure 1. Scheme of the intercropping established on November 23 of 2016 with corn + Peigeon pea + Palisade grass

Grazing phase. For the grazing phase of the experiment, the 9-ha area was divided in six 1.5-ha pens in a randomized block experimental design with three tretaments and two replicates (pens). Treatments were determined according to each strategy of corn harvest: WCS (harvest happened 90 days after drilling), HMC (harvest occurred 118 days after drilling) or CG harvest, which did not occur.

On February 22 of 2017 the two pens assigned for WCS were harvested when DM ranged within 30 to 35%. The two pens assigned for HMC were harvested on March 20 of 2017 when grain moisture content was within 28 through 32% (11). A number of thirty non-castrated Nelore steers with mean body weight (BW) of 345 kg and 18 months of age were randomly assigned to graze the six 1.5-ha pens (two pens after WCS harvest, two pens after HMC harvest, and two pens that were supposed to be harvested for CG).

Forage availability was the criteria used for animal entrance for grazing. In the pens after HMC harvest or no-harvest (which was supposed to be harvested for CG), animals started grazing on March 23 of 2017, whereas in the area harvested for WCS, grazing started on April 12 of 2017.

The conitunous grazing with a variable stocking rate was the system adopted in the present work, following the "put-and-take" techinique (16). The stocking rate adjustment occurred every 21 days based on the aninals' BW recording and forage availability.

In addition to forage, animals were daily fed a supplement constituted by 62.7% ground corn, 22% soybean meal, 1.5% urea, 6.7% sodium chloride, 3.2% limestone, 1.9% dicalcium phosphate, and 2% mineral/vitamin premix, which was offered at an amount of 2 g/kg BW throughout the entire grazing period. The supplement contained 20% Crude Protein (CP), 72.6% Total Digestible Nutrients (TDN), 2.93% Ether Extract (EE), 1.74% Calcium, and 0.64% Phosphorus. The mineral/vitamin premix contained 140 g/kg Calcium, 30 g/kg Phosphorus, 30 mg/kg Cobalt, 500 mg/kg Copper, 10 mg/kg organic Chromium, 8,000 mg/kg Sulfur, 330 mg/kg Fluorine, 30 mg/kg Iodine, 2,500 mg/kg Magnesium, 1,000 mg/kg Manganese, 8.5 mg/kg Selenium, 115 g/kg Sodium, 1,700 mg/kg Zinc, and 500 mg/kg Narasin.

Feedlot phase. The grazing phase ended on June 23 of 2017. In the following day, the same 30 Nelore animals were moved to the experimental feedlot at the School Farm for finishing during 91 days (seven days to adapt for the new facilities and feedlot diets, and 84 days for data recording). The mean BW and age in the beginning of the feedlot was 411.3 kg and 20 months, respectively.

Prior to the feedlot animals were ranked by BW and randomly assigned to receive diets (Table 1) based on three sources of corn according to the harvest strategy (treatments): WCS, HMC or CG (the latter was bought in from a feed industry since CG was not harvested as previously reported). Subsequently the first randomization by initial BW to each treatment group, animals were again randomly assigned by the type of housing, where twelve animals were housed in individual pens and 18 housed in six collective pens (three animals per pen).

Table 1. Ingredient and nutrient composition of the experimental diets[1]

Ingredients, % of DM	WCS[12]	HMC[13]	CG[14]
Corn + Pigeon pea + Palisade grass silage	48.0	-	-
Sugar cane silage	-	38.3	40.1
High moisture corn	-	51.5	-
Ground corn	-	-	49.5
Ground sorghum grain	42.7	-	-
Soybean meal	7.0	8.0	8.0
Urea	0.8	0.7	0.9
Mineral/vitamin premix[2]	1.5	1.5	1.5
Nutrient composition			
DM[3], %	48.38 ± 1.79	45.48 ± 1.21	49.98 ± 1.77
CP[4], % of DM	12.13 ± 0.79	11.21 ± 0.77	11.17 ± 1.67
TDN[5], % of DM	70.75 ± 6.44	71.79 ± 3.56	69.45 ± 6.41
NFC[6], % of DM	39.58 ± 9.06	45.06 ± 5.42	39.62 ± 8.13
NDF[7], % of DM	40.30 ± 9.84	36.53 ± 6.43	42.78 ± 10.50
ADF[8], % of DM	23.38 ± 6.33	23.06 ± 4.08	25.03 ± 6.86
EE[9], % of DM	2.59 ± 0.78	3.09 ± 0.50	2.54 ± 0.70
Ash, % of DM	5,41 ± 0,63	4,11 ± 0,14	4,90 ± 0,64
Ca[10], % of DM	0.34 ± 0.04	0.22 ± 0.07	0.31 ± 0.07
P[11], % of DM	0.26 ± 0.03	0.17 ± 0.02	0.21 ± 0.05

[1]Mean analysis of composite samples (n = 6), [2]Contained 18% Ca, 20 g/kg P, 17g/kg Mg, 26.7g/kg S, 66.7 g/kg Na, 25.2 mg/kg Co, 416 mg/kg Cu, 490 mg/kg Fe, 25.2 mg/kg I, 832 mg/kg Mn, 7 mg/kg Se, 2,000 mg/kg Zn, 833.5 mg/kg Monenzin, 83,200 IU/kg vitamin A, 10,400 IU/kg vitamin D, 240 IU/kg vitamin E, [3]Dry matter, [4]Crude protein, [5]Total digestive nutrients, [6]Non-fiber carbohydrates = 100 - CP% - NDF% - EE% - ash%, [7]Neutral detergent fiber, [8]Acid detergent fiber, [9]Ether extract, [10]Calcium, [11]Phosphorus, [12]Whole crop silage, [13]High moisture corn, [14]Corn grain (not harvested; bought in).

Individual and collective pens had an area of 10 and 50 m^2, respectively, and volumetric size of feed bunks in individual and collective housing was 0.35 and 1.05 m^3, respectively. The feed bunk space in each collective pen was 3.8 meters long (1.26 m/animal).

Along the twelve individual pens there were six drinkers (one drinker for two animals) with an individual capacity of 240 L. Three drinkers were available at the six collective pens (one drinker for two pens) with an individual capacity of 380 L. All drinkers had automatic floats that allowed a continuous water flow.

Steers were fed once a day between 05:00 to 07:00 am in amounts that ensured 10 to 15% of orts (*ad libitum* intake). The three experimental diets were formulated and balanced to meet the recommendations for Nelore cattle finished in a feedlot with an expected weight gain of 1.8 kg/day (17).

Sugar cane silage and WCS samples were collected every week and dried in a forced-air circulation oven for 72 hours at 65°C for DM determination (18) to adjust a possible variation of the dietary nutrient composition throughout the feedlot phase.

Diet samples were collected every other week and stored frozen at -4°C. Soon after the end of the feedlot phase, samples were thawed at room temperature, merged to form one composite sample per treatment and dried in a forced-air circulation oven for 72 hours at 65°C for DM analysis (18). Diet samples were then ground using a Willey mill to pass a 1-mm screen and analyzed for CP, EE, ash, Ca, P (18), neutral detergent fiber, and acid detergent fiber (19).

Feed refusals were weighed every day and dry matter intake (DMI) was determined by subtracting feed offered from feed that was refused.

Body weight (BW) was recorded every three weeks during grazing and every two weeks during the feedlot phase of the experiment (1, 14, 28, 42, 56, 70, and 84 days relative to the beginning of the feedlot phase). In both phases BW was recorded after a twelve-hour solid fasting.

Subcutaneous fat thickness (SFT) was obtained every 28 days (1, 28, 56, and 84 days after the beginning of the feedlot) by ultrasonography between the 12th and 13th ribs. The assessed area was covered by a thin layer of soybean oil to provide a better contact between the probe and the animal skin (20).

Animals were slaughtered on September 25 of 2017 in an abattoir located at Mineiros, Goiás State, Brazil. Prior to transportation to the slaughterhouse, steers were weighed after a 12-hour solid fasting and slaughtered following the procedures and normal flow of the slaughterhouse. After hide removal and evisceration, carcasses were weighed to determine the hot carcass weight (HCW). Dressing percentage (DP) was calculated as the proportion between HCW and BW before slaughter.

All experimental procedures were approved by the IF Goiano Ethical Committee in the Use of Animals (decision number 4263020316 and 6009010317 for the grazing and feedlot phases, respectively).

Data analysis. The experimental design was completely randomized with three treatments (WCS, HMC, and no-harvest) and two replicates (pens) during the grazing phase, and three treatments (WCS, HMC, and CG) and 30 replicates (non-castrated Nelore steers) during the feedlot phase.

The data were analyzed using the "R" open system (21) in a mixed model with repeated measurements in time, considering corn harvest strategies as fixed effects, and pen or animal as random for the grazing and feedlot phases, respectively. The model accounted for the effects of treatment, time (week of the experiment in both phases), and the interaction of treatment by time.

The structure of covariance that best fitted to the model was chosen according to the lowest Bayesian Information Criterion. Analysis for DMI was run separately between individual and collective housing during the feedlot phase of the study. When a fixed effect was significant ($p\leq0.05$), means were compared using the Tukey test.

RESULTS

Mean productivity of WCS was 23,329±764.1 kg of fresh matter/ha and 7,203.4±225.4 kg of DM/ha. Mean productivity of HMC was 2,947.8±171.9 kg/ha and mean yield of CG was 2,195.5±128.6 kg/ha (both in a fresh matter basis).

We decided not to harvest the area with CG because of its very low yield (2,195.5±128.6 kg/ha) plus the difficulties to hire a combine harvester for only three ha (two 1.5 ha-pens), therefore the animals grazed this treatment with all forage components (corn + pigeon pea + Palisade grass). For the feedlot phase of the study, CG was bought in from a feed industry.

Forage production. The DM yield and nutritional value of the forage components after each corn harvest (or no-harvest) is reported in Table 2. Overall, total forage DM yield (corn + pigeon pea + Palisade grass) was increased ($p\leq0.05$) in the area that was supposed to be harvested for CG. Likewise, each individual forage component also had the greatest ($p\leq0.05$) DM yield in the area that was originally planned to be harvested for CG. These data indicate that the choice of not harvesting CG allowed the maximum DM production of the forage components for subsequent grazing, which may be an interesting alternative when corn crop is not worthy to be harvested for grain due to a low yield.

DM forage production was similar ($p>0.05$) between WCS and HMC, regardless if forage components were measured separately or as a total (Table 2).

Table 2. Effect of corn harvest strategy on DM yield and nutritional value of forage components during the grazing phase of the study (April through June of 2017).

Item	Corn			Pegeon pea			Palisade grass			Total		
	WCS[7]	HMC[8]	CG[9]	WCS	HMC	CG	WCS	HMC	CG	WCS	HMC	CG
DM[1] (kg/ha)	0 b	639.8 b	2,171.9 a	19.7 b	40.6 b	189.8 a	1,286 b	926 b	1,688 a	1,322 b	1,604 b	3,571 a
CP[2], % of DM	-	5.9	6.2	25.0	25.5	24.8	7.2 a	5.7 b	4.0 c	6.7	6.2	6.5
EE[3], % of DM	-	2.0	1.9	3.4	1.4	3.1	1.9	1.7	1.7	1.9	1.8	1.6
NDF[4], % of DM	-	45.2	49.9	60.2	69.0	62.2	68.7 b	70.8 ab	76.7 a	70.8	70.5	61.4
ADF[5], % of DM	-	26.1	27.0	48.8	46.4	51.5	44.9	45.5	46.8	44.3	44.2	38.0
Lignin, % of DM	-	0.9	2.3	26.0	17.2	24.5	4.38	4.8	4.4	4.7	5.3	5.1
TDN[6], % of DM	-	64.0	60.9	62.3	56.6	60.8	48.8 a	46.7 a	42.0 b	47.2	47.1	53.4

[1]Dry matter, [2]Crude protein, [3]Ether extract, [4]Neutral detergent fiber, [5]Acid detergent fiber, [6]Total digestive nutrients, [7]Whole crop silage, [8]High moisture corn, [9]Corn grain (not harvested); a, b, and c within the same row indicate diference (P≤0.05) by Tukey test

The nutritional value of the Palisade grass was changed (p≤0.05) by corn harvest strategy (Table 2). CP and TDN were increased (p≤0.05) and NDF was decreased (p≤0.05) in pens harvested for WCS. Contrarily, CP and TDN had the lowest (p≤0.05) values and NDF was highest (p≤0.05) in the pens with no-harvest.

Grazing phase. Animal performance during the grazing phase is reported in Table 3. Stocking rate differed (p≤0.05) according to the corn harvest strategy. The area with no-harvest had the greatest (p≤0.05) stocking rate (3.02 LU/ha), followed by HMC (1.97 LU/ha) and WCS, which had the lowest (p≤0.05) stocking rate (1.35 LU/ha), since a longer interval of time was necessary to allow the regrowth of pigeon pea and Palisade grass to enable the first grazing cycle. This result suggests that the interval of time demanded by forage to regrow since harvest until first grazing may be relevant for animal performance in CLIS. For instance, WCS harvest occurred earlier than HMC (February 22 vs. March 20 of 2017; WCS vs. HMC, respectively). However, animals started grazing the area harvested for HMC earlier than WCS (March 23 vs. April 12 of 2017; HMC vs. WCS, respectively), which demonstrates that when forage needs more time to regrow the initial grazing will occur later.

Table 3. Effect of corn harvest strategy on animal performance of 30 non-castrated Nelore steers during the grazing phase of the study (April through June of 2017).

Item	WCS[2]	HMC[2]	CG[4]
Initial BW, kg	360	344	342
Final BW, kg	413	410	408
Daily supplement intake (kg/animal)	0.228	0.305	0.327
Daily weight gain (kg/animal)	0.836	0.805	0.789
Stocking rate (LU[1]/ha)	1.35 c	1.97 b	3.02 a
Weight gain per area (kg of BW/ha)	105 c	154 b	210 a

[1]Livestock unit = 450 kg of BW, [2]Whole crop silage, [2]High moisture corn, [3]Corn grain; a, b, and c within the same row indicate diference (p≤0.05) by Tukey test

Feedlot phase. Animals fed WCS and housed in individual pens increased (p≤0.05) DMI (expressed in kg/day, BW% and g/kg $BW^{0.75}$) in comparison with animals fed HCM in the same kind of housing (Table 4). However, such an increase (p≤0.05) in DMI was not trasnslated (p>0.05) in a greater BW for animals fed WCS. Furthermore, there was no response (p>0.05) of corn harvest strategy on DMI for animals housed in collective pens (Table 4). Likewise, BW was not influenced (p>0.05) by corn harvest strategy during the feedlot phase of the study (Table 4). These data indicate that the source of corn according to the harvest strategy is not relevant on the performance of beef animals finished in a a feedlot as long as the nutritional level of diets are similar, as reported in Table 1.

Table 4. Effect of corn harvest strategy on animal performance of 30 non-castrated Nelore steers finished in a feedlot (June through September of 2017).

Item	WCS[6]	HMC[7]	CG[8]	SEM[9]	P-values
Individual pens					
DMI[1] (kg/day)	10.69 a	8.76 b	9.63 ab	0.48	0.05
DMI (BW%)[2]	2.23 a	1.83 b	2.00 ab	0.08	≤0.05
DMI (g/kg $BW^{0,75}$)[3]	104.43 a	85.70 b	93.66 ab	4.15	≤0.05
FCR (kg DM/kg gain)[4]	6.03	5.95	6.68	0.79	0.77
Collective pens					
DMI (kg/day)	31.76	26.80	27.42	1.02	0.07
DMI (BW%)	2.14	1.83	1.88	0.06	0.07
DMI (g/kg $BW^{0,75}$)	132.79	113.46	116.32	3.83	0.06
FCR (kg DM/kg gain)[4]	5.88	5.83	7.77	0.64	0.18
BW[5], kg (day 1)	407.71	412.42	413.92		
BW, kg (day 14)	438.67	444.13	445.29		
BW, kg (day 28)	470.04	468.58	466.46		
BW, kg (day 42)	492.13	490.63	491.04	12.78	0.94
BW, kg (day 56)	510.00	496.25	497.25		
BW, kg (day 70)	542.17	531.54	530.38		
BW, kg (day 84)	565.00	546.58	546.96		

[1]Dry matter intake, [2]Dry matter intake expressed as a BW%, [3]Dry matter intake in relation to metabolic weight, [4]Feed conversion ratio, [5]Body weight, [6]Whole crop silage, [7]High moisture corn, [8]Corn grain, [9]Standard error of means
a, b within the same row indicate diference (p≤0.05) by Tukey test.

Similarly, there was no effect (p>0.05) of corn harvest strategy on SFT, pre-slaughter BW, HCW, and DP (Table 5), again suggesting that the final product of corn harvest does not alter (p>0.05) some carcass traits provided that the nutritional value of feedlot diets remains similar (Table 1). Moreover, regardless of the source of corn after harvest, deposition of SFT was slightly over 3 mm (Table 5). Such SFT leves are considered to be desirable to prevent carcass shortening caused by escessive low temperature at the cold storage, which may result in loss of meat tenderness (22).

Table 5. Effect of corn harvest strategy on subcutaneous fat thickness (SFT), pre-slaughter BW, hot carcass weight (HCW), and dressing percentage (DP) of 30 non-castrated Nelore steers finished in a feedlot (June through September of 2017)

Item	WCS[1]	HMC[2]	CG[3]	SEM[4]	P-values
SFT, mm	3,38	3,21	3,23	0,12	0,58
Pre-slaughter BW, kg	565,0	546,6	547,0	14,0	0,57
HCW, kg	312,4	294,7	298,1	8,9	0,34
DP, %	55,2	53,9	54,5	0,4	0,08

[1]Whole crop silage, [2]High moisture corn, [3]Corn grain, [4]Standard error of means

DISCUSSION

The increase in NDF concentration at the expense of a decreased CP and TDN in Palisade grass was possibly due to the greater level of maturity of this forage in the area with no-harvest during the grazing period. Another possibility for the increased NDF content in this same treatment may have been the shade effect of the corn crop over the Palisade grass, which may have lowered the leaf:stem ratio (23) and triggered a greater distribution of the photo-assimilated compounds in the cell wall to make up the absence of light and estimulate stem elongation (24).

Given that forage supply is a key factor to increase weight gain both per animal and per area in CLIS (25,26,27), in a short-term scenario, the choice of not harvesting CG allowed the maximum DM production of the forage components for subsequent grazing (Table 2), which in turn resulted in an increased (p≤0.05) stocking rate (3.02 LU/ha; Table 3) and weight gain per area (210 kg of BW/ha; Table 3). These data suggest that when forage is already established and does not need to regrow after a given harvest strategy, there will be a concomitant increase in stocking rate and animal performance.

Nevertheless, it is worth to highlight that regardless of the corn harvest strategy (or no-harvest), the three treatments yielded a mean weight gain of 0.81 kg/day/animal (Table 3), which is considered to be desirable for grazing animals in tropical conditions (28,29,30). The data reported here indicate that CLIS may be a valuable tool to mitigate the negative effects of long and intense dry seasons (typical in tropical regions) on forage DM production and consequentely on the performance of animals raised on pasture.

Overall, the data reported in this study suggest that corn harvest strategies have a greater impact on grazing animals rather than the finishing phase in a feedlot, possibly because the grazing phase was longer and gathered a whole range of external factors compared with the feedlot phase, such as climate, soil fertility, genetic potential of forage species for DM production, regrowth capacity, and, most importantly, the three corn harvest strategies that affected ($p \leq 0.05$) the stocking rate and weight gain per area, as described in Table 3. Conversly, the feedlot phase was shorter, but mostly due to an equivalent level of nutrients when formulating and balancing the three experimental diets (Table 1), no effect ($p > 0.05$) of corn harvest strategy was detected on BW growth, feed conversion ratio (Table 4), SFT, pre-slaughter BW, HCW, and DP (Table 5).

Thus, it is possible to infer that a given corn harvest strategy should be chosen according to the production system and focus of the beef farm, as well as the perspectives of the economic scenario. For instance, if the target is to obtain high levels of weight gain during grazing and considering there would be an extra forage source for silage production to be fed in the feedlot (e.g., sorghum, sugar cane or an industry reidue), HMC and CG should be the preferable corn harvest strategies since there would be a greater DM forage production for grazing and still an energy feed for the feedlot diet. Conversely, if there is limitation or a shortfall for silage production to be fed in a feedlot, WCS should be the indicated corn harvest strategy, although, in this scenario, the first grazing cycle would be compromised due to the longer interval of time demanded for forage to regrow.

For future perspectives, researchers should focus on determining the effects of indeed harvesting CG on the performance of grazing animals and on assessing the economic data of raising and finishing beef animals in different CLIS, which was not addressed in this work.

In conclusion, WCS should be recommended in production beef systems with emphasis on silage production for the finishing phase in a feedlot, whereas HMC and CG should be indicated in intensive grazing beef systems.

Acknowledgments

The authors appreciate the support of Esmar Gonçalves da Cunha (Medical Doctor and beef farmer) who generously lent the 30 Nelore animals for this experiment. Scholarship support for Lucas Ferreira Gonçalves was from Brazilian National Council for Scienctific and Technological Development (CNPq). Scholarship support for Matheus Silva Rodrigues was from IF Foiano.

Conflict of interest

The authors declare no conflict of interest throughout all steps of the present work (data collection, statistical analysis, laboratory analyses, and manuscript writing).

REFERENCES

1. Associação Brasileira das Indústrias Exportadoras de Carnes. ABIEC. Beef report. Perfil da Pecuária no Brasil; 2021. http://abiec.com.br/publicacoes/beef-report-2021/

2. Braga GB, Ferreira Neto JS, Ferreira F, Amaku M, Dias RA. Caracterização dos sistemas de criação de bovinos com atividade reprodutiva na região Centro-Sul do Brasil. Brazilian Journal of Veterinary Research and Animal Science. 2015; 52(3):217-227. http://10.11606/issn.1678-4456.v52i3p217-227

3. Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C. Food security: the challenge of feeding 9 billion people. Science. 2010; 327(5967):812-818. https://doi.org/10.1126/science.1185383

4. Dias-Filho MB. Os desafios da produção animal em pastagens na fronteira agrícola brasileira. Revista Brasileira de Zootecnia. 2011; 40 (special supplement):270-279. http://www.sbz.org.br/revista/artigos/66282.pdf

5. Alary V, Corbeels M, Affholder F, Alvarez S, Soria A, Valadares Xavier JH, Silva FAM, Scopel E. Economic assessment of conservation agriculture options in mixed crop-livestock systems in Brazil using farm modelling. Agricultural Systems. 2016; 144:33-45. https://doi.org/10.1016/j.agsy.2016.01.008

6. Moraes AD, Carvalho PCF, Lustosa SBC, Lang CR, Deiss L. Research on integrated crop-livestock systems in Brazil. Revista Ciência Agronômica. 2014; 45(5):1024-1031. https://doi.org/10.1590/S1806-66902014000500018

7. Veysset P, Lherm M, Bébin D, Roulenc M. Mixed crop-livestock farming systems: a sustainable way to produce beef? Commercial farms results, questions and perspectives. Animal. 2014; 8(8):1218-1228. https://doi.org/10.1017/S1751731114000378

8. Sant-Anna SAC, Jantalia CP, Sá JM, Vilela L, Marchão RL, Alves BJR, Urquiaga S, Boddey RM. Changes in soil organic carbon during 22 years of pastures, cropping or integrated crop/livestock systems in the Brazilian Cerrado. Nutrient Cycling in Agroecosystems. 2017; 108(1):101-120. http://10.1007/s10705-016-9812-z

9. Vilela L, Martha Junior GB, Macedo MCM, Marchão RL, Guimarães Júnior R, Pulrolnik K, Maciel GA. Sistemas de integração lavoura-pecuária na região do Cerrado. Pesquisa Agropecuária Brasileira, 2011; 46(10):1127-1138. https://doi.org/10.1590/S0100-204X2011001000003

10. Oliveira LM, Santos RT, Rodrigues MS, Santana MM, Wander AE, Carvalho ER. Impacto da alimentação de bovinos de corte terminados em confinamento: variáveis médias e marginais. Custos e @gronegócio online. 2021; 17(special edition):28-54. http://www.custoseagronegocioonline.com.br/especialv17/OK%202%20cortes.pdf

11. Pereira KA, Ribeiro RV, Oliveira AR, Amaral AG. Parámetros en la utilización de silaje de grano húmedo de maíz en la bovinocultura de corte. Revista Colombiana de Ciencia Animal. 2019; 11(1):102-113. https://doi.org/10.24188/recia.v11.n1.2019.622

12. Daniel JLP, Bernardes TF, Jobim CC, Schmidt P, Nussio LG. Production and utilization of silages in tropical areas with focus on Brazil. Grass and Forage Science. 2019; 74(2):188-200. https://doi.org/10.1111/gfs.12417

13. Owens FN, Secrist DS, Hill WJ, Gill DR. The effect of grain source and grain processing on performance of feedlot cattle: a review. Journal of Animal Science. 1997; 75(3):868-879. https://doi.org/10.2527/1997.753868x

14. Nocek JE. Characterization of in situ dry matter and nitrogen digestion of various corn grain forms. Journal of Dairy Science. 1987; 70(11):2291-2301. https://doi.org/10.3168/jds.S0022-0302(87)80289-8

15. Cardoso MRD, Marcuzzo FFN, Barros JR. Classificação climática de Köppen-Geiger para o Estado de Goiás e o Distrito Federal. Acta Geográfica. 2014; 8(16):40-55. https://doi.org/10.18227/2177-4307.acta.v8i16.1384

16. Rouquette Jr FM. Grazing systems research and impact of stocking strategies on pasture-animal production efficiencies. Crop Science. 2015; 55(6):2513-2530. https://doi.org/10.2135/cropsci2015.01.0062

17. National Research Council - NRC. Nutrient requirements of beef cattle. 7th revised edition. Washington, DC: National Academy Press, 2000. 242p.

18. Association of Official Analytical Chemists - AOAC. Official methods of analysis. 17th edition. AOAC International, Gaithersburg, MD, 2000.

19. Goering HK, Van Soest PJ. Forage fiber analyses (apparatus, reagents, procedures and some applications). Agricultural Handbook nº 379. Agricultural Research Service - USDA, Washington, DC, 1970.

20. Brethour JR. The repeatability and accuracy of ultrasound in measuring backfat of cattle. Journal of Animal Science. 1992; 70(4):1039-1044. https://doi.org/10.2527/1992.7041039x

21. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing, 2019. http://www.Rproject.org/

22. Alves DD, Goes RHTB, Mancio AB. Maciez da carne bovina. Ciência Animal Brasileira. 2005; 6(3):135-149. https://revistas.ufg.br/vet/article/view/370

23. Leonel FP, Pereira JC, Costa MG, Marco Júnior P, Lara LA, Queiroz AC. Comportamento produtivo e características nutricionais do capim-braquiária cultivado em consórcio com milho. Revista Brasileira de Zootecnia. 2009; 38(1):177-189. https://doi.org/10.1590/S1516-35982009000100022

24. Samarakoon SP, Wilson JR, Shelton HM, Growth, morphology and nutritive quality of shaded *Stenotaphrum secundatum*, *Axonopus compressus* and *Pennisetum clandestinum*. The Journal of Agricultural Science. 1990; 114(2):161-169. https://doi.org/10.1017/S0021859600072154

25. Mezzalira JC, Carvalho PCF, Trindade JK, Bremm C, Fonseca L, Amaral MF, Reffatti MV. Produção animal e vegetal em pastagem nativa manejada sob diferentes ofertas de forragem por bovinos. Ciência Rural. 2012; 42(7):1264-1270. https://doi.org/10.1590/S0103-84782012005000039

26. Franzluebbers AJ, Stuedemann JA. Crop and cattle production responses to tillage and cover crop management in an integrated crop-livestock system in the southeastern USA. European Journal of Agronomy. 2014; 57:62-70. https://doi.org/10.1016/j.eja.2013.05.009

27. Oliveira CAO, Bremm C, Anghinoni I, Moraes A, Kunrath TR, Carvalho PCF. Comparison of an integrated crop-livestock system with soybean only: Economic and production responses in southern Brazil. Renewable Agriculture and Food Systems. 2014; 29(3):230-238. https://doi.org/10.1017/S1742170513000410

28. Reis RA, Ruggieri AC, Casagrande DR, Páscoa AG. Suplementação da dieta de bovinos de corte como estratégia do manejo das pastagens. Revista Brasileira de Zootecnia. 2009; 38(special supplement):147-159. https://doi.org/10.1590/S1516-35982009001300016

29. Machado PAS, Valadares Filho SC, Valadares RFD, Paulino MF, Paulino PVR, Marcondes MI. Desempenho e exigências de energia e proteína de bovinos de corte em pasto suplementados. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2012; 64(3):683-692. https://doi.org/10.1590/S0102-09352012000300021

30. Hoffmann A, Moraes EHBK, Mousquer CJ, Simioni TA, Gomer FJ, Ferreira VB, Silva HM. Produção de bovinos de corte no sistema pasto-suplemento no período da seca. Nativa. 2014; 2(2):119-130. https://doi.org/https://doi.org/10.31413/nativa.v2i2.1298