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Animal performance, carcass characteristics and beef quality of steers fed with a whole oat or maize grain-based diet

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Abstract

Aim of the study: We evaluated the use of oat grain as an alternative source of energy to maize grain in high energy finishing diets. Maize crop production in arid and semi-arid areas is poor or non-existent. Thus, small grains such as oats have become an alternative in high energy rations due to their versatility and ease of cultivation.

Area of study: Semiarid region of Buenos Aires province, Argentina.

Material and methods: Sixteen Angus steers were randomly assigned to two dietary treatments based on whole oats grain (OD) or whole maize grain (MD) for 61 days. Diets were formulated iso-nitrogenous and iso-energetic. Animal performance, carcass attributes and beef quality traits were evaluated. *Longissimus thoracis* steaks were wet-aged at 4°C for either 4 or 14 days.

Main results: Similar results were found between OD and MD for the variables of performance, carcass evaluation and water retention in fresh meat. No interactions between diet and ageing period were found for any of the variables evaluated. The MD beef was lighter and had a redder appearance than the OD beef. The 4 days-aged beef showed higher values of L*, a* and b* and was more saturated than the 14 days-aged beef. However, the perception of beef colour by the human eye, evaluated through the CIEDE2000 metric, showed no differences among diets and ageing periods.

Research highlights: Oat grain could be used in replacement of maize grain as an energy source in fattening rations of beef cattle, obtaining similar animal performance and meat quality.

Additional key words: beef cattle; meat quality; colour; water-holding capacity.

Abbreviations used: a* (redness); ADF (acid detergent fibre); ADG (average daily gain); b* (yellowness); bDM (beef dry matter); BFT (back fat thickness); BW (body weight); CCW (cold carcass weight); CL (cooking loss); CP (crude protein); CWL (carcass weight loss); DL (drip loss); DM (dry matter); DP (dressing percentage); EE (ether extract); EJ (expressible juice); FBW (final body weight); F:G (feed conversion efficiency); HCW (hot carcass weight); LA (long aged meat, 14d); L* (lightness); MD (whole maize grain-based diet); ME (metabolizable energy); MVM (mineral-vitamin-monensin premix); NDF (neutral detergent fibre); OD (whole oat grain-based diet); PtL (purge-thaw loss); REA (rib eye area); SA (short aged meat, 4d).

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Introduction

Red meat is a source of high-value protein, energy, and a wide range of essential micronutrients, such as vitamins A, B_6, B_{12}, D, E, iron, zinc and selenium, among others (Daley et al., 2010). Several studies have shown that animal genetics, farming practices, type of diet and ageing (understood as the process where meat is stored under controlled refrigerated conditions to improve its eating quality) can influence the characteristics of meat and its nutritional and organoleptic properties (Daley et al., 2010; Kim et al., 2016). The type of feed offered to cattle affects the rate of protein deposition and fat synthesis, which may subsequently have an impact on the colour, water-holding capacity and cooking properties of beef (Priolo et al., 2001). Besides tenderness and juiciness, ageing is a value-adding process that can enhance other beef properties such as colour and water holding capacity (Kim et al., 2018). Short ageing periods may benefit the meat industry by providing more appealing bright red colour (Ramanathan et al., 2020). However, long ageing periods may improve the water holding capacity, enhancing juiciness of the meat (Kim et al., 2015), but cause decolouration, reducing blooming potential (Kim et al., 2018). The latter is not desirable because meat colour is an important variable at the retail level indicating freshness and quality (Ramanathan et al., 2020).

Argentina is known worldwide for its traditional grass-fed beef, based on low-input grazing systems occasionally supplemented with small amounts of grain. Typically, 2-year-old steers from British crosses grazing medium to high quality pastures exhibit a daily gain ranging from 600 to 700 g/day. More recently, beef cattle production has turned over more intensive grain-fed systems, because cow-calf farmers retain calves and rear them on grain-supplemented pastures or in confinement until slaughter (Pighin et al., 2016). This is due to the geographic expansion of the cash-crop frontier, driven by rising grain prices, increasing cost of land, greater demand of animal products and low efficiency of the pasture-fed systems. Since then, increasingly more cattle is fed on grain (Arelovich et al., 2011; Pighin et al., 2016). Although most feedlot diets in Argentina are based on maize grain (Pighin et al., 2016), its crop yield in marginal areas of low rainfall is poor or non-existent (Arelovich et al., 2011). Thus, the availability of maize grain is either insufficient or too expensive to cover the demands of high-input systems such as feedlots.

Small grain crops, such as wheat, oats, rye and barley can be used as alternative energy supplements (Dion & Seoane, 1992; Plascencia et al., 2018). The oats crop is attractive to livestock producers in marginal areas because of the simplicity of production, versatility, adaptation to adverse weather conditions and grain-forage dual purpose characteristics (Martínez et al., 2010). Since Argentinean consumers prefer bright red colour meat (Pighin et al., 2016), and that long ageing periods could provide greater water retention, we want to assess whether oats could replace maize without affecting animal performance as well as meat colour and water holding capacity.

Previous results have demonstrated that calves fed with diets containing 60% pelleted maize or oat grain did not show any significant differences in performance (Arelovich et al., 2012). Another study with young steers on diets with 55% whole oats or maize grain, showed a 40% higher protein deposition rate (measured as growth of the ribeye area), but 38% less back-fat thickness for those fed with oats than those fed with maize, without any detrimental effects on performance (Arelovich et al., 2013). Feeding whole grain is advantageous because the cost of processing is avoided. Moreover, in high grain rations whole oats could stimulate mastication and rumination because of the higher fibre content compared to maize, facilitating grain adaptation and reducing the risk of developing acidosis (Ørskov et al., 1973). However, performance and beef quality data are still scarce for cattle finishing on whole oat-based diets. The objective of this trial was to contrast animal performance, carcass attributes and beef quality traits, evaluated in two ageing periods, of steers fed diets based on either whole maize or oat grain, included in iso-energetic and iso-nitrogenous diets at similar intake levels. In addition, this experiment was intended to test whether 4-days aged meat had similar visual and water holding properties than a 14-days aged meat, regardless of the type of grain used in the diet.

Material and methods

All procedures in this study were approved by the Institutional Animal Care and Use Committee of the National Institute of Agricultural Technology (CICUAE INTA – CERBAS; Approval No. 165) and were in accordance with Argentinian Animal Welfare Handbook (SENASA, 2015).

Animals, dietary treatments and general management

The trial was conducted at the Instituto Nacional de Tecnología Agropecuaria (INTA) experimental station at Bordenave, Buenos Aires province, Argentina. Sixteen Aberdeen Angus steers (327 ± 4 kg body weight, BW; age 14 months) were randomly divided into two groups of eight steers each and were assigned to the following finishing dietary treatments in a complete randomized design (n=8): (i) whole oat grain-based diet (OD) and (ii) whole maize grain-based diet (MD). Both diets were formulated to reach iso-nitrogenous and iso-energetic levels (14.62% CP and 2.44 Mcal ME/kg DM) including 6% of a mineral-vitamin premix (Raciones Argentinas S.A.). All the ingredients, except the grain, were supplied

Table 1. Ingredient and chemical composition of diets based on whole maize or oat grain fed to Angus steers.

Item[(1)]	Dietary treatment[(2)]	
	OD	MD
Ingredient, % DM		
Whole oat grain	86	-
Whole maize grain	-	67
Sunflower meal	8	23
Wheat middlings	-	4
MVM-Premix[(3)]	6	6
Chemical composition		
DM, %	90.08	88.17
CP, %	14.43	14.57
NDF, %	32.05	32.25
ADF, %	14.03	9.56
EE, %	6.72	3.78
Ashes, %	5.55	4.70
NFC, %	40.52	43.81
ME, Mcal/kg DM	2.45	2.58

[(1)] DM: dry matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre; EE: ether extract; NFC: non-fibre carbohydrates; ME: metabolizable energy. [(2)] OD: diet based on whole oat grain; MD: diet based on whole maize grain. [(3)] Mineral-Vitamin-Monensin Premix composition: 70% wheat middlings (used as component carrier), 23% $CaCO_3$, 2% NaCl and 5% commercial mix plus monensin (Raciones Argentinas S.A.). The commercial mix per kg included: vitamin A 850,000 IU; vitamin D_3 170,000 IU; vitamin E 1,500 IU; Ca 24.5 g; Mg 5 g; S 2 g; Fe 7.75 g; Co 36 mg; Cu 3.4 mg; I 180 mg; Se 34 mg; Mn 3 g; Zn 10.08 g and sodium monensin 1 g.

pelletized. Analysis of crude protein (CP = g N/100 g DM × 6.25) was carried out by macro-Kjeldahl Analyses (AOAC, 1990); neutral detergent fibre (NDF) and acid detergent fibre (ADF) by an ANKOM Fibre Analyzer (Ankom Technology, Fairport, New York, USA) following the detergent system procedures (Van Soest et al., 1991); ether extract (EE) with a Goldfish fat extraction apparatus (AOAC, 1990) and metabolizable energy (ME) by in vitro digestibility equations (NRC, 2016a) were performed for each ingredient separately. Composition of the diets are shown in Table 1.

Animals were housed individually in 30 m^2 pens with permanent access to water and shade and were fed once a day at 10:00 a.m. The experimental period consisted of 14 d for adaptation and 61 d for measurements. Once the voluntary intake reached approximately 2% of body weight in each diet the adaptation period was concluded. This intake level (2%) was sustained across the trial according to progressive BW changes. Thus, DM intake across the experimental period averaged 7.30 and 7.58 kg/animal·day for OD and MD, respectively. At the beginning of the study, all animals were dewormed with 2 mL/100 kg of 1% Ivermectin (Vermectín, Laboratorio Over, Argentina) poured on with 20 mL per animal of Cypermethrin (Fatro, Von Franken, Argentina) and they were vaccinated against foot and mouth disease. The trial finished when the animals reached an average of 380 kg BW. For reasons not associated with this trial, a steer assigned to OD treatment was removed from the trial, therefore, n=7 for OD.

Animal performance and live carcass evaluation

The initial and final BW were recorded at the beginning and end of the experimental period, at 9:00 a.m. before feeding, to calculate BW change. The average BW was determined fortnightly to adjust the amount of feed offered. Average daily gain (ADG) and feed conversion efficiency (F:G) were calculated from BW increases and daily dry matter (DM) intake.

Changes in the rib eye area (REA) and back fat thickness (BFT) were determined by ultrasound at the beginning and end of the experimental period. These measurements were both taken from the same image at the joints of the 12th-13th thoracic vertebrae over the *Longissimus thoracis* muscle with an ultrasound scanner Aloka SSD 500 w/2x. The software BioSoft Toolbox Model Pro 500 vers. 2.1 (Biotronics Inc., Ames, IA, USA) was used for image capture and those were processed at the Center of Ultrasound Images Interpretation (CIIE –INTA Castelar, Argentina).

Slaughter procedures and post-mortem carcass evaluation

At the end of the trial the steers were shipped to a commercial abattoir. Individual hot carcass weight (HCW) was determined immediately after slaughter and the cold carcass weight (CCW) after 24 h chilling at 4°C. Carcass weight loss (CWL) was calculated as the ratio between HCW and CCW and expressed as a percentage of HCW. Dressing percentage (DP) was calculated as the relationship between fasted final BW and HCW. The pH was recorded in the *Longissimus thoracis* muscle at 1 and 24 h post mortem, between the 10th and 12th ribs of the right-side carcass with a portable pH-meter Altronix TPA-IV with automatic temperature compensation.

Sections containing the 10th, 11th and 12th ribs were collected from the left-side carcass of all the animals after 24 h post mortem. Samples were transported on ice to the Animal Nutrition Laboratory at the Universidad Nacional del Sur where the *Longissimus thoracis* muscle was removed. Duplicated meat subsamples of each set of the 10th rib steaks were processed following Honikel (1998) procedures to obtain drip loss (DL) at 24 and

Table 2. Animal performance and ultrasound beef variables of Angus steers fed oats (OD) or maize (MD) whole grain-based diets.

Variable	Dietary treatments		SEM[1]	p-value
	OD	MD		
Final body weight, kg	382.57	382.88	6.00	0.9810
Average daily gain, kg	0.91	0.96	0.08	0.7855
Feed to gain ratio, kg/kg	8.40	8.30	0.68	0.9457
Initial rib-eye area, cm^2	54.53	54.84	2.03	0.9429
Final rib-eye area, cm^2	62.67	61.92	1.87	0.8499
Rib-eye area tissue growth, cm^2/d	0.13	0.12	0.03	0.7911
Initial back fat thickness, mm	2.96	3.34	0.24	0.4442
Final back-fat thickness, mm	5.33	6.61	0.41	0.1269
Back-fat thickness tissue growth, cm^2/d	0.04	0.05	0.01	0.3203

(1) SEM: standard error of the mean.

48 h and cooking loss (CL). Also, expressible juice (EJ) was obtained following Cañeque & Sañudo (2000) procedures.

Beef ageing evaluation

Steaks from both the 11th and 12th ribs were weighed individually, vacuum-packaged and assigned to four treatments. These treatments combined the two dietary treatments (OD and MD) with two post mortem wet-ageing periods at 4°C, as a 2×2 factorial experiment. The wet-ageing periods were 4-days (hereafter 'short ageing (SA)') and 14 days (hereafter 'long ageing (LA)'). After completion of each ageing period, the steak samples were frozen at -20°C for further analysis.

The weight of the steaks prior to vacuum packaging was measured, then, after a 24 h thawing at 5°C, the steaks were dried with paper towels and reweighed. Purge-thaw loss (PtL,%) was calculated by the difference in weight of the sample before and after thawing. Beef dry matter content (bDM) was also determined.

Colour variables were evaluated randomly at five spots in each sample. These measurements were taken after a blooming period of approximately 1 h at 5°C. A CR-400 Minolta chroma meter (Konica Minolta Sensing Americas Inc., Ramsey, NJ, USA) with illuminant D65 (2° observer) was used to determine CIE lightness (L*), redness (a*) and yellowness (b*). This instrument was previously calibrated with a white plate. Measurements of the pH were made at three random points in the beef samples using a portable pH-meter Altronix TPA-IV with automatic temperature compensation. Hue angle, Chroma and the CIEDE2000 metric (ΔE_{00}), from the International Standard ISO CIE 11664-6:2014, were calculated. The CIEDE2000 metric formula quantifies the perceptual distance between colours in a similar way to how humans perceive the differences (Luo et al., 2001) and is presented in Eq. (1). The variables ΔL, ΔC and ΔH correspond to the differences between L*, Chroma and Hue angle, respectively. The variables S_L, S_C and S_H represent weight functions, K_L, K_C and K_H represent correction terms and R_T is the rotation function that accounts for the interference between the Chroma and Hue angle differences in the blue portion of the space.

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L}{K_L S_L}\right)^2 + \left(\frac{\Delta C}{K_C S_C}\right)^2 + \left(\frac{\Delta H}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C}{K_C S_C}\right)\left(\frac{\Delta H}{K_H S_H}\right)} \quad (1)$$

Statistical analysis

Differences in animal performance variables (body weight, average daily gain, feed to gain ratio, rib-eye area, back-fat thickness, rate of tissue grow) and carcass and fresh meat variables (hot carcass weight, cold carcass weight, dressing percentage, pH, carcass weight loss, drip loss, expressible juice, cooking loss) were compared using the Student's t-test ($p \leq 0.05$) with PROC TTEST in SAS (SAS University Edition, SAS Institute Inc., Cary, NC, USA). Data from the quality of aged meat (purge-thaw loss, pH, L*, a*, b*, hue angle chroma, beef dry matter) were tested using two-way ANOVA ($p \leq 0.05$) with PROC GLM in SAS. The model included the diet by ageing interaction.

Results

Animal performance and ultrasound data

No significant differences (p>0.05) were found for any performance variables of the steers fed with OD or MD (Table 2). The final body weight and ADG were similar

Table 3. Carcass and fresh beef quality traits of Angus steers that received oats (OD) or maize (MD) whole grain-based diets.

Variable	Dietary treatments		SEM[(1)]	p-value
	OD	MD		
Hot carcass weight, kg	209.29	223.25	4.20	0.0978
Cold carcass weight, kg	202.83	215.79	4.08	0.1157
Dressing percentage, %	57.55	61.40	0.65	0.0004
pH_{1h}	6.76	6.66	0.07	0.5088
pH_{24h}	5.54	5.50	0.02	0.3172
Carcass weight loss, %	3.08	3.36	0.13	0.3172
Drip $loss_{24h}$, %	0.81	0.81	0.09	0.9818
Drip $loss_{48h}$, %	1.50	1.40	0.15	0.7369
Expressible juice, %	23.39	24.06	0.50	0.5281
Cooking loss, %	28.98	33.36	0.98	0.0189

[(1)] SEM: standard error of the mean.

between dietary treatments. Body weight increased 54.43 and 57.50 kg (p=0.77) for OD and MD steers, respectively. The REA increase was 8.14 and 7.09 cm^2 (p=0.78) and BFT increase was 2.37 and 3.27 mm (p=0.31) for OD and MD steers, respectively.

Carcass characteristics and beef quality

Carcass and fresh meat data are shown in Table 3. Even though no differences (p>0.05) were detected, numerically, HCW for MD steers was 6.7% higher than for OD steers, and CCW for MD was 6% higher than for OD. However, there was a difference (p<0.05) of 7% in DP between the OD and MD steers. Meat from both treatments had the same pH and showed similar CWL, DL and EJ values (p>0.05). During the first 24 hours, 54% and 58% of the DL occurred for OD and MD meat, respectively. However, MD fresh meat lost 15% more water as CL (p<0.05) than OD (Table 3).

The effect of diet and the ageing period on beef quality traits are reported in Table 4. No significant interaction effect between type of diet and ageing period was found for any of the variables evaluated. No differences (p>0.05) were observed in PtL, pH, a*, b*, chroma and bDM between the type of diet. However, the beef from MD showed 5% more lightness (p<0.05) and a 2% higher hue angle than that from OD steers, regardless of the ageing time. Conversely, the variables which showed no difference (p>0.05) between ageing periods were pH and hue angle. Meat aged for a long period showed more PtL, L*, a* b*, chroma and bDM (p<0.05) than meat aged for a short period of time, regardless of the type of diet consumed by the animals. CIEDE200 calculations (ΔE_{00}) were 1.655 and 2.471 for OD-MD meat and SA-LA meat, respectively.

Discussion

Performance and grain composition

In marginal semiarid regions, climatic constraints as well as high prices limit the inclusion of maize grain as an energy source for high-concentrated diets. However, oat is a versatile multipurpose crop that can be grazed, as well as harvested for hay or grain, and is cultivated more easily in these marginal areas. The available oats genotypes showed variable fibre, protein and fat content as well as lipid profile (Martínez et al., 2010). The range of EE, CP and NDF reported by Martínez et al. (2010) for 15 autochthonous Argentinian varieties was 4.87-6.92%, 8.46-13.80% and 32.5-38.40%, respectively. Because of this variability, when using whole oat grain to feed cattle, knowing the nutrient composition is critical to meet nutritional requirements and predict the performance response. The composition of the oat grain used in this trial was EE = 7.33%, CP = 13.60% and NDF = 30.78%, higher for EE and lower for NDF than values reported by those authors. The high fat content of oat grain is relevant because the OD had 78% more EE than the MD. Although the non-fibre carbohydrates of the diets were 8% higher for MD than OD, the difference in fat content is expected to increase the energy intake of cattle, levelling the concentration of both diets. The estimated values using the BCNRM 2016 software (NRC, 2016b) suggest that the ME levels of OD and MD were 2.70 and 2.60 Mcal ME/kg, respectively. This could represent an energy increase of 4% for OD compared to MD which could be attributed to the fat content of oats, showing that the energy intake of both diets could be very similar.

As a premise for this trial, both diets have been formulated to be iso-nitrogenous and similar in energy content. Then, OD had 28% more grain than MD, while the larger CP

Table 4. Quality traits of beef from Angus steers fed whole oats (OD) or maize (MD) based-grain diets and wet-aged for 4 (SA) or 14 (LA) days.

Variable	Diet		Ageing		SEM[(1)]	p-value		
	OD	MD	SA	LA		Diet	Ageing	D × A
Purge-thaw loss, %	3.26	3.44	2.69[a]	4.02[b]	0.20	0.5441	0.0002	0.0660
pH	5.54	5.53	5.52	5.55	0.01	0.9066	0.1992	0.1779
L*	37.33[A]	39.28[B]	37.00[a]	39.74[b]	0.48	0.0156	0.0012	0.4212
a*	24.09	24.31	23.13[a]	25.29[b]	0.41	0.7657	0.0067	0.3121
b*	13.41	13.93	13.21[a]	14.16[b]	0.25	0.2671	0.0497	0.1166
Hue angle, degrees	29.08[A]	29.82[B]	29.73	29.21	0.16	0.0127	0.0691	0.0604
Chroma	27.58	28.02	26.64[a]	28.99[b]	0.47	0.6064	0.0108	0.2425
Beef dry matter, %	25.53	25.69	25.01[a]	26.22[b]	0.20	0.6459	0.0019	0.6070

[(1)] SEM: standard error of the mean. Means within rows followed by different uppercase or lowercase indicate statistical differences ($p<0.05$) between dietary or ageing treatments, respectively.

content of oats compared with maize required a larger concentration of sunflower meal and wheat middlings to MD to make both diets iso-nitrogenous. These differences in grain and sunflower meal levels in both diets may cause a confounding effect. Then, the influence of the diet on measured variables could not be attributed exclusively to the type of grain utilized. However, the NDF content of both diets resulted 32%, which may have influenced similarly the diet utilization (Arelovich et al., 2008). Since energy and protein are major nutritional requirements, we would expect that the response of animals to both treatments to be the same. This reasoning is confirmed by the fact that no differences were found between the diets for final BW, ADG, F:G ratio, REA and BFT. Furthermore, HCW and CCW also showed similar values for both treatments.

Likewise in a previous trial with steers fed diets including the same proportions of whole oats or maize grain (Arelovich et al., 2013), to which only the CP level of both diets was equalized, no differences in animal performance (ADG, F:G, FBW) were found. Although data comparing diets containing oats or maize as a whole grain are scarce, both grains have been contrasted in diets using diverse processing methods and inclusion levels. Thus, when oat flakes and broken maize were compared at the same ration level (Dion & Seoane, 1992), or when oats and maize grains were evaluated through various processing methods (Owens et al., 1997), no differences were found in animal performance (ADG or F:G) in either. However, when 80% of pelleted oats or maize were included in two different diets, F:G showed no differences, but DM intake and ADG were higher for animals fed with the maize ration (Marcenac et al., 2009). Therefore, the decision to supply whole or processed grains would be subject to the productive and economic objectives of the farmer.

The REA and BFT values reported in this trial were lower than those found by Pordomingo et al. (2012), but similar to those reported by Pouzo et al. (2015) and Santin Jr et al. (2021) for steers fed variable amounts of maize grain. Although no differences were found in this trial between treatments for REA and BFT, the increase in REA was 15% greater for OD than MD steers, whereas the increase in BFT was 38% greater for MD steers. Similarly, Arelovich et al. (2013) found analogous results of these variables when evaluating diets based on whole maize or oat grain of growing cattle, but instead they reported significant differences in the REA growth rate, showing that steers fed with oats had a 66% greater rate of muscle growth than those fed with maize. However, the reason for this difference has still not been elucidated, but it could be related to secondary compounds, such as polyphenols and antioxidants, present in the oat grain (Peterson, 2001) that may act as growth promoters (Serra et al., 2021). The older age of the steers used in the present trial, which was on finishing cattle, compared to Arelovich et al. (2013) (14 months vs. 6 months), could explain the absence of statistical differences in REA tissue growth reported in the current trial, since animals had a lower growth rate at the time of measurements (Lawrence et al., 2012).

Carcass and beef quality traits

The carcass weight evaluation is one of many indicators for assessing the economic value of the commercial carcasses. Despite no statistical differences were found at FBW and HCW, MD carcasses were 6.7% heavier than OD. Since carcass weight is directly related to the income perceived by the livestock producer, this could be important from an economic point of view if prices of maize result cheaper than oats, because F:G was similar for both diets. In addition, DP showed significant differences and OD carcasses had 7% lower yield than MD carcasses. This finding agrees with Cattelam et al. (2018b), who reported no differences in FBW, HCW and REA but also found a 6% lower DP for steers and heifers fed diets with high in whole oats compared with whole maize grains.

Similarly, Fruet et al. (2016) reported no differences in FBW and HCW but significant differences in DP in sheep. Animals fed whole oat grain diet had a DP almost 13% lower than those fed with a whole maize grain diet, without finding any differences in the weight of diverse cuts of meat. Both experiments attributed the difference in DP to the greater amount of gastrointestinal content found in animals fed oats compared to maize grain at slaughter, since they did not find differences at viscera weight but found that animals fed oats had 55% (Fruet et al., 2016) and 40% (Cattelam et al., 2018a) more gastrointestinal content than animals fed maize. Nevertheless, the DP values found in the current trial were higher than those found by Cattelam et al. (2018b). Remarkably, the DP values reported by Chambaz et al. (2003), who used a diet with similar levels of ME and CP (2.67 Mcal/kg DM and 13.5%, respectively) in Angus steers, and by Pouzo et al. (2015), who supplemented grazing steers with 0.7% BW of cracked maize and increasing amounts of flaxseed, were around 12% lower than those found in the current trial.

The pH values at 1 and 24 h post-mortem did not vary between treatments and also after 24 h of cooling, they were within the limits considered adequate for beef (5.5 – 5.8, Puolanne, 2017). In agreement with Muela et al. (2010), no differences in CWL were found after the chilling period because both treatments also showed similar BFT values, resulting in a similar level of carcass fat insulation.

Although DL showed similar values for both treatments, the values found in the current trial were lower than those reported by Chambaz et al. (2003) for Angus steers. This is a favourable characteristic since the ability to bind water within the protein matrix is one of the most important factors in meat juiciness (Frank et al., 2017). Also, the variation in the juiciness and appearance of the meat are explained, in part, by the cooking loss. Since they are negatively correlated, high values of CL are expected to produce meat with lower juiciness and a less attractive colour on the surface (Kim et al., 2018). This causes a less optimal eating quality meat, turning CL into a variable of high economic interest (Aaslyng et al., 2003). The differences found in CL in this trial could indicate that beef from MD was less juicy than OD. Anyway, according to the USDA Table of Cooking Yields for Meat and Poultry (Showell et al., 2012), values of CL between 10 and 34% are acceptable for rib-eye cuts, showing that data found in this trial were considered normal. Contrary to this trial, Cattelam et al. (2018b) found no differences in CL between oats and maize diets and, like Chambaz et al. (2003), reported lower values than those of this trial. However, the CL values shown by Pordomingo et al. (2012) were similar to those of the current research.

Grain type and ageing attributes

Since there was no diet by ageing period interactions, the type of grain did not affect the beef ageing. Lightness and hue angle were the variables that showed differences between OD and MD beef, indicating that OD was darker but with less red appearance than MD. In accordance with this, Saeed et al. (2019) found that the inclusion of maize grain in Dorper lamb diet increased the lightness of meat.

The LA (14 d) exhibited greater PtL than SA (4 d) beef. These results are consistent with Vieira et al. (2009) who evaluated beef aged for 3 and 10 days prior to freezing and found that longer ageing periods contributed to grater water losses. However, other studies evaluated even longer ageing periods (3 to 4 weeks) prior to freezing and found greater water retention as ageing time increased (Kim et al., 2015). Likewise, the bDM of LA was higher than that of SA, as could be expected since LA beef exhibited a higher water loss during the purge-thaw process.

Differences in L*, a*, b* and chroma found in aged beef samples indicate a brighter, redder, yellower and more saturated values on LA meat. These differences could be attributed to the breakdown of certain proteins and enzymatic changes that occur during ageing, resulting in meat with a brighter and slightly redder colour (Jayasooriya et al., 2007). In accordance with this research, Rivaroli et al. (2020) also found that beef aged for one day had lower values of L* than beef aged for 14 days, without finding any differences in a* and b*. Additionally, the values of L* were higher; and a* and b* were lower than those found at the present trial. The colour variables in this trial are similar to those reported by Kim et al. (2016) who evaluated beef samples that were exposed at two wet-ageing temperatures. Conversely, our values contrast with those measured in fresh meat which often has a lower range of values for a* and a higher range for b* than found in this trial (Pordomingo et al., 2012; Santin Jr et al., 2021).

Colour, tenderness, juiciness and flavour of meat are important characteristics and vital criteria for the consumers' purchasing decisions. Since only colour can be appreciated by the naked human eye; the degree of discolouration is an indicator of freshness, wholesomeness and acceptability; and mainly determines the intention of consumers to buy meat (Mancini & Hunt, 2005). According to the CIEDE2000 equation, which compares numerical differences between two colours and relates them to the perception of colour by the human eye (Luo et al., 2001), OD or MD beef and SA or LA beef did not present any visual differences. In both cases, the values obtained by using the metric were below three, which is the threshold from which the human eye could perceive differences between two colours (Pereira et al., 2020). This demonstrates that, despite the statistical differences found in the colour variables, the beef had similar visual characteristics and the consumer could not be able to difference one from the other.

The versatility and adaptation of oats in semiarid regions make it an alternative to the use of maize grain in high energy diets since the performance of the animals was not influenced by the diets, except in DP, attributing it to a greater filling of the gastrointestinal tract in the animals fed with oats. Also, in general, the water retention properties of OD and MD beef were similar, except for cooking loss. The meat from MD showed higher losses than OD. The colour characteristics of SA and LA beef were similar; however, MD beef was lighter and redder than OD beef. Despite these differences, the naked human eye could not differentiate between OD and MD beef or between SA and LA beef. Therefore, increasing the ageing period beyond 4 days would not improve the organoleptic properties evaluated in this trial.

All the results obtained in this work apply to the range of performance, type of animal and days of feeding like in the present study. Further research would elucidate whether the responses observed would replicate for higher performance, longer feeding periods and heavier animals at slaughter. The tenderness and juiciness of the meat obtained from the different diets should also be considered, as well as the study of secondary compounds present in the oat grain and their possible influence on the growth of the animal and composition of the meat.

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