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Performance of feedlot steers on silage stored using different plastic films

Desempenho de novilhos confinados alimentados com silagem armazenadas com diferentes filmes plásticos

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Highlights

Silage sealed with DF200 plastic film resulted in higher animal ADG.
Animals fed DF200 sealed silage showed better feed efficiency.
Carcass performance was superior for animals fed DF200 sealed silage.
Diets composed of DF200 sealed silage exhibited better apparent digestibility.

Abstract

This study aimed to assess animal performance, ingestive behavior, apparent diet digestibility, and carcass traits in feedlot finished steers fed corn silage stored using different double sided plastic films. The experimental period lasted 100 days, with 16 days for adaptation and three 28 day assessment periods. Thirty ½ blood Angus Nellore steers with average age and weight of 12 months and 366.5 kg, respectively, were used. The experimental design applied was completely randomized blocks consisting of three treatments (DF110 µm - 110 µm thick double sided polyethylene; DF200 µm - 200 µm thick double sided polyethylene; and DFBO - oxygen impermeable film composed of 80 µm thick double sided polyethylene overlaid with translucent 20 µm thick polyamide vacuum film), with five repetitions each, consisting of a pen containing two animals. Corn silage sealed with DF200 resulted in an average increase of 0.182 kg day^{-1} in animal weight gain and approximately 10.96% in feed efficiency in animals

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that consumed this silage. Silage sealed with DF200 showed greater apparent DM digestibility, with a 6.97% increase compared to DF110, and carcass yield 8.75 and 11.53% higher than that obtained with DFBO and DF110, respectively. DF200 sealed silage also promoted an increase in daily carcass gain, which was 11.47% higher than that of DF110. DF200 and DFBO are the most suitable plastic films for sealing corn silage in trench silos, since they improve rumen dry matter degradation and promote greater carcass gains in animals during the feedlot period when compared to the control.
Key words: Carcass gain. Carcass traits. Ingestive behavior. Oxygen barrier film. Polyethylene.

Resumo

Objetivou-se avaliar o desempenho animal, comportamento ingestivo, digestibilidade aparente e características de carcaça de novilhos terminados em confinamento alimentados com silagem de milho armazenada com diferentes filmes plásticos dupla face. O período experimental teve duração de 100 dias, sendo 16 dias para adaptação e três períodos de avaliação de 28 dias cada. Foram utilizados 30 novilhos ½ sangue Angus Nelore, com idade média de 12 meses e peso médio de 366,5 kg. O delineamento experimental foi em blocos inteiramente casualizados, composto por três tratamentos: DF110 polietileno dupla face com 110 μm de espessura; DF200 polietileno dupla face com espessura de 200 μm; e DFBO - filme impermeável ao oxigênio composto de polietileno dupla face com 80 μm de espessura sobreposto por filme translúcido de poliamida a vácuo com 20 μm de espessura, com cinco repetições cada, sendo cada repetição composta por um curral com dois animais. A utilização do DF200 para a selagem da silagem de milho proporcionou um aumento médio de 0,182 kg no ganho de peso dos animais no dia^{-1}, bem como promoveu uma melhoria média de cerca de 10,96% na eficiência alimentar dos animais alimentados com a silagem selada com este filme Silagens seladas com DF200 promoveram maior digestibilidade aparente da matéria seca (MS) da dieta (6,97% a mais em relação ao DF110), aumento no rendimento de carcaça (8,75% em relação ao DFBO e 11,53% em relação ao DF110), e também, incremento no ganho diário de carcaça (11,47% superior ao DF110). Os filmes DF200 e DFBO são os mais indicados para selagem de silagem de milho em silos de trincheira, pois resultam em maior degradação ruminal da matéria seca e aumentam o ganho de carcaça dos animais no período de confinamento em relação ao controle.
Palavras-chave: Características de carcaça. Comportamento ingestivo. Filme barreira de oxigênio. Ganho de carcaça. Polietileno.

Introduction

Optimizing corn silage yield is vital in beef cattle farming, since forage quality directly affects productive performance and the financial return for farmers (Neumann et al., 2018). However, the ensiling process is complex and involves many variables that can influence fermentation levels and patterns (M. S. J. D. Silva et al., 2015).

Several different factors influence the ensiling process and the plastic film used to seal the silo is a controllable variable. Plastic film selection should aim to reduce losses caused by the lack of anaerobiosis in silos due to inadequate sealing with low quality plastic films that allow oxygen penetration (Bernardes, 2016; Cristo et al., 2021).

Storage failures can result in dry matter and nutrient loss, disposal of ensiled material, and reduced intake, directly impacting feed management and animal performance (Wilkinson & Fenlon, 2014).

The plastic films used to seal silos can directly affect silage preservation and must be resistant to mechanical damage, handling, weather (wind, rainfall, and hail), and UV rays, with good insulation capacity and low oxygen permeability. All these characteristics ensure the maintenance of anaerobic conditions inside the silo during storage and the feed out period (Bernardes et al., 2018; Borreani et al., 2018).

Polyethylene film is commonly used to seal trench silos due to its low cost and mechanical properties. However, it is not completely impermeable to oxygen, which can penetrate the ensiled mass (Scheidt et al., 2023). The main factors that differentiate types of polyethylene sealing are tarp thickness and the presence of an oxygen impermeable layer (Cristo et al., 2021).

Maintaining anaerobic conditions inside the silo is essential for satisfactory fermentation and correct preservation of the ensiled mass (Gayer et al., 2019). Thus, when seeking weight increases and carcass gains, obtaining a stable environment without O2 can alter animal ingestive behavior and fiber digestibility (Neumann et al., 2018).

In this context, the present study aimed to assess the effect of corn silage stored in trench silos sealed with different double sided plastic films on animal performance, ingestive behavior, apparent diet digestibility, and carcass traits in feedlot finished steers.

Material and Methods

All the experimental procedures were previously approved by the Animal Ethics Committee (CEUA) (Official Letter 021/2018). The experiment was conducted in Guarapuava, Paraná state, Brazil (25° 22' 57.6” S, 51° 29' 50” W, approximately 1,100 m.a.sl.). Climate in the region is subtropical mesothermal humid (Cfb) according to Köppen’s classification, with cool summers, moderate winters and no dry season. Average annual values for rainfall, minimum and maximum temperature, and relative humidity are 1,944 mm, 12.7 and 23.5 ºC, and 77.9%, respectively.

Experimental design, animals and facilities

For grain and silage production, corn (*Zea mays* L.) was planted on February 11, 2017, using early cycle Maximus Viptera 3 (Syngenta®) hybrid seeds, with hard kernels and glyphosate resistance biotechnology. A no till system was adopted, using row spacing of 0.80 m, sowing depth of 0.04 m, and 5 seeds per linear meter, aiming at a final population of 62,500 plants ha^{-1}.

Corn plants were harvested 145 days after emergence (DAE) at the dent stage (R5), using a JF® precision forage harvester (C-120 AT S2), with average particle size adjusted to 2.35% in the first sieve (>1.9cm), 52.45% in the second (1.9-0.8cm), and 43.98% in the third (<0.8cm).

The experimental animals used were 30 previously dewormed Angus Nellore steers from the same herd, with average initial weight and age of 366.5 kg ± 3 kg and 12 months, respectively.

The DF110 treatment consisted of a Plus Agrolord® 110 μm thick double sided polyethylene plastic film (Basso Pancote), DF200 of a 200 μm thick double sided polyethylene plastic film (Carga Pesada®), and DFBO of a Polydress® O2 Barrier 2IN1 plastic film (RKW) with an 80 μm layer of double sided polyethylene protective film overlaid with a translucent 20 μm thick polyamide vacuum film, ensuring greater oxygen impermeability.

The material collected for each treatment was stored in 12 trench silos, each with length, width and height of 15, 1.2 and 1.2m, respectively. The silos were opened simultaneously 75 days after sealing and feed out was conducted over 100 days, with 0.15 m of silage removed daily. The top silage and any visibly deteriorated silage were discarded.

The experimental setup consisted of 15 feedlot pens, each measuring 15 m^2 (2.5 m x 6.0 m). Each pen contained a 2.30 m long, 0.60 m wide, and 0.35 m tall concrete feeder and a metallic drinking trough controlled by an automatic float.

The experiment lasted 100 days for feedlot finishing, consisting of 16 days for adaptation to the diets and experimental facilities, followed by three sequential 28 day assessment periods. The animals were fed twice a day, at 6:00 a.m. and 4:00 p.m.

Experimental diets and feed management

Voluntary feed intake was recorded daily, by weighing the amount offered and the leftovers from the previous day, with daily adjustments to allow for leftovers of 5% of the amount offered on a dry matter (DM) basis.

The diets consisted of a mixture of 40% corn silage and 60% pelleted concentrate, on a DM basis. The pelleted concentrate contained the following ingredients: soybean meal, wheat bran, malt radicle, corn, soybean hulls, calcitic limestone, dicalcium phosphate, livestock urea, common salt, and vitamin and mineral premix.

In addition to the adjustments, leftovers in the trough were visually assessed daily and a feed score established on a scale of 1 to 6, where: 1 - 60% silage and 40% concentrate; 2 - 50% silage and 50% concentrate; 3 - 40% silage and 60% concentrate; 4 - 30% silage and 70% concentrate; 5 - 20% silage and 80% concentrate; and 6 - 10% silage and 90% concentrate, on a DM basis.

A fecal score from 1 to 5 was determined daily via visual assessment, as follows: 1- watery feces lacking consistency; 2 - loose feces, with few ripples and no definitive shape; 3 - pasty feces in piles between 1 and 4.5 cm high with 2 to 4 concentric rings; 4 - low-liquid feces in piles between 5 and 7.5 cm high; 5 - hardened feces in piles greater than 7.5 cm high, according to a methodology adapted from Ferreira et al. (2013).

Samples of corn silage sealed with different plastic films and the experimental diets used in animal feed were dried in a forced air oven at 55 °C for 72 hours to determine partial dry matter. The pre dried samples were ground in a Wiley mill with a 1 mm diameter sieve and dried in a forced air oven at 105 °C for 16 hours to determine total dry matter (DM) (D. J. Silva & Queiroz, 2009), mineral matter (MM) and crude protein

(CP) content, according to the Association of Official Analytical Chemists [AOAC] (1995). Neutral detergent fiber (NDF) content was obtained according to Van Soest et al. (1991), using thermostable α-amylase. Acid detergent fiber (ADF) and lignin (LIG) content were determined according to Goering and Van Soest (1970) and total digestible nutrients (TDN) according to equations proposed by Weiss et al. (1992). Table 1 lists the chemical composition of the ingredients used in animal feed (silage and experimental diets) on a total dry matter basis.

Table 1
Chemical composition of the silage and experimental diets

Parameter	Silage - Plastic Films		
	DF110	DF200	DFBO
Dry Matter (DM), %	42.07	42.61	41.08
Mineral Matter (MM), % DM	2.31	2.32	2.40
Crude Protein (CP), % DM	6.77	6.79	7.26
Neutral Detergent Fiber (NDF), % DM	53.67	52.92	53.54
Acid Detergent Fiber (ADF), % DM	30.03	29.38	29.12
Lignin (LIG), % DM	5.19	5.03	5.14
Total Digestible Nutrients (TDN), %	66.82	67.28	67.45
	Experimental diets - Plastic Films		
	DF110	DF200	DFBO
Dry Matter (DM), %	70.73	71.27	71.37
Mineral Matter (MM), % DM	4.98	5.16	4.90
Crude Protein (CP), % DM	14.52	14.81	14.54
Neutral Detergent Fiber (NDF), % DM	40.83	39.41	40.23
Acid Detergent Fiber (ADF), % DM	19.54	18.67	19.44
Lignin (LIG), % DM	5.62	5.50	5.46
Total Digestible Nutrients (TDN), %	74.16	74.77	74.23

Ingestive behavior, apparent feed digestibility, and productive characteristics

Ingestive behavior was analyzed from noon on the first day of assessment to noon on the third day. Observations were made by eight observers per shift over a 48 hour period in a six hour shift schedule, with readings taken at 3 minute intervals. Data on ingestive behavior were divided into idleness (Id), rumination (RUM), water consumption (WC), and feed consumption (FC), expressed in hours day^{-1}. Additionally, in line with the same methodology, the frequency of feeding (Fe), drinking (Dr), urination (Ur), defecation (Def), and non ingestive oral behavior (NIOB) was recorded in number of times day^{-1}. For nighttime observation, the environment was maintained under artificial lighting.

For apparent digestibility, composite diet samples of each treatment were taken during the experimental period. Feed collections were performed once a day over two consecutive days and the samples stored in a freezer. At the end of the assessment, samples were thawed, homogenized to form a composite sample per pen and treatment, and stored at -15 ºC. Daily feed intake and leftovers were measured for two consecutive days (48 hours), along with the total fecal output of the animals in each pen. During the apparent digestibility test, a homogeneous sample of the feces produced was collected every six hours and stored under refrigeration. The weight of the fecal sample for each six hour period was proportional to the total volume of feces produced. Diet and feces samples were dried in a forced air oven at 55°C until constant weight and corrected for total dry matter at 105 °C to determine DM content according to D. J. Silva and Queiroz (2009). The fecal and leftover DM content of each experimental unit was determined using the same procedures adopted in diet analysis.

The apparent DM digestibility coefficient of the experimental diets was calculated according to the following formula: apparent DM digestibility coefficient (%) = [(g ingested nutrient – g excreted nutrient) ÷ g ingested nutrient] x 100.

Ingestive behavior and apparent digestibility were determined at the end of the first and third assessment periods of feedlot finishing.

Animals were weighed at the beginning and end of each 28 day experimental period, after a 10 hour solid fast. The variables evaluated were body weight (BW, kg), average dry matter intake, expressed in kg animal day^{-1} (DMI, kg day^{-1}), average DMI expressed in percentage of body weight (DMI, BW%), average daily weight gain (ADG, kg day^{-1}) and feed efficiency (FE, kg kg^{-1}).

DMI was estimated as the difference between the daily amount of feed provided and the amount of feed left over from the previous day, corrected for total dry matter. DMI, BW% was obtained based on the ratio between DMI and average BW for the period, multiplied by 100 (1) (DMI, BW%= DMI /BW*100). ADG was calculated by the difference between the final (BW_f) and initial (BW_i) BW for the experimental period divided by the number of days (ADG= BW_f - BW_i/ 28), and FE by the ratio of ADG to DMI (FE= ADG/ DMI).

Carcass characterization

At the end of feedlot finishing, animals were solid fasted for 10 hours to weigh them before shipment to the slaughterhouse, obtaining the farm weight. Carcass gain (CG) in the feedlot period, expressed in kg, was calculated based on the difference between hot carcass weight at slaughter and initial body weight (BWi) under a theoretical carcass yield of 50%. Based on the 84 day feedlot period, average carcass gain (ACG) in kg day^{-1} was determined by the ratio of CG to BW, the efficiency of consumed dry matter conversion into carcass (ECC) in kg DM kg carcass^{-1}, and the efficiency of weight gain conversion into carcass (CY ADG %) by the ratio of ACG to ADG (ACG/ADG). Hot carcass weights were considered for these calculations.

Four developmental measurements were taken of the carcasses, as follows: carcass length (CL), arm length (AL), thigh thickness (TT), and arm girth (AG), according to the methodologies proposed by Muller (1987). Additionally, subcutaneous fat thickness (FT) was measured along the *Longissimus dorsi* muscle between the 12th and 13th ribs, using a digital caliper.

Upon slaughter, the following body parts were also collected for weighing: head, tongue, tail, leather, feet, and testicles (external components), as well as the heart, kidneys, liver, lungs, spleen, full rumen-reticulum, full abomasum, and full intestines (vital organs).

Statistical analysis

The experimental design used randomized blocks with three treatments and five repetitions, where each repetition corresponded to a pen containing two animals. Data collected for each variable were submitted to analysis of variance followed by Tukey's test at 5% significance, using SAS statistical software (Statistical Analysis System Institute [SAS Institute], 1993).

For parameters related to animal performance and carcass traits, each variable was analyzed in accordance with the statistical model: $Y_{ijk} = \mu + V_i + B_J + E_{ijk}$; where: Y_{ijk} = dependent variables; μ = overall mean of all observations; V_i = effect of types of double sided film of order "i", where 1 = DF110, 2 = DF200, and 3 = DFBO; BJ = effect of the block of order "J", where 1 = first, 2 = second, 3 = third, 4 = fourth and 5 = fifth; and E_{ijk} = residual random effect.

For parameters related to apparent DM digestibility and ingestive behavior, expressed in hours a day^{-1} and times a day^{-1}, each variable was analyzed according to the statistical model: $Y_{ijkl} = \mu + V_i + P_j + B_k + (V{*}P)_{ij} + E_{ijkl}$; where: Y_{ijk} = dependent variables; μ = overall mean of all observations; V_i = effect of types of double sided film of the i-th order, where 1 = DF110, 2 = DF200, and 3 = DFBO; P_j = effect of the feedlot period of the j-th order, where 1 = first moment and 2 = second moment; B_k = effect of the block of the k-th order, where 1 = first, 2 = second, 3 = third, 4 = fourth and 5 = fifth; $(V{*}P)_{Ij}$ = effect of the interaction between the type of double sided film and the i-th order feedlot period, and E_{ijk} = residual random effect. The summary of the analysis of variance indicated no significant interaction (P>0.05) between types of plastic films and feedlot periods, based on the average value of each parameter.

Results and Discussion

Animal performance and dry matter intake

For ADG and FE (Table 2), there was a significant difference (P<0.05) between the different films evaluated. Animals fed DF200 sealed silage obtained a higher ADG, with maximum increases of 0.207 and 0.156 kg animal day^{-1} in the first and third periods, respectively, when compared to those that received silages from the other treatments. With respect to FE, animals were 14.50 and 10.19% more efficient in the first and third periods, respectively, in relation to the mean of the other treatments.

Table 2
Performance and dry matter intake of steers fed corn silage stored in trench silos sealed with different double sided plastic films

Parameters*	Plastic films			Mean	SEM	P>F
	DF110	DF200	DFBO			
ADG, kg day^{-1}:						
0 to 28 days	1.26 b	1.47 a	1.27 b	1.33	0.059	0.0274
0 to 56 days	1.51 a	1.59 a	1.50 a	1.53	0.050	0.7191
0 to 84 days	1.37 b	1.52 a	1.39 b	1.43	0.043	0.0341
DMI, kg day^{-1}:						
0 to 28 days	9.88 a	10.05 a	9.98 a	9.97	0.176	0.9288
0 to 56 days	10.16 a	10.17 a	10.21 a	10.18	0.195	0.9953
0 to 84 days	10.06 a	10.10 a	9.89 a	10.02	0.197	0.9005
DMI, BW%:						
0 to 28 days	2.33 a	2.25 a	2.30 a	2.29	0.037	0.6737
0 to 56 days	2.41 a	2.36 a	2.38 a	2.38	0.032	0.8142
0 to 84 days	2.29 a	2.24 a	2.22 a	2.25	0.031	0.6811
FE (ADG DMI^{-1}):						
0 to 28 days	0.12 b	0.14 a	0.12 b	0.134	0.005	0.0403
0 to 56 days	0.14 a	0.15 a	0.14 a	0.150	0.004	0.4721
0 to 84 days	0.20 b	0.22 a	0.20 b	0.213	0.005	0.0466
Daily feed score:						
0 to 28 days	2.96 a	2.32 a	2.81 a	2.70	0.178	0.2159
0 to 56 days	2.91 a	2.46 a	2.94 a	2.77	0.139	0.9302
0 to 84 days	2.86 a	2.54 a	2.92 a	2.77	0.124	0.7287
Daily fecal score:						
0 to 28 days	3.06 a	2.92 a	3.12 a	3.04	0.039	0.2694
0 to 56 days	2.96 a	2.99 a	2.99 a	2.98	0.026	0.1623
0 to 84 days	2.86 a	2.73 a	2.81 a	2.80	0.036	0.0716

* ADG: average daily gain, kg day^{-1}; DMI: dry matter intake, kg day^{-1}; DMI, BW%: dry matter intake, % body weight; FE: feed efficiency; and SEM: Standard error of the mean. Means followed by different lowercase letters in the same row differ according to Tukey's test ($\rho < 0.05$).

Neumann et al. (2018) compared two types of double sided film sealing, namely conventional sealing with 110 µm polyethylene film and double sealing using two polyethylene films, totaling approximately 200 µm. The authors reported that the 200 µm double sided film resulted in higher ADG, with an increase of 0.245 kg animal day^{-1} compared to animals in the 110 µm polyethylene film treatment.

In another study, Neumann et al. (2021) evaluated the ADG of feedlot steers that received corn silage sealed with different double sided plastic films (100 µm, 200 µm, and O_2 barrier film), and observed greater weight gain in animals fed the silage sealed with the 200 µm when compared to the 100 µm plastic film (1.892 kg day^{-1} versus 1.653 kg day^{-1}).

Based on the results obtained in the present study and those of Neumann et al. (2021) and Neumann et al. (2018), 200 µm provides a more efficient seal, quickly consuming the oxygen present in the ensiled mass, inhibiting the activity of aerobic microorganisms, and reducing the temperature of the material (Neumann et al., 2021). This minimizes nutrient losses, preserves chemical composition, and maintains the digestibility of corn silage, resulting in better feed use by the animals (Borreani et al., 2007; Neumann et al., 2017).

Neumann et al. (2021) reported that silage sealed with 200 µm double sided plastic film promotes higher DMI (10.02 kg animal day^{-1}) and DMI (2.25%) compared to that obtained in animals fed 110 µm polyethylene sealed silage. This did not occur in the present study because dry matter intake expressed in kg day^{-1} (DMI) and per 100 kg body weight (DMI) were not affected by the different double sided plastic films (P>0.05). It would be controversial to increase the FE of these animals, given that they exhibited a higher ADG without changing their DM intake.

However, Machado (2019) investigated oxygen barrier film as a replacement for conventional polyethylene film and observed similar performance and carcass traits in animals fed silage from the different treatments, which contrasts with our findings. The author attributed this outcome to the UV protective coating of the two films, which mitigated the effect of the plastic film used to seal the silo on animal performance.

Parra et al. (2021) and Cristo et al. (2021) reported that conventional low thickness polyethylene films commonly used to seal silos result in poor silage preservation, lower DMI, a larger amount of visually inedible silage, higher yeast counts, and lower lactic acid and soluble carbohydrate concentrations, associated with higher pH and temperature.

The different double sided plastic films studied here caused no significant changes (P>0.05) in the daily feed and fecal scores as the feedlot periods advanced (Table 2), indicating no diet selection by the animals since the daily scores remained constant throughout the assessment period.

Ingestive behavior

As observed for productive performance, ingestive behavior (Table 3) was influenced by the different plastic films used to seal the silos (P<0.05). Animals fed DF110 sealed silage spent more hours consuming feed (FC) and water (WC) (2.59 and 0.18 hours day^{-1}, respectively) compared to those fed silage from the DF200 (2.29 and 0.12 hours day^{-1}, respectively) and DFBO treatments (2.12 and 0.15 hours day^{-1}, respectively). For rumination (RUM) and idleness (Id), expressed in hours day^{-1} (Table 3), the type of film used to seal the silo had no effect on these activities (P>0.05).

Table 3
Ingestive behavior in hours day^{-1} and activity frequency in times day^{-1} of steers fed corn silage stored in trench silos sealed with different double sided plastic films

Parameters*	Plastic films			Mean	SEM	P>F
	DF110	DF200	DFBO			
Hours day^{-1}						
FC	2.59 a	2.29 b	2.12 b	2.33	0.0943	0.0148
WC	0.18 a	0.12 b	0.15 b	0.15	0.0056	0.0180
RUM	5.15 a	4.85 a	5.78 a	5.17	0.2547	0.0866
Id	16.12 a	16.79 a	15.97 a	16.29	0.3033	0.2085
Times day^{-1}						
Fe	15.63 a	12.17 b	14.13 ab	13.97	0.6078	0.0053
Dr	5.54 a	4.54 a	4.83 a	4.97	0.2481	0.2444
Def	6.33 a	5.71 a	7.08 a	6.37	0.2444	0.1249
Ur	5.42 a	4.25 a	5.33 a	5.00	0.1631	0.1693
NIOB	5.04 a	3.71 ab	2.63 b	3.79	0.1567	0.0086

* FC: feed consumption; WC: water consumption; RUM: Rumination; Id: Idleness; Fe: Feeding; Dr: Drinking; Def: Defecation; Ur: Urination; NIOB: non ingestive oral behavior; and SEM: Standard error of the mean.
Means followed by different lowercase letters in the same row differ according to Tukey's test ($\rho<0.05$).

Neumann et al. (2018) observed changes in ingestive behavior in animals fed silage sealed with a 200 µm double sided film, longer idle time and reduced rumination, feeding, and solid excretion time. It should be noted that the animals in that study selected the diet, while in the present study feed scores were similar because the animals consumed the same diet throughout the evaluation period. Moreover, ingestive behavior also changed in our study, with animals fed silage sealed with the low thickness film exhibiting increased feeding frequency and time and more frequent drinking and non ingestive oral behavior.

Diets with higher energy concentrations require less feeding time, whereas larger amounts of NDF require longer feeding periods (Missio et al., 2010; Souza et al., 2019). Another important factor is the ease of NDF hydrolysis, since the greater the hydrolysis, the faster NDF is eradicated from the rumen, reducing physical filling and enabling greater voluntary feed intake (Oba & Allen, 1999). This may have contributed to behavioral changes in the animals, since the diets were isoenergetic and isofibrous, demonstrating the influence of the plastic film on the ensiled material.

In the presence of oxygen, facultative aerobic microorganisms in the silage trigger oxidation, mainly of sugars and polysaccharides, and use organic acids as a substrate, reducing the energy value of the feed and contributing to higher butyric acid levels due to silo sealing failure caused by poor quality plastic film. DM intake declines under high organic acid concentrations, which may trigger metabolic disorders (Krizsan & Randby, 2007).

Animals fed DF110 sealed silage spent more time ingesting feed and water (FC and WC) and displayed greater feeding (Fe) frequency (Table 3) (15.63 times day^{-1}) than those fed silage sealed with the DF200 film (12.17 times day^{-1}). In turn, animals in the DFBO treatment showed intermediate feeding frequency (14.13 times day^{-1}), not differing from the other treatments (P>0.05).

The plastic film also affected NIOB (P< 0.05), with greater frequency (5.04 times day^{-1}) in animals fed a diet containing DF110 sealed silage compared to those in the DFBO treatment (2.63 times day^{-1}), but no difference in relation to the DF200film (3.71 times day^{-1}).

Defecation (Def) and urination (Ur) frequency were not affected by the type of double sided plastic film used for silo sealing (P>0.05).

Total fecal output and apparent dry matter digestibility

With respect to apparent DM digestibility of the diet and ingestive behavior, no interaction was observed between the factors assessed. Fecal output from confined animals differed significantly (P<0.05) between treatments (Table 4), with DF200 animals obtaining lower values, expressed in kg NM day^{-1} or kg DM day^{-1} (13.58 and 2.50, respectively) than those fed DF110 sealed silage (17.66 and 3.00, respectively). Steers in the DFBO treatment exhibited intermediate values (P>0.05) (15.57 and 2.76, respectively).

Table 4
Total fecal output, kg day^{-1}, natural or dry basis, fecal dry matter, and apparent dry matter digestibility in steers fed corn silage stored in trench silos sealed with different double sided plastic films

Plastic films	Feedlot period		Mean
	1st Moment	2nd Moment	
		Total fecal output, kg NM day^{-1}	
DF110	18.17	17.15	17.66 A
DF200	14.01	13.15	13.58 B
DFBO	15.39	15.75	15.57 AB
Mean	15.86 a	15.13 a	
		Fecal DM, %	
DF110	17.24	16.90	17.07 A
DF200	18.78	17.94	18.36 A
DFBO	18.08	17.68	17.88 A
Mean	18.04 a	17.45 a	
		Total fecal output, kg DM day^{-1}	
DF110	3.11	2.89	3.00 A
DF200	2.63	2.37	2.50 B
DFBO	2.77	2.75	2.76 AB
Mean	2.84 a	2.63 a	
		Apparent DM digestibility, %	
DF110	68.07	67.51	67.79 B
DF200	72.44	72.60	72.52 A
DFBO	70.11	68.59	69.35AB
Mean	70.21 a	69.97 a	

Means followed by different lowercase letters in the same row and uppercase letters in the same column differ according to Tukey's test (ρ< 0.05) and the F test (ρ< 0.05), respectively.

Apparent DM digestibility (Table 4) was higher (72.52%) for the diet containing silage sealed with the DF200 film than that recorded with the other films. On average, apparent DM digestibility was 6.97% greater in the DF200 than DF110 treatment, justifying the data presented in Table 2 regarding animal performance and DM intake.

Animals that received silage sealed with the DF200 film showed superior performance. This demonstrates the positive effect of the plastic film on preserving the ensiled feed, which directly affected animal performance, since the forage to concentrate ratio of the diet remained constant for all treatments throughout the experimental period. In addition, there was no diet selection by the animals (as shown in Table 2), demonstrating that corn plant nutrients were preserved during fermentation, resulting in greater digestibility and use of the forage fraction supplied to the animals.

In regard to the results obtained for fecal output, apparent DM digestibility, and ingestive behavior, Wilkinson and Rinne (2017) emphasize that decreased feces production associated with increased digestibility of ruminant diets is line with growing concerns about the environmental impact of agricultural and livestock practices. This reinforces the importance of improving feed preservation efficiency, optimizing the use of natural resources, ensuring nutrient availability, and increasing the productive efficiency of animals.

Performance, carcass traits, and non-carcass yield components

Carcass performance (Table 5) in animals fed DF200 sealed corn silage was 8.75 and 11.53% higher than that recorded in the DFBO and DF110 treatments, respectively. For ACG (kg day^{-1}), animals from the DF200 treatment achieved an 11.47% greater gain than those in the DF110 treatment, but did not differ statistically from DFBO (P>0.05). This result is attributed to the plastic film used, given that the animals were of the same genetic group, had similar initial body weights and maintained a constant diet throughout the experimental period.

Table 5
Performance and carcass traits of steers fed corn silage stored in trench silos sealed with different double sided plastic films

Parameters*	Plastic films			Mean	SEM	P>F
	DF110	DF200	DFBO			
BWi, kg	363.40 a	367.40 a	368.40 a	366.5	2.488	0.6767
BWf, kg	478.70 b	495.80 a	485.80 ab	486.8	5.643	0.0449
HCW, kg	262.20 b	273.50 a	266.90 ab	267.6	2.996	0.0334
CY, %	54.77 a	55.16 a	55.00 a	54.98	0.139	0.5477
ACG, kg day^{-1}	0.96 b	1.07 a	0.98ab	1.004	0.024	0.0205
CG, kg	80.53 b	89.82 a	82.59 b	84.30	2.080	0.0203
CY ADG, %	70.20 a	69.95 a	73.18 a	71.10	1.247	0.5288
ECC, kg	10.60	9.50 a	10.13 a	10.10	0.214	0.1705
FT, mm	4.40 a	4.40 a	4.30 a	4.40	0.254	0.9831
CL, m	1.28 a	1.30 a	1.29 a	1.29	0.006	0.3770
TT, cm	23.1 a	22.2 a	22.4 a	22.60	0.377	0.6120
AL, cm	37.50 a	38.10 a	38.80 a	38.10	0.443	0.5169
AG, cm	46.40 a	47.60 a	48.50 a	47.50	0.650	0.4532

*BWi: initial body weight; BWf: final body weight; HCW: hot carcass weight; CY: carcass yield; ACG: average carcass gain, expressed in kg day^{-1}; CG: carcass gain in the feedlot period; CY ADG: efficiency weight gain conversion into carcass, which was obtained by the ratio of ACG to ADG (ACG / ADG), expressed in %; ECC: efficiency of consumed dry matter conversion into carcass; FT: fat thickness; CL: carcass length; TT: thigh thickness; AL: arm length; AG: arm girth, and SEM: Standard error of the mean. Means followed by different lowercase letters in the same row differ according to Tukey's test ($\rho < 0.05$).

In general, there was no significant difference (P>0.05) between treatments for carcass yield (CY), fat thickness (FT), carcass length (CL), thigh thickness (TT), arm length (AL), and arm girth (AG), (Table 5) with mean values of 54.98%, 4.4 mm, 1.29 m, 22.6 cm, 38.1 cm and 47.5 cm, respectively.

For body weight at slaughter (BWf) and hot carcass weight (HCW), animals fed DF200 sealed silage exhibited higher values (P<0.05) at the end of the feedlot period (495.8 and 273.5 kg, respectively) compared to those from the DFBO (485.8 and 266.9 kg, respectively) and DF110 treatments (478.7 and 262.2 kg, respectively). This result complements the higher ADG, FE (Table 2) and CG (Table 5) obtained for animals from the DF200 treatment, demonstrating that this silage promoted greater productive efficiency during the feedlot period, leading to higher carcass weights and contributing to a better financial return at the end of this period. No significant difference (P>0.05) was observed for ACG, ADG (kg day^{-1}), and ECC (Kg).

Cristo et al. (2021) found that although different polyethylene plastic films had no chemical influence on corn silage, they directly affected fermentation. The authors reported different results for corn silage fermentation parameters such as pH and ethanol production, as well as DM digestibility. The same may have occurred in the present study, whereby the DF200 film promoted a better anaerobic environment inside the silo and, consequently, greater nutrient preservation in the silage, thus increasing ADG (kg day^{-1}), ACG (kg day^{-1}), and CG (Kg).

Volatile compounds such as alcohols, volatile fatty acids, esters, acetone, biogenic amines, gamma aminobutyric acid, and mycotoxins may be present in the silage, reducing the DMI and, consequently, ADG of animals fed silage sealed with poor quality polyethylene films (Ogunade et al., 2018; Parra et al., 2021).

Although these parameters were not measured in the present study, these compounds and silage microbiological quality are believed to have affected ADG and carcass performance related parameters, despite not having influenced DMI.

In a comparative study, Neumann et al. (2018) tested the effect of different types of sealing on performance and carcass gain and observed an increase of 11.81% in ACG and 12.01% for CG using a 200 μm thick double sided plastic film compared to a double sided 110 μm thick polyethylene plastic film. The authors attributed these results to better use of the fiber fraction of the forage due to the insulation capacity of the plastic film, reducing the entry of O2 into the silo.

According to Lima et al. (2017), silage sealed using polyethylene based films with an average thickness of 110 μm contains larger populations of microorganisms such as bacilli, fungi, and yeasts, which can damage the ensiled mass by degrading structural (hemicellulose, cellulose, and pectin) and storage polysaccharides (starch), directly impacting animal productive performance. Polysaccharides are degraded extracellularly into fundamental units (monosaccharides), which enter the ruminal bacterial cells and are metabolized into pyruvate, prompting the formation of short chain fatty acids (Kozloski, 2017).

Regardless of the type of sealing used, good carcass yields were achieved, with an average of 54.98%, and carcasses that met the subcutaneous fat cover requirements of the slaughterhouse (above 4 mm) aimed at preventing cooling losses, since the recommended minimum is 3 mm (Muller, 1987). In the present study, animals fed silage sealed with the DF200 μm film exhibited a higher hot carcass weight. According to Ítavo et al. (2023), higher weights at slaughter can modify performance and carcass traits, improving carcass conformation and fat cover. These parameters are important in feedlot assessment because they are related to cost dilution and final product quality.

Neumann et al. (2008) cited fiber content and the amount of energy in the diet as factors that may affect non carcass components and carcass traits. The authors also reported that vital organ size is related to energy requirements for maintenance, feed intake, and animal performance.

For non carcass components (Table 6), no changes (P>0.05) were detected in animals fed corn silage sealed with different types of double sided plastic film. Similar results were obtained by Neumann et al. (2024), who evaluated three different types of sealing: double sided film with three polyethylene layers (90 μm thick), double sided film with three layers of polyethylene (200 μm), and a single layer polyethylene film (150 μm).

Table 6
Non carcass yield components, as a percentage of body weight, in steers fed corn silage stored in trench silos sealed with different double sided plastic films

Parameters*	Plastic films			Mean	SEM	P>F
	DF110	DF200	DFBO			
Vital organs, % BW:						
Heart	0.36 a	0.35 a	0.37 a	0.36	0.004	0.0774
Liver	1.18 a	1.17 a	1.09 a	1.15	0.053	0.7511
Lungs	0.97 a	0.94 a	0.98 a	0.97	0.015	0.5568
Kidneys	0.19 a	0.19 a	0.23 a	0.20	0.013	0.3974
Spleen	0.44 a	0.41 a	0.38 a	0.40	0.016	0.1342
Full abomasum	0.34 a	0.30 a	0.40 a	0.35	0.024	0.3051
Full rumen reticulum	8.52 a	8.69 a	8.39 a	8.54	0.178	0.8009
Full intestines	5.43 a	4.83 a	5.25 a	5.17	0.081	0.0623
External components, % BW:						
Head	2.40 a	2.41 a	2.39 a	2.40	0.023	0.9774
Tongue	0.18 a	0.17 a	0.17 a	0.17	0.004	0.1185
Leather	9.05 a	9.48 a	9.16 a	9.23	0.205	0.6934
Tail	0.25 a	0.25 a	0.26 a	0.25	0.007	0.8228
Feet	2.11 a	2.32 a	2.11 a	2.18	0.036	0.0715
Testicles	0.31 a	0.32 a	0.33 a	0.32	0.008	0.6242

SEM: Standard error of the mean. Means followed by different lowercase letters in the same row differ according to Tukey's test (ρ<0.05).

Conclusion

Sealing silage with DF200 double sided plastic film promotes better nutrient use by animals, greater daily weight gain, increased feed efficiency and carcass gain, and better apparent dry matter digestibility of the diet supplied to feedlot finished steers. Thus, based on the parameters assessed, DF200 film is the most suitable sealant for corn silage stored in trench silos.

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