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Effect of the seal type in corn silage on steer performance

Efeito do tipo de vedação em silagem de milho sobre o desempenho de novilhos confinados

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Highlights

The 200 µm polyethylene promoted better nutrient conservation in corn silage.
The type of seal impacts the amount of loss of ensiled material.
The 200 µm polyethylene resulted in an increase in average daily weight gain.

Abstract

Silage making involves several steps that require specific materials to minimize contact between the ensiled material and the external environment. This is because the removal of oxygen and the sealing of the material are directly related to the integrity of the process. The research was conducted at the Animal Production Center (NUPRAN) of the Midwestern Paraná State University (UNICENTRO) in Guarapuava, Paraná State, Brazil, aiming to evaluate the effect of sealing corn silage silos on losses and nutritional value of forage and supplying this silage on the performance, dry matter intake, apparent digestibility, and ingestive behavior of feedlot finished steers. The diets consisted of 35% corn silage and 65% concentrate on a dry matter basis. The feeding period lasted 112 days, with 28 days of adaptation and 84 days of evaluation divided into 3 periods of 28 days each. Thirty-six ½ Angus Nellore steers, intact males, with an average initial weight of 401 kg and an average age of 12 months were used. The experimental design was a randomized complete block design, consisting of three treatments with six repetitions, in

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which each pen with two animals represented an experimental unit: T_1 - LDPE90 (double-sided tarpaulin with 3 layers of low-density polyethylene, 90 µm thickness); T_2 - LDPE200 (double-sided tarpaulin with 3 layers of low-density polyethylene, 200 µm thickness); and T_3 - LDPE/HDPE (silver tarpaulin with 1 layer of low-density polyethylene cross-laminated with high-density polyethylene in x-shape between the polymers, 150 µm thickness). The use of LDPE200 for sealing corn silage silos resulted in reduced losses, increased aerobic stability, and increased ruminal digestibility of DM compared to other types of polyethylene. Feedlot-finished beef steers fed corn silage from LDPE200-sealed trench silos showed higher average daily gain (1.509 kg day^{-1}), apparent digestibility of dry matter (63.39%), and improved efficiency of converting ingested DM into carcass (10.79 DCG DMI^{-1}) compared to LDPE/HDPE and LDPE90. The LDPE200 polyethylene is the most suitable for sealing corn silage silos due to its ability to provide greater stability of the ensiled mass, reduce losses, increase ruminal degradability of DM, and improve the feedlot finished steer performance.
Key words: Dry matter digestibility. Feed efficiency. Weight gain.

Resumo

A qualidade da confecção da silagem envolve diversas etapas, a qual exige a utilização de matérias específicos que evitem ao máximo o contato do material ensilado com o ambiente externo, visto que a retirada do oxigênio e o isolamento do material ensilado são fatores diretamente relacionados com a integridade do processo. O trabalho de pesquisa foi realizado no Núcleo de produção animal (NUPRAN) da Universidade estadual do centro-oeste (UNICENTRO), em Guarapuava, PR, Brasil, objetivando avaliar o efeito de vedação em silos de silagem de milho sobre perdas e valor nutricional da forragem, assim como sobre o desempenho, consumo de matéria seca, digestibilidade aparente e comportamento ingestivo de novilhos terminados em confinamento. As dietas foram constituídas por 35% de silagem de milho e 65% de concentrado, na base seca. O período de confinamento foi de 112 dias, sendo 28 dias de adaptação e 84 dias avaliativos divididos em 3 períodos de 28 dias cada. Foram utilizados 36 novilhos ½ Angus Nelore, machos inteiros, com peso médio inicial de 401 kg e idade média de 12 meses. O delineamento experimental foi em blocos casualizados, constituído de três tratamentos com seis repetições, onde cada baia com dois animais representou uma unidade experimental: T1 - PEBD90 (Lona dupla face de 3 camadas de polietileno de baixa densidade, com espessura de 90 µm); T2 - PEBD200 (Lona dupla face de 3 camadas de polietileno de baixa densidade, com espessura de 200 µm); e T3 - PEBD/PEAD (Lona em cor prata com 1 camada de polietileno de baixa densidade com polietileno de alta densidade em laminação cruzada em "x" entre os polímeros, com espessura de 150 µm). O uso do PEBD200 na vedação de silos de silagem milho promoveu redução de perdas, maior estabilidade aeróbia e aumentou a digestibilidade ruminal da MS em relação aos demais tipos de polietileno. Novilhos terminados em confinamento, com a alimentação de silagem de milho de silos trincheiras vedados com PEBD200 apresentaram maior ganho de peso médio diário (1,509 kg dia^{-1}), digestibilidade aparente da matéria seca (63,39 %) e melhor eficiência de transformação da MS ingerida em carcaça (10,79 DMI DCG^{-1}) comparativamente às vedações PEBD/PEAD e PEBD90. A vedação com PEBD200 é o mais indicado na conservação de silagem de milho, devido sua capacidade de proporcionar maior estabilidade aeróbia da massa ensilada, reduzir perdas durante o armazenamento, aumentar degradação ruminal da MS e melhorar o desempenho de novilhos terminados em confinamento.
Palavras-chave: Digestibilidade da MS. Eficiência alimentar. Ganho de peso.

Introduction

In feedlots and/or semi-feedlots of beef cattle, the bulk source traditionally used is corn silage. The ensiling process aims to maintain the nutritional value and health status of the forage as close as possible to the original material harvested in the field. The sealing system used in storage silos is of outstanding importance in obtaining an ideal anaerobic environment that optimizes the fermentation process of the mass, minimizing nutrient losses during the storage process (Parra et al., 2021).

Selecting a good quality polyethylene allows for the reduction of losses of the ensiled material through isolation from the external environment, generating stable anaerobic conditions in the internal environment of the silo after fermentation, reducing undesirable microbial activity and the occurrence of chemical reactions that destabilize the concentration of gases, temperature and pH of the environment, which interfere with the nutritional quality of the silage (Silva & Santos, 2016).

When referring to losses in silage, it is important to pay attention to macroscopic and, consequently, microscopic changes. These parameters have a major impact on animal feed and may result in nutritional deficiencies in the diet. Sealing and fermentation are directly related to the quality of the nutrients preserved in the silage (Macêdo & Santos, 2019).

Different types of tarps are available on the market, with wide variations in technical specifications regarding density, thickness, number of layers, and polyethylene origin, as well as color and anti-UV treatment. This soon raises questions from producers regarding the choice of material, as well as the expected cost-benefit (Cristo et al., 2021).

Therefore, the present study aimed to evaluate the performance, dry matter intake, apparent digestibility, ingestive behavior, and carcass traits of steers finished in confinement and fed corn silage stored in silos with different sealing tarps.

Material and Methods

The experimental procedures were previously submitted to the Committee on Ethical Conduct for the Use of Animals in Experimentation (CEUA/UNICENTRO), approved for execution (Official Letter number 021/2018), and carried out at the Animal Production Center (NUPRAN) of the Agricultural and Environmental Sciences Sector of the Midwestern Paraná State University (UNICENTRO).

Corn (*Zea mays*, L.) was planted in no-till on October 2nd, 2020 with seeds of the early-cycle hybrid P2770VYHR (Pionner®) to produce grains and silage, grains with a hard texture and biotechnology for resistance to Glyphosate. Seeds were sown in a row spacing of 45 cm, a sowing depth of 4 cm, with a distribution of 3.4 seeds per linear meter, which resulted in a final population of 69,000 plants ha^{-1}.

The basal fertilization used 530 kg ha^{-1} of the 08-20-20 (N-P-K+) fertilizer and topdressing fertilization consisted of 350 kg ha^{-1} of 45-00-00 urea. Management before planting corn was based on the control of weeds and insects by the chemical method using the herbicide based on *Glyphosate* (commercial product Roundup WG: 2.65 kg ha^{-1}), *Imidacloprid* + *Beta-cyfluthrin* (commercial product Connect: 0.75 L ha^{-1}), and mineral oil (commercial product Nimbus: 0.5 L ha^{-1}). In post-emergence control, Glyphosate (commercial product Roundup WG: 2.50 kg ha^{-1}) and *Alpha-cypermethrin* (commercial product Imunit: 0.18 L ha^{-1}) were applied, based on a technical report of the crop. Insecticide application was carried out with Thioacetimidate 216 g L^{-1} + *Methanol* 383.5 g L^{-1} (commercial product Bazuka® 216 SL at 0.60 L ha^{-1}).

Corn plants were harvested 129 days after emergence (DAE) at the dent grain phenological stage (R5) using a JF® precision forage harvester (C-120 AT S2) at 20 cm above the ground and average particle size adjustment with a proportion of 11.4% on the first sieve (>1.9 cm), 52.1% on the second sieve (1.9-0.7 cm), and 36.5% on the third sieve (<0.7 cm). The material was transported and homogeneously deposited in nine trench silos, three silos for each treatment, in a level and well-drained place with concrete floor and walls, measuring 1.2 m wide, 1.0 m high, and 12 m long. Compaction was performed using a roller compactor to compact the specific mass of approximately 200 kg of DM m$^{3-1}$, and then the material was sealed and protected according to the treatments evaluated. The time for filling and sealing each silo varied between 6 and 8 hours. Each silo was designed to feed two pens with two animals each, for 112 days of feedlot, under silo feed-out management with a cut slice thickness of 11 cm day^{-1}. The silos were opened simultaneously, 61 days after ensiling.

During ensiling, three bags were placed in the profile of each silo, containing original material with known weight. The designation bags refers to a malleable nylon bag made of 100% polyamide, with 85 μm mesh, and dimensions of 12 cm x 50 cm in diameter and length, respectively. These bags were placed in the initial, middle, and final portions of each silo (0.5 m in height), keeping them centered from the side walls of each silo, and allocated to these positions as the silo was filled.

Each bag was identified, weighed individually when empty, and weighed again after filling with the original material on a digital scale accurate to 1 gram, resulting in 2,000 g of material inside the bag. Flexible PVC clamps were used to seal the bags.

Upon inserting the bags, in each of the silos, similar samples (homogeneous and representative) of the original materials were collected for pre-drying to determine the DM content of the original material in each of the treatments. The bags were retrieved according to silage use during the silo feed-out; each bag was weighed again and the material was sent for pre-drying to determine the DM content of the resulting silage. This procedure allowed for estimating chemical losses by comparing the weight of the retrieved material.

Before silage making, samples of the entire plant and structural components: stalk, leaves, bracts, cob, and grains (original material) were taken in the crop area, weighed, and pre-dried in a forced-air oven at 55 °C. After 72 hours, they were weighed again to determine the dry matter (DM) content, according to the Association of Official Analytical Chemists [AOAC] (1995).

This procedure allowed for estimating the productive potential of green biomass (kg ha^{-1}) and ensiled dry matter (kg ha^{-1}), as well as the physical structure of the plant and the dry matter values of the plant and its structural components for agronomic characterization of the crop. The first ear height (m), plant height (m), and number of dry leaves per plant were also determined (Table 1).

Table 1
Physicochemical parameters of the different crude palm oil samples

Parameters[1]	Average value
Green biomass production (kg ha^{-1})	58.382
Dry biomass production (kg ha^{-1})	18.429
First ear insertion height (m)	0.98
Plant height (m)	2.10
Number of dry leaves by plant	3.4
Dry matter content (%):	
Stalk	21.82
Leaves	30.44
Bracts + Cob	28.74
Grains	59.40
Whole plant	31.68
Plant without grains	26.11
Physical composition of the plant (% DM):	
Stalk	18.83
Leaves	16.45
Bracts + Cob	17.95
Grains	46.78

[1] Field data (2020/2021 harvest).

Thirty-six male Angus Nellore steers from the same herd, with an average initial weight of 401 kg and an average age of 12 months, were the experimental animals. They were housed in 18 half-roofed pens of 15 m^2 each (2.5 × 6.0 m). Each pen had a concrete trough measuring 2.30 m long, 60 cm wide, and 35 cm deep, and a metal drinker controlled by a float. The distribution of animals in the experimental units was carried out based on body weight (BW) and through carcass ultrasonography (Aloka® SSD-500 Vet) consisting of an echo camera coupled to a 17 cm, 3.5 MHz probe for the distribution of animals considering the parameters of loin eye area (LEA), marbling index, and rump fat thickness (RFT).

The experimental design was randomized blocks, consisting of three treatments with six repetitions, where each pen with two animals represented an experimental unit. The animals were given silage stored using three types of polyethylene sealing from the company Okubo®, Ribeirão Preto, São Paulo State: T_1 – LDPE90 (Double-sided tarpaulin with 3 layers of low-density polyethylene, 100% virgin material, 90 μm thickness, 0% transparency, anti-UV additive, and 108 g m^{2-1} weight); T_2 – LDPE200 (Double-sided tarpaulin with 3 layers of low-density polyethylene, 100% virgin material, 200 μm thickness, 0% transparency, anti-UV additive, and 108 g m^{2-1} weight); and T_3 – LDPE/HDPE (Silver colored tarpaulin with 1 layer of low-density polyethylene cross-laminated with high-density polyethylene in x-shape between the polymers, 150 μm thickness, opaque transparency, anti-UV additive, and weight of 150 g m^{2-1} weight).

The experimental period lasted 112 days, divided into four periods of 28 days, with the first period for adaptation and the three subsequent periods for evaluation. The animals were fed twice a day, at 06h00 and 17h00. Voluntary feed intake was recorded daily by weighing the amount offered and the leftovers from the previous day, and daily adjustments were made to maintain leftovers at 5% DM. Food was supplied as a total mixed ration (TMR). Diets consisted of 35% corn silage and 65% concentrate, on a dry matter basis.

To estimate dry matter losses, 24 bags were placed inside the experimental silos during ensiling. The bags were distributed according to each treatment and each repetition and were filled homogeneously with original material of known weight. The designation of bags refers to a 100% flexible polyamide nylon bag, with 85 μm mesh, and dimensions of 12 × 50 cm in diameter and length, respectively. Each bag was identified, weighed individually when empty, and weighed again after filling. Flexible PVC clamps were used to seal the bags. The final specific mass of the silage in the bags was determined using a compactor roller in the silo, seeking the same compaction between the original material of the bags and the silo.

Silage physical losses were estimated daily during the experimental period by weighing the silage considered visibly spoiled upon silo feed-out, which was discarded immediately. The values obtained were corrected for weekly dry matter contents. Silage pH readings were taken using a benchtop digital potentiometer, according to the methodology established by Cherney and Cherney (2003).

The ruminal dry matter degradation of the silage was estimated by the in situ technique using nylon bags measuring 12 × 8 cm, 50 μm mesh size, containing 5 g of dry sample of each material, ground to 1 mm, for subsequent incubation in the rumen (Nocek, 1988). The ruminal incubation times used were 24, 48, 96, and 168 hours. This experiment used two steers housed in the Beef Cattle Didactic Unit of the Midwestern Paraná State University, 80 months of age, with an average body weight of 850 kg, and equipped with a ruminal cannula positioned using the ruminostomy technique, previously approved by the Committee on Ethical Conduct for the Use of Animals in Experimentation (CEUA/UNICENTRO), under official letter 019/2023.

A qualitative score of the trough leftovers was daily assigned, which ranged from 1 to 5, where the graduation of the respective scores was as follows: 1 (65% silage and 35% concentrate); 2 (50% silage and 50% concentrate); 3 (35% silage and 65% concentrate); 4 (20% silage and 80% concentrate); and 5 (5% silage and 95% concentrate), on a dry matter basis, with a score of 3 considered ideal.

During the feedlot period, composite samples of silage from each treatment and concentrate were collected to determine their chemical composition. Samples were dried in a ventilated oven at 55 °C for 72 hours, ground in a Wiley mill with a 1 mm diameter sieve, and analyzed for dry matter (DM), crude protein (CP), mineral matter (MM), and ether extract (EE) according to AOAC (1995). The neutral detergent fiber (NDF) content was estimated as proposed by Van Soest et al. (1991) with thermostable α-amylase and acid detergent fiber (ADF) and lignin (LIG), according to Goering and Van Soest (1970). The estimate of total digestible nutrients (TDN) was obtained according to Weiss et al. (1992). The determination of starch content in the diet was performed by the enzymatic method proposed by Bach Knudsen et al. (1997).

The concentrate was prepared at the commercial feed factory of Cooperativa Agrária (Guarapuava, Paraná, Brazil), formulated based on soybean meal, corn, wheat bran, soybean hulls, malt radicle, calcitic limestone, dicalcium phosphate, livestock urea, common salt, and vitamin-mineral premix, and presented as pellets. The concentrate presented average contents of 91.97% DM, 6.36% MM, 20.20% CP, 2.05% EE, 31.47% NDF, 13.08% ADF, 4.73% LIG, 78.68% TDN, 1.67% Ca, and 0.58% P. The guaranteed levels in the premix per kg of concentrate were 14,000 IU of vit. A; 1,800 IU of vit D3; 75 IU of vit. E; 0.70 g of S; 0.12 g of Mg; 3.0 g of Na; 1.0 mg of Co; 18 mg of Cu; 1.1 mg of I; 29.0 mg of Mn; 0.35 mg of Se; 72.2 mg of Zn, and 40 mg of sodium monensin.

Table 2 lists the chemical composition of the corn silages used to feed the animals and the average values of the experimental diets, on a total dry matter basis.

Table 2
Chemical composition of silage evaluated in animal feed and average values of experimental diets, based on total dry matter

Composition	Types of polyethylene – Silage		
	LDPE90	LDPE200	LDPE/HDPE
Dry Matter (DM), %	33.66	35.98	30.54
Mineral Matter (MM), % DM	2.76	2.49	2.53
Crude Protein (CP), % DM	6.83	6.86	7.08
Ether extract (EE), % DM	2.27	1.94	2.25
Neutral Detergent Fiber (NDF), % DM	49.24	49.95	48.76
Acid Detergent Fiber (ADF), % DM	29.88	30.06	29.57
Lignin (LIG), % DM	3.20	3.86	3.66
Total Digestible Nutrients (TDN), %	66.93	66.80	67.17
	Types of polyethylene – Experimental diets		
	LDPE90	LDPE200	LDPE/HDPE
Dry Matter (DM), %	71.56	72.37	70.47
Mineral Matter (MM), % DM	4.77	4.67	4.69
Crude Protein (CP), % DM	15.52	15.53	15.61
Ether extract (EE), % DM	2.13	2.01	2.12
Neutral Detergent Fiber (NDF), % DM	36.05	36.30	35.88
Acid Detergent Fiber (ADF), % DM	18.28	18.34	18.17
Lignin (LIG), % DM	3.95	4.18	4.11
Total Digestible Nutrients (TDN), %	74.57	74.52	74.65

Animals were weighed at the beginning, on days 28, 56, 84, and at the end of the experiment, after solid fasting for 12 hours to determine the average daily weight gain (ADG). Rations and leftovers were weighed daily to determine the daily DM intake (DMI), expressed in kg day^{-1}, or daily DM intake of body weight (DMI, BW), expressed as a percentage. Data from ADWG and DMI were used to calculate feed efficiency (FE).

From the ADG, DMI, and carcass yield (CY) data, the total carcass gain (TCG), daily carcass gain (DCG), and the efficiency of conversion of ingested DM into carcass (ECDMC) were calculated. The TCG was calculated by the ratio of the ADG to the CY, multiplied by the number of feedlot days (TCG = (ADG ×CY/100) × 112). The DCG was calculated based on the 112-day feedlot period (DCG = TCG/112). The ECDMC was represented by the ratio of the DCG to the DMI (ECDMC = DCG / DMI).

The animals' ingestive behavior was evaluated in the middle phase of the feedlot period, over a continuous period of 72 hours, starting at noon on the first day and ending at noon on the fourth day of evaluation. Observations were made by nine observers per shift, for 72 hours, taking turns every 6 hours, with readings taken at regular intervals of 3 minutes. Data on ingestive behavior, represented by the activities of idling, ruminating, drinking, and feeding, were expressed in hours day^{-1}. Furthermore, following the same methodology, the frequency of occurrence of the activities of feeding, drinking, urinating, and defecating was determined, expressed as the number of times per day^{-1}. During the nighttime observation, the environment was kept under artificial lighting.

The digestive behavior, based on the determination of the apparent digestibility of the diet, was also analyzed in the middle phase of the feedlot period. For this purpose, composite samples of the diets of each treatment were made during the experimental period. The food collections were carried out once a day, following the methodology of collecting for three consecutive days and storing in a freezer. After the end of the evaluation, samples were thawed, homogenized to form a composite sample, by pen and treatment, and stored at -15 ºC.

Together, daily feed intake and leftovers from three consecutive days were measured (72 hours), along with the total collection of feces produced by the animals in each pen. During the apparent digestibility test, a homogeneous sample of the feces produced was collected and stored under refrigeration at six-hour intervals. After three consecutive days of collection, these were mixed and homogenized into a composite sample for laboratory analysis. The weight of the feces sample from each six-hour interval was proportional to the total volume of feces produced.

The DM and NDF of the leftovers and feces of each experimental unit were determined using the same procedures adopted in the diet analysis. The apparent DM digestibility (DMD) was calculated using the following formula: DMD (%) = [(DM ingested – DM excreted) / DM ingested] × 100.

To calculate NDF digestibility, the same formula was used, multiplying the ingested diet, leftovers, and feces by the respective proportions of each variable, obtained in the laboratory.

The feces of each pen were also scored daily, according to a methodology adapted from Looper et al. (2001) and Ferreira et al. (2013), grading from 1 to 5, being: 1 (watery feces, without consistency); 2 (runny feces, with few ripples, without defined shape); 3 (pasty feces with 1-4.5 cm high piles and 2-4 concentric rings); 4 (soft feces with 5-7.5 cm high piles); and 5 (hardened feces with over 7.5 cm high piles). Score 3 is considered ideal.

At the end of the experimental period, the rib eye area (LEA), marbling, ratio, subcutaneous fat thickness of the *Longissimus dorsi* muscle, and rump fat thickness were evaluated using a set of equipment consisting of an echo camera (Aloka® SSD-500 Vet) coupled to a 17 cm, 3.5 MHz probe. Measurements were taken between the 12th and 13th ribs, across the *Longissimus dorsi* muscle, following the recommendations of Herring et al. (1994). The ratio, which represents the relationship between the height and width of the LEA, was calculated from the LEA measurements. The images were interpreted by the laboratory responsible for data quality assurance (Designer Genes Technology) using the "BIA/

DGT Brasil" software. Marbling was assessed by the presence of visible white flecks between muscle fibers in the *Longissimus dorsi* and scored using indices ranging from 1 (non-existent) to 5 (excessive) adapted from the system proposed by Müller (1987).

After 12 hours of solid fasting, the animals were weighed for final body weight and transported to the slaughterhouse Cooperativa Agroindustrial Aliança de Carnes Nobres - COOPERALIANÇA, (Entre Rios District, Guarapuava, Paraná State, Brazil), located 20 km away. The standards adopted by the slaughterhouse follow the current legislation for the slaughter of cattle, under federal inspection.

The carcasses were evaluated individually according to the guidelines of Müller (1987), where the hot carcass weight, carcass yield, and subcutaneous fat thickness (*Longissimus dorsi,* hindquarter, rib, and forequarter) were determined. Four development measures were evaluated in the carcasses: carcass length, which is the distance between the medial cranial edge of the pubic bone and the medial cranial edge of the first rib; arm length, which is the distance between the olecranon tuberosity and the radiocarpal joint; arm perimeter, obtained in the median region of the arm using a tape measure; and the thigh thickness, measured using a compass, perpendicular to the carcass length, taking the greatest distance between the cut that separates the two half carcasses and the lateral muscles of the thigh, according to the methodologies suggested by Müller (1987).

Upon slaughter, the non-carcass body parts of the slaughtered steers were also characterized by collecting the weights of the following components: head, tongue, tail, leather feet, and testicles (called external components); and heart, kidneys, liver, lungs, spleen, empty rumen-reticulum, full rumen-reticulum, full abomasum and empty abomasum (called vital organs).

The UNIVARIATE procedure was applied to assess the presence of outliers. Then, the data related to performance, digestibility, and carcass traits were subjected to ANOVA using the GLM Statistical Analysis System Institute [SAS Institute] (1993), adopting a significance level of 10% ($P \leq 0.10$).

The analysis of each variable for the parameters related to animal performance, ingestive behavior, performance, and carcass traits followed the statistical model: $Y_{ijk} = \mu + TP_i + B_j + E_{ij}$; Where: Y_{ij} = dependent variables; μ = Overall mean of all observations; TP_i = Effect of the type of polyethylene of order "i", being 1 = LDPE90, 2 = LDPE200 and 3 = LDPE/HDPE; B_j = Effect of the block of order "j", being 1 = first, 2 = second, 3 = third, 4 = fourth, 5 = fifth and 6 = sixth; and E_{ij} = Residual random effect.

Results and Discussion

Data in Table 3 show that the silos sealed with LDPE200 presented, throughout the study period (0 to 112 days), a lower average for the temperature gradient (14.49 °C), and silage temperature (28.46 °C) than those sealed with LDPE90 (16.58 and 30.55°C, respectively) or LDPE/HDPE (17.44 and 31.41°C, respectively). For the periods of 29 to 112 days of silo feed-out, silos sealed with LDPE200 and LDPE90 remained more stable and with less aerobic degradation, with lower values (P<0.10) for silage temperatures and the temperature gradient between the silage and the environment, compared to the LDPE/HDPE.

Table 3
Temperature gradient between silage and the environment, pH, and temperature of corn silage stored in sealed trench silos with different types of polyethylene, according to the period of use

Parameter	Types of polyethylene			Mean	Coefficient of variation	Prob.
	LDPE90	LDPE200	LDPE/HDPE			
Temperature Gradient, °C:						
0 to 28 days	19.27 a	13.18 b	17.12 a	16.52	16.12	0.0231
29 to 56 days	16.34 b	14.98 b	19.48 a	16.93	16.99	0.0048
57 to 84 days	14.84 b	14.48 b	16.71 a	15.34	14.47	0.0001
85 to 112 days	15.86 b	15.32 b	16.48 a	15.89	16.00	0.0001
Mean	16.58	14.49	17.44			
Silage pH:						
0 to 28 days	3.61 a	3.52 b	3.62 a	3.58	5.21	0.0145
29 to 56 days	3.56 a	3.52 b	3.58 a	3.55	3.45	0.0666
57 to 84 days	3.42 a	3.33 b	3.49 a	3.41	4.28	0.0489
85 to 112 days	3.32 a	3.22 b	3.36 a	3.28	7.08	0.0434
Mean	3.48	3.40	3.51			
Silage Temperature, °C:						
0 to 28 days	36.68 a	30.59 b	34.53 a	33.93	15.18	0.0001
0 to 56 days	29.95 b	28.59 b	33.08 a	30.54	17.71	0.0001
0 to 84 days	28.53 b	28.17 b	30.40 a	29.04	16.24	0.0001
0 to 112 days	27.02 b	26.47 b	27.64 a	27.05	13.33	0.0001
Mean	30.55	28.46	31.41			

Means within a row followed by different lowercase letters differ significantly according to the Tukey test at 10%.

Regarding the silage pH, from the beginning to the end of the silo feed-out period (01 to 112 days), the sealing with LDPE200 always showed lower (P<0.10) pH values (3.40) than with LDPE90 (3.48) and with LDPE/HDPE (3.51), which did not differ statistically between the sealings evaluated (P>0.10).

The stability of the silage temperature and pH is due to the preservation of a stable and effective anaerobic environment, provided by the LDPE200 tarpaulin, presenting more efficient fermentation compared to the other sealings tested, resulting in greater production of acetic acid and consequently stabilizing the lower pH (Caregnato et al., 2019). According to Neumann et al. (2021a), silages with yeast and mold activity increase the consumption of organic acids present in the silage, presenting an increase in pH and silo temperature, which did not occur in the ensiled mass of the tested sealing materials.

The ruminal degradation of DM and the physical and chemical losses of the silage (Table 4) showed significant differences (P<0.10) between the different seals tested. The silages stored in silos sealed with LDPE200 showed higher values (P<0.10) of ruminal degradation at 24, 48, 96, and 168 hours (60.56; 74.31; 79.38; 83.45% DM, respectively) than the other seals tested. In the evaluation of physical and chemical losses of silage DM during the silo feed-out period, sealing with LDPE200 resulted in lower (P<0.10) losses (5.22 and 5.55% of DM, respectively) compared to sealing with LDPE90 (11.95 and 8.69% of DM, respectively) and with LDPE/HDPE (12.26 and 10.31% of DM, respectively), which justifies the greater ruminal degradation of DM in silage with LDPE200 sealing.

Table 4
In situ rumen degradation of dry matter and physical and chemical losses of corn silage stored in sealed trench silos with different types of polyethylene

Parameter	Types of polyethylene			Mean	Coefficient of variation	Prob.
	LDPE90	LDPE200	LDPE/HDPE			
Rumen degradation (% DM):						
24 hours	52.16 b	60.56 a	55.56 b	56.09	5.61	0.0332
48 hours	64.98 b	74.31 a	69.87 b	69.72	3.96	0.0358
96 hours	75.06 b	79.38 a	75.41 b	76.61	5.82	0.0474
168 hours	77.39 b	83.45 a	77.99 b	79.61	2.37	0.0308
Losses (% DM):						
Physical	11.95 a	5.22 b	12.26 a	9.81	6.92	0.0004
Chemical	8.69 a	5.55 b	10.31 a	8.18	3.76	0.0001

Means within a row followed by different lowercase letters differ significantly according to the Tukey test at 10%.

In silages with an efficient fermentation process, there is a higher preservation of nutrients that results in greater ruminal degradation due to a greater concentration of nutrients in the feed (Generoso et al., 2019). After opening the silo, there are apparent physical losses and, consequently, chemical losses, enabling the proliferation of spoilage microorganisms, responsible for the degradation of nutrients in the material (Tabbaco et al., 2020).

In Table 5, the ADG showed a significant difference (P<0.10) between the different seals tested. The seal with LDPE200 promoted higher values throughout the experimental period (112 days of feedlot) of 1.455 kg day^{-1} compared to the seal with LDPE90 (1.362 kg day^{-1}) and the LDPE/HDPE, which did not differ (1.390 kg day^{-1}) from the other treatments.

As for the FE (ADG: DMI, kg kg^{-1}), there was no difference (P>0.10) between the seals tested during the first and second periods (1 to 56 days). For the rest of the experimental period (57 to 112 days), the LDPE200 seal presented higher values (0.150 and 0.147, respectively) than the LDPE90 seal (0.137 and 0.136, respectively) and the sealing with LDPE/HDPE did not differ (0.141 and 0.139, respectively) from the other treatments.

The effectiveness of LDPE200 in maintaining the environment in anaerobic conditions and preserving the nutrients in corn silage ensured better ADG (kg day^{-1}) for the animals (Neumann et al., 2018). Regarding the FE (ADG: DMI, kg kg^{-1}) of the animals, during the evaluation periods, the silage stored with the LDPE200 tarpaulin provided better nutrient preservation, providing late results concerning animal performance (Souza et al., 2022). In general, the data on better weight gain and feed efficiency obtained with the LDPE200 seal are a reflection of the greater temperature and pH stability of the silage during the period of use of the silage in animal feeding (Table 3) combined with greater ruminal degradation of DM and NDF (Table 4).

Table 5
Average daily weight gain (ADG, kg day^{-1}), daily dry matter intake expressed in kg day^{-1} (DMI) or by 100 kg of body weight (DMIBW), feed efficiency (FE), and qualitative score for bunk and feces of feedlot steers fed corn silage from sealed trench silos with different types of polyethylene

Parameter	Types of polyethylene			Mean	Coefficient of variation	Prob.
	LDPE90	LDPE200	LDPE/HDPE			
ADG, kg day^{-1}:						
0 to 28 days	1.482 b	1.604 a	1.497 ab	1.528	16.10	0.0578
0 to 56 days	1.403 b	1.512 a	1.426 ab	1.447	16.68	0.0660
0 to 84 days	1.398 b	1.465 a	1.379 ab	1.414	9.64	0.0178
0 to 112 days	1.362 b	1.455 a	1.390 ab	1.402	7.77	0.0124
DMI, kg day^{-1}:						
0 to 28 days	9.49 a	9.82 a	9.58 a	9.63	6.70	0.6742
0 to 56 days	10.22 a	10.12 a	10.05 a	10.13	7.29	0.9240
0 to 84 days	10.55 a	10.23 a	10.22 a	10.33	6.58	0.7110
0 to 112 days	10.50 a	10.26 a	10.30 a	10.35	7.93	0.8659
DMI, % BW:						
0 to 28 days	2.24 a	2.30 a	2.30 a	2.28	5.83	0.6471
0 to 56 days	2.22 a	2.23 a	2.25 a	2.24	5.36	0.9350
0 to 84 days	2.18 a	2.16 a	2.19 a	2.18	5.22	0.9425
0 to 112 days	2.12 a	2.09 a	2.12 a	2.11	5.28	0.8735
FE, ADG DMI kg kg^{-1}:						
0 to 28 days	0.157 a	0.163 a	0.156 a	0.159	13.87	0.8145
0 to 56 days	0.143 a	0.154 a	0.146 a	0.148	7.98	0.3060
0 to 84 days	0.137 b	0.150 a	0.141 ab	0.142	7.12	0.0521
0 to 112 days	0.136 b	0.147 a	0.139 ab	0.141	6.24	0.0442
Trough score:						
0 to 28 days	2.51 a	2.92 a	2.97 a	2.80	13.15	0.1081
0 to 56 days	2.74 a	2.98 a	2.97 a	2.90	11.10	0.3580
0 to 84 days	2.81 a	2.97 a	3.00 a	2.93	10.29	0.5223
0 to 112 days	2.84 a	2.93 a	3.00 a	2.92	9.26	0.6186
Fecal score:						
0 to 28 days	2.87 a	2.89 a	2.90 a	2.88	3.80	0.8948
0 to 56 days	2.90 a	2.93 a	2.93 a	2.92	3.79	0.9156
0 to 84 days	2.91 a	2.93 a	2.91 a	2.92	3.05	0.9349
0 to 112 days	2.93 a	2.93 a	2.91 a	2.92	2.34	0.8503

Means within a row followed by different lowercase letters differ significantly according to the Tukey test at 10%.

For DMI (kg day^{-1}) and DMI (% BW), there was no significant difference (P>0.10) between the different seals tested, which corroborates Neumann et al. (2021b). As for the trough and fecal scores, there was no statistical difference (P>0.10) between the different polyethylenes used for ensiling corn silage. This indicates that the animals showed no food selectivity; the score closest to 3.00 was considered ideal.

In Table 6, the parameters DCG (kg day^{-1}), TCG (kg), and DCG ADG^{-1} (%) did not present statistical differences (P>0.10) between the different polyethylenes tested. LDPE200 provided better (P<0.10) efficiency of conversion of ingested DM into carcass (DCG DMI^{-1}) with 10.79 kg kg^{-1}, compared to 11.21 and 11.62 kg kg^{-1}, respectively for the LDPE/HDPE and LDPE90 seals.

Table 6

Daily carcass gain, expressed in kg day^{-1} (DCG), total carcass gain in kg (TCG), carcass gain efficiency (DCG/ADG^{-1}, %), and the efficiency of conversion of ingested DM into carcass (DMI/TCG^{-1}), as well as value at slaughter and gain during the finishing period for loin eye area (LEA), ratio, marbling, subcutaneous fat thickness (SFT), and rump fat thickness (RFT), of feedlot steers fed corn silage from sealed trench silos with different types of polyethylene

Parameter	Types of polyethylene			Mean	Coefficient of variation	Prob.
	LDPE90	LDPE200	LDPE/HDPE			
DCG (kg day^{-1})	0.908 a	0.957 a	0.920 a	0.928	8.21	0.5307
TCG (kg)	101.7 a	107.2 a	103.1 a	104.0	8.23	0.4287
DCG ADG^{-1} (%)	66.95 a	65.74 a	66.44 a	66.38	9.63	0.9710
ECDMC (DCG DMI^{-1})	11.62 b	10.79 a	11.21 b	11.20	9.15	0.0133
At slaughter:						
LEA	86.43 a	86.88 a	86.26 a	86.52	3.62	0.9396
Ratio	0.53 a	0.52 a	0.53 a	0.53	6.07	0.8655
Marbling	3.19 a	3.05 a	3.21 a	3.15	8.14	0.5124
SFT (mm)	8.86 a	8.85 a	8.89 a	8.87	13.48	0.9979
RFT (mm)	10.60 a	10.73 a	10.95 a	70.76	11.66	0.8854
Finishing gains:						
LEA	19.18 a	22.17 a	19.66 a	20.34	16.10	0.2820
Marbling	0.41 a	0.49 a	0.42 a	0.44	29.20	0.8940
SFT (mm)	4.73 b	5.33 a	5.15 ab	5.07	14.06	0.0689
RFT (mm)	5.58 b	6.54 a	6.36 ab	3.16	11.20	0.0295

Means within a row followed by different lowercase letters differ significantly according to the Tukey test at 10%.

In the evaluation at slaughter, the parameters LEA, Ratio, Marbling, SFT (mm), and RFT (mm) showed no statistical difference (P>0.10). In the values of finishing gains, the parameters LEA and Marbling did not present statistical differences (P>0.10). For the parameters SFT (mm) and RFT (mm), there was a statistical difference (P<0.10) between the different polyethylenes tested, in which LDPE200 was superior (5.33 and 6.54, respectively) to sealing with LDPE90 (4.73 and 5.58, respectively) and LDPE/HDPE did not differ from the other treatments.

On different seal types, Neumann et al. (2018) reported that the plastic films used to seal the silo did not influence the carcass traits, which does not corroborate the data of the present study.

The fecal production (kg day^{-1}), expressed in DM or NM, and fecal DM content (%), listed in Table 7, did not present statistical differences (P>0.10) between the different types of polyethylene used for corn ensiling. About the apparent digestibility of DM (%) and NDF (%), the LDPE200 sealing had higher values (68.39 and 42.20, respectively) compared to the LDPE90 (66.85 and 39.84, respectively) and LDPE/HDPE (65.57 and 37.35, respectively).

The surface of trench silos or surface silos poses a greater environmental challenge in silage preservation due to the difficulties in compacting and sealing the material. Thus, the quality of the fermentation process is reflected in the DM digestibility and NDF digestibility of corn silage (Neumann et al., 2021a). Therefore, it is suggested that the LDPE200 seal provided greater preservation of silage nutrients (Generoso et al., 2019) and consequently allowed greater ruminal digestibility of DM and NDF (%).

The carcass performance data in Table 8, for initial body weight (kg), slaughter body weight (kg), hot carcass weight (kg), and carcass yield (%) indicated no significant differences (P> 0.10) between the polyethylenes tested.

Table 7
Fecal production in kg day^{-1}, on a natural or dry matter basis, fecal dry matter content, and apparent DM digestibility (DMD) and neutral detergent fiber (NDF) of the ration for feedlot steers fed corn silage from sealed silo trenches with different types of polyethylene

Parameter	Types of polyethylene			Mean	Coefficient of variation	Prob.
	LDPE90	LDPE200	LDPE/HDPE			
Fecal production (kg DN day^{-1})	21.20 a	19.25 a	21.04 a	20.50	14.81	0.4927
Fecal dry matter content (%)	16.36 a	16.41 a	16.19 a	16.32	3.91	0.8317
Fecal production (kg DM day^{-1})	3.46 a	3.14 a	3.40 a	3.33	12.51	0.4036
DM Digestibility (DMD, %)	66.85 b	68.39 a	65.57 b	66.94	2.95	0.0422
NDF Digestibility (%)	39.84 b	42.20 a	37.35 b	39.93	8.21	0.0335

Means within a row followed by different lowercase letters differ significantly according to the Tukey test at 10%.

Table 8
Performance, characteristics, and non-carcass components of feedlot steers fed corn silage from sealed trench silos with different types of polyethylene

Parameter	Types of polyethylene			Mean	Coefficient of variation	Prob.
	LDPE90	LDPE200	LDPE/HDPE			
Initial body weight (kg)	402.9 a	404.7 a	395.3 a	401.0	3.58	0.5152
Slaughter body weight (kg)	554.8 a	558.2 a	554.1 a	555.7	4.31	0.7227
Hot carcass weight (kg)	302.7 a	306.2 a	301.0 a	303.3	4.68	0.5631
Carcass yield (CY, %)	54.56 a	54.85 a	54.32 a	54.58	2.89	0.8623
Fat thickness (mm):						
Longissimus dorsi	6.46 a	6.50 a	6.00 a	6.32	10.94	0.4089
Forequarter	4.92 ab	5.42 a	4.08 b	4.81	21.56	0.0583
Rib	6.25 b	7.33 a	6.75 ab	6.78	17.11	0.0481
Hindquarter	7.83 b	8.33 a	7.92 ab	8.03	10.33	0.0762
Quantitative characteristics (cm):						
Carcass lenght	139.96 a	142.46 a	142.33 a	141.58	2.56	0.4365
Thigh thickness	28.17 a	27.03 a	28.71 a	27.97	6.04	0.2591
Arm lenght	38.58 a	38.04 a	37.96 a	38.19	3.40	0.6752
Arm perimeter	45.38 a	45.46 a	45.71 a	45.51	3.15	0.9169
Vital organs (% BW):						
Heart	0.32 a	0.38 a	0.39 a	0.36	15.39	0.1174
Liver	1.15 a	1.18 a	1.23 a	1.19	12.46	0.6620
Lungs	0.98 a	0.96 a	0.93 a	0.96	9.12	0.6437
Kidneys	0.27 a	0.26 a	0.23 a	0.25	18.26	0.2898
Spleen	0.86 a	0.85 a	0.82 a	0.84	9.24	0.7769
Full rumen-reticulum	6.11 a	6.16 a	6.28 a	6.18	13.72	0.9378
Empty rumen-reticulum	2.09 a	2.23 a	2.22 a	2.18	7.34	0.3280
Full abomasum	1.09 a	1.10 a	1.06 a	1.09	7.16	0.6803
Empty abomasum	1.07 a	1.07 a	1.05 a	1.06	7.15	0.8815
External components (% BW):						
Head	2.62 a	2.62 a	2.73 a	2.66	7.34	0.5773
Tongue	0.29 a	0.29 a	0.30 a	0.30	7.26	0.4889
Tail	0.34 a	0.36 a	0.35 a	0.35	13.58	0.6324
Leather	7.72 a	8.13 a	7.90 a	7.92	10.79	0.7109
Feet	1.77 a	1.71 a	1.77 a	1.75	7.39	0.7115
Testicles	0.31 a	0.33 a	0.33 a	0.32	14.74	0.7674

Means within a row followed by different lowercase letters differ significantly according to the Tukey test at 10%.

Carcass conformation has a commercial impact due to the visual aspect of the carcass, the degree of marbling, and muscle hypertrophy (Neumann et al., 2018). For the forequarter fat thickness (mm), the LDPE200 seal was superior (5.42) to LDPE/HDPE (4.08), and the LDPE90 seal did not differ from the other seals (4.92). For the fat thickness (mm) of the rib and hindquarter, there was a statistical difference (P<0.10), where the LDPE200 seal presented higher values (7.33 and 8.33, respectively) than LDPE90 (6.25 and 7.83) and LDPE/HDPE (6.75 and 7.92) did not differ from the other polyethylenes evaluated.

For the fat thickness (mm) of the *Longissimus dorsi,* quantitative characteristics (cm), vital organs (% BW), and external components (% BW), there was no statistical difference (P> 0.10) between the different seals evaluated, the same result found by Neumann et al. (2018).

The fat thickness (mm) in the carcass was related to the ability of LDPE200 to maintain the ensiled material in adequate anaerobic conditions and external factors, providing ideal fermentation conditions for the preservation of nutrients in corn silage (Macêdo & Santos, 2019; Parra et al., 2021).

Table 9 presents the ingestive behavior data expressed in hours per day^{-1} for the activities of food intake, water intake, ruminating, and idling in times per day^{-1}, and for the activities of feeding, drinking, defecating, and urinating of the steers. In general, the ingestive behavior of the animals, expressed in hours per day^{-1} and in times per day^{-1}, did not show statistical differences (P>0.10) between the different types of polyethylene tested to seal corn silage.

Table 9

Ingestive behavior expressed in hours per day^{-1} for food intake, water intake, ruminating, and idling, and in times per day-1 for feeding, drinking, defecation and urination of feedlot steers fed corn silage from sealed trench silos with different types of polyethylene

Parameter	Types of polyethylene			Mean	Coefficient of variation	Prob.
	LDPE90	LDPE200	LDPE/HDPE			
Hours per day^{-1}:						
Food intake	2.32 a	2.89 a	2.56 a	2.59	17.14	0.1308
Water intake	0.26 a	0.21 a	0.22 a	0.23	23.55	0.5234
Ruminating	5.47 a	5.40 a	5.01 a	5.29	4.47	0.2841
Idling	15.98 a	15.54 a	16.23 a	15.92	10.27	0.3406
Times per day^{-1}:						
Feeding	14.5 a	15.7 a	12.9 a	14.4	15.50	0.1460
Drinking	7.4 a	6.3 a	6.1 a	6.6	18.77	0.1945
Defecation	9.5 a	9.7 a	8.9 a	9.4	16.35	0.6244
Urination	7.5 a	7.6 a	7.8 a	7.6	16.54	0.8342

Means within a row followed by different lowercase letters differ significantly according to the Tukey test at 10%.

Neumann et al. (2018) state that the greater the proportion of the digestible portion of the fiber fraction of the feed, the greater its digestibility and consequently the greater animal performance, related to the ability of the plastic film to maintain the anaerobic environment.

The use of LDPE200 in sealing corn silage silos reduced losses of ensiled mass, maintained aerobic stability, and increased ruminal digestibility of DM compared to other types of polyethylene, as well as consequently allowing animals finished within 112 feedlot days to display greater daily weight gain, apparent digestibility of the diet and better carcass finishing, in addition to improving the efficiency of conversion of DM ingested into carcass compared to seals with LDPE/HDPE and LDPE90.

Conclusion

Using LDPE200 to seal corn silage in trench silos reduces losses of ensiled material, promotes greater aerobic stability, increased ruminal DM degradation, and greater feed efficiency in the performance of feedlot steers.

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