

## Performance and ultrasound measurements of beef cattle fed diets based on whole corn or oats grains

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This study intended to contrast dietary effects of whole grain oats versus corn included in rations with moderate roughage content on animal performance, beef ultrasound measurements, rumen and blood parameters. Ten Aberdeen Angus steers (203 kg) in individual pens were fed twice daily on either whole oats (OD) or corn (CD) based diets. Measurements were: DM intake (DMI), average daily gain (ADG), feed to gain ratio (F/G); back fat (BF) and rib eye area (RA); blood parameters. Four cannulated steers were used to study rumen pH, NH<sub>3</sub>-N and grain degradability. Rations dietary components were 55% grain, 30.1% barley straw, and 10.6% whole soybeans. Despite calculated higher ME supply ( $P = 0.0887$ ) no differences were found for DMI, ADG, or F/G. Metabolizable protein intake (19.4%) was larger and degradable protein intake (43.3%) smaller for CD compared with OD ( $P < 0.01$ ). The growth rate ( $\text{cm}^2 \text{d}^{-1}$ ) for RA was 40% greater for OD, but larger BF deposition ( $P = 0.0787$ ) was found for CD. Blood Mg was higher for OD ( $p = 0.0564$ ), nevertheless other blood parameters remained unaffected. Rumen pH and NH<sub>3</sub>-N were not influenced by diet, variations were only observed within time periods. Rumen pH decreased linearly from 7.05 to 6.13 and 7.11 to 6.37 for OD and CD respectively ( $P < 0.05$ ). Minimum NH<sub>3</sub>-N concentrations ( $\text{mg dL}^{-1}$ ) were reached 12 and 18 h after morning meal for OD (7.10) and CD (5.82) respectively. Rumen degradation was larger for oats than corn. Whole oats rather than corn fed up to 55% of total DM seems to improve protein deposition, without significant changes in animal performance, rumen environment or blood parameters.

**Key words:** Blood steers, feed efficiency, parameters, rumen environment.

### INTRODUCTION

In Argentina feeding grain in intensive beef cattle rather than grass finishing operations became more usual two decades ago. Then, few enterprises grew as commercial feedlots while many others remained as a commercial segments integrated within different sized farms (Arelovich et al., 2011). Pen feeding is frequently used at different stages of growth and finishing. Although corn (*Zea mays* L.) is the choice to include in beef cattle diets, other grains and by-products are available in the market.

Wherever corn crop is environmentally and economically feasible, it is the most preferred energy source for growing-fattening in beef cattle intensive systems. It is well known that corn has the highest energy content (NRC, 1996) contrasted to other grains. About 80-85% processed corn grain would be included in a typical feedlot diet. Many studies showed that

grain processing leads to enhanced animal performance because of increased starch availability; diminished mycotoxin activity and improvement of mixing properties (Owens et al., 1997). However, economic returns from corn processing would vary with price, feed efficiency response, energy cost, and size of operation (Macken et al., 2006). Processing methods seems to increase in cost with processing intensity, and the feed efficiency threshold at which processing becomes profitable also increases (Macken et al., 2006).

Forage level and type of grain in the diet would also affect biological and economic response to grain processing (Owens et al., 1997; Macken et al., 2006). At moderate to high roughage levels in the diet, smaller differences in animal performance could be expected regardless of whole or processed grain or different grain sources are included. In addition, feeding whole grains in moderate to high forage diets could be of benefit for animal health as well as for beef quality.

High physically effective NDF content due to high forage proportion reduced acidosis risk by sustaining pH at 5.8 over a longer period of time (Yang and Beauchemin, 2009). The NDF content of a grain like whole oats (*Avena sativa* L.) can also contribute to a healthier rumen environment and whole animal welfare. As far as consumers concern about beef quality, differences

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between grass-fed and grain-fed cattle were addressed in many studies. A review of Daley et al. (2010) suggests that to obtain a healthier lipid profile and higher antioxidant content in cattle require finishing on 100% forage-based diets, which could influence feed efficiency, economics, and some beef attributes. When oats was supplemented as whole grain to grazing steers increased performance without significant changes in beef lipid profile was observed (Marinissen et al., 2006; 2008). Oats grain has shown some potential to substitute for corn in a 55% grain pelleted diet without significant effect on performance in young growing cattle (Arelovich et al., 2012). There is scarce information available evaluating how the inclusion of whole grains of different sources in moderate to high roughage diets may influence animal performance and beef characteristics. The objective of this study was to compare performance, beef ultrasound measurements, ruminal parameters, and blood serum profile of steers receiving moderate forage whole corn or whole oats based diets.

## MATERIALS AND METHODS

The study was conducted at Departamento de Agronomía, Universidad Nacional del Sur (UNS), Bahía Blanca (38°44' S, 62°10' W), Argentina. Feeding conditions and facilities were intended to resemble those followed by producers of the area. Practices for animal care followed those recommended for animal well being by the Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA, 2012).

### Animals and treatments

Ten weaned Aberdeen Angus steers (203 ± 18 kg; age 32 wk) were selected from UNS herd. Each steer was treated with 5 mL of ivermectin (Merial Argentina, Martínez, Provincia de Buenos Aires, Argentina) for internal and external parasites, vaccinated with 5 mL of polyvalent IR T (Rosenbusch, Buenos Aires, Argentina) and 5 mL of neuroenteritis vaccine (Laboratorio Invesbio S.R.L., Buenos Aires, Argentina). The animals were identified by means of numbered plastic tags, assigned by average weight to two groups and randomly allotted to individual pens (3.3 m × 5 m). Plastic feeders and water troughs were placed in each pen.

The experimental dietary treatments were: 1) whole oats grain based diet (OD) and 2) whole corn grain based diet (CD), both formulated to reach isoprotein levels (14% CP). The diets comprised (DM basis) 55% grain (either corn or oats), 30.1% barley (*Hordeum vulgare* L.) straw, 10.6% whole soybean (*Glycine max* [L.] Merr.) and 4.3% supplemental premix plus urea and monensin (Table 1). For diet preparation the roughage was processed with a hammer mill (Carlos Mainero and Co., Bell Ville, Córdoba, Argentina) through a 30 mm mesh and subsequently added to the other components of each diet

**Table 1. Composition of diets based on whole corn or oats grain fed to Aberdeen Angus steers.**

Item	Dietary treatment	
	OD	CD
Ingredient, %		
Barley straw	30.05	30.03
Whole cereal grains	54.96	54.37
Whole soybeans	10.40	10.83
UVM-Premix <sup>1</sup>	4.60	4.77
Chemical composition <sup>2</sup>		
DM, %	88.80	88.90
CP, %	14.80	14.00
NDF, %	45.70	31.80
ADF, %	23.20	15.40
ME, Mcal kg <sup>-1</sup>	2.31	2.64

OD: diet based on whole oats grain; CD: diet based on whole corn grain; DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; ME: metabolizable energy.

<sup>1</sup>UVM-Premix (urea-vitamin-mineral premix). Urea was included to adjust to isoprotein levels both diets with the same proportions of corn or oats which differ in CP content. Wheat middling was used as a carrier for: urea, CaCO<sub>3</sub>, NaCl and a vitamin-mineral supplement. The composition of the whole premix was: 48.2% and 50.2% (wheat middling); 13.6% and 10.5% (urea); 24.2% and 25.3% (CaCO<sub>3</sub>); 0.20% and 0.22% (vitamin-mineral supplement). The vitamin-mineral supplement composition per kg was: vitamin A 3 333 330 IU; vitamin D<sub>3</sub> 666 666 IU; vitamin E 3 000 g; vitamin B<sub>1</sub> 0.560 g; vitamin B<sub>2</sub> 0.660 g; nicotinic acid 1.600 g; Zn 38.330 g; Mn 12.330 g; Fe 8.330 g; Cu 3.330 g; S 50.000 g; Mg 12.330 g; Co 160.000 mg; Se 73.000 mg; I 160.000 mg; Monensin 15 000 g.

<sup>2</sup>Analyzed values (duplicate samples) for DM, CP (AOAC, 2000), NDF, ADF (Van Soest et al., 1991). ME was estimated from tabular values of each dietary component (NRC, 1996).

in a horizontal mixer (Marion Mixer, Rapids Machinery Company, Marion, Iowa).

Treatments were assigned randomly to pens. Animals were fed twice a day at 08:00 and 17:30 h. Diets were restricted to 5 kg DM daily per animal during previous 13 d adaptation; followed by a 60 d experimental period in which diets were offered *ad libitum*.

Refusals were weighed, recorded, and discarded before feeding. Feed and refusals grab samples were collected from each pen daily composited within animal and dried at 60 °C in a forced air oven to constant weight. After drying, each sample was ground through a 2-mm screen in a Wiley mill (Standard Model 3, Arthur H. Thomas, Philadelphia, USA) and stored for later analysis.

Feed chemical determinations included crude protein (CP = g N 100 g<sup>-1</sup> DM × 6.25) by macro-Kjeldahl N analyses (AOAC, 2000). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined with an ANKOM Fiber Analyzer (Ankom Technology, Fairport, New York, USA) following the detergent system procedures (Van Soest et al., 1991), including  $\alpha$ -amylase but without sodium sulfite. Feed ingredient and chemical composition are reported on Table 1. Diet daily supply was managed according to the feed rejected and weighed daily, and procedures for next day allowances followed the criteria shown in Table 2, which allowed a gradual increase in daily intake.

### Performance, blood and ultrasound measurements

The DM intake (DMI) was computed by subtracting dry

**Table 2. Criteria utilized for daily dietary supply to each individual feeder.**

Feed refusal	Feed allowance respect to previous day	
	g d <sup>-1</sup>	
< 100		Increase 250
100 to 250 (3 consecutive days)		Increase 250
250 to 500		No change
> 500 (3 consecutive days)		Reduce 250

orts weight from dry weight of the feed provided for each individual. Steers were weighed at 30 d intervals before feeding at 08:00 h and were not withheld from feed or water. Average daily gains (ADG) and feed to gain (F/G) ratio were computed from live weight differences and intake data. Blood samples were obtained by caudal vein venipuncture at the last day of the experiment. Serum analyses were performed for glucose, non esterified fatty acids (NEFA), total protein, Ca, P, Mg, Na, and K were determined by automated methods in a commercial lab.

At the beginning and final stage of the experimental period live animal measurements by ultrasound techniques were performed. The cattle were evaluated to determine changes in rib eye area (RA), back fat (BF) and hip fat (HF) thickness. An ultrasound scanner (Falco 100, Pie Medical Equipment, Maastricht, The Netherlands) was used to determine 12<sup>th</sup> rib BF and RA (*Longissimus dorsi* muscle area) both in the same image. A second image was for fat thickness at hip, positioning the transducer between the hip and the ischium. The software BioSoft Toolbox model Pro 500 version 2.1 (Biotronics Inc., Ames, Iowa, USA) was used for image capture. The number of ultrasound observations was two per animal and parameter (RA, BF, and HF), the first at the beginning and the second at the end of the 60 d experimental period. Images were processed at the Centro de Interpretación de Imágenes Ecográficas (CIIE-Instituto Nacional de Tecnología Agropecuaria INTA Castelar, Argentina). The rate of tissue growth ( $\Delta$  TG) from the end to the beginning of the experimental period for RA and BF were calculated from the differences in thickness established at for each observation in time. Dietary DM composition, DMI, individual initial body weight, body condition and breed; and available environmental temperature were introduced in the computer NRC-model (NRC, 1996) to estimate metabolizable protein (MP) as well as degradable intake protein (DIP) for each individual. These calculations were performed to contrast predicted gains with actual ADG's.

### Rumen parameters and *in situ* evaluation of grains

To further describe experimental diets digestion, four ruminally cannulated Aberdeen Angus steers were allocated to a completely randomized design, receiving both dietary treatments following procedures described above. Then, rumen pH and NH<sub>3</sub>-N concentrations were determined. Rumen liquid was obtained at 0, 2, 4, 6, 8, 12, 18, and 24 h after the morning meal, and filtered through four layers of cheesecloth. The pH of the filtrate

was measured immediately before the inhibition of the microbial activity of fluid by adding 2 mL of a 7.2 N HCl solution (Merchen et al., 1986). Rumen samples were immediately frozen and kept for NH<sub>3</sub>-N determination. A colorimetric procedure was used to evaluate NH<sub>3</sub>-N concentrations (Broderick and Kang, 1980) using 50  $\mu$ L aliquots from the ruminal samples and a spectrophotometer (Beckman DU 64, Beckman Instruments, Fullerton, California, USA).

The degradability parameters of oats and corn grains incubated in Dacron bags were also established. For this *in situ* study all four cannulated animals were adapted for 7 d to the diet; used as replicates and oats and corn were the treatments. Then 10  $\times$  20 cm Dacron bags (Ankom Technology Corporation, Fairport, New York, USA) containing only oats or corn grain were inserted at different time intervals. The same number of bags containing either corn or oats was exposed to the rumen environment for 0, 2, 4, 6, 8, 12, 24, and 30 h after feeding. The bags were dried, weighed, filled with the ground substrates and sewed to a polyester cord with a metal weight attached to its extreme in order to achieve proper immersion in the ventral sac. Before insertion of bags through the rumen cannula they were soaked in water at 20 °C, and those from 0 h were not exposed. After extraction at the corresponding incubation times, bags were immediately rinsed under tap water and subsequently frozen to stop fermentation. Later on, bags were rinsed again in a washing machine, dried at 60 °C, and re-weighed. The weight data were analyzed by a computer program to estimate degradability parameters, by fitting them into the equation  $EDMD = a + [bc/(c + k)]$ , where EDMD was effective DM degradability; *a*, the soluble fraction; *b*, the potentially degradable insoluble fraction and *c*, the rate of degradation of the rumen degradable fraction *b* and *k*, the rumen fractional dilution rate (Ørskov and McDonald, 1979). The utilized rumen fractional dilution rate was  $k = 0.05$  for both grains.

### Statistical analyses

The feeding trial was conducted as a completely randomized experiment and the variables were studied by ANOVA. The means were declared different when a significant F-test for treatment ( $\alpha = 0.05$ ) was detected. For time-sequence data regression analyses were employed to test the relationships between pH and NH<sub>3</sub>-N across 24 h period. For the *in situ* study ANOVA was performed for degradation parameters with animals as replicates. The software InfoStat (Di Rienzo et al., 2010) was used for all data analysis.

## RESULTS

### Productive performance, blood and beef quality parameters

Although calculated daily ME intake tended to be higher

for CD ( $P = 0.0887$ ) compared to OD, no differences were found for daily DM intake, ADG or F/G (Table 3). Mean live weight change followed an identical pattern across time for both experimental diets across the weighing periods, as illustrated by Figure 1.

The average CP content of the diet resulted slightly higher for OD compared with CD, attributable to expected deviations generated by manipulation of the ingredients in the mixing process (Table 1). However due to slight numeric differences in total DM intake, total protein intake resulted non significant, averaging 945 and 921 g  $d^{-1}$  for OD and CD, respectively. Nevertheless, significant differences ( $P < 0.01$ ) between both treatments in MP and DIP intake (Table 3) were predicted from the differences in protein degradability arising from tabular values for corn and oats grains (NRC, 1996). Thus expected MP intake was 19.4% larger and DIP 43.3% smaller for CD compared with OD.

Blood concentration of Mg was higher in those animals receiving the OD diet ( $P = 0.0564$ ). All other blood parameters measured were not affected by experimental diets (Table 4).

Initial, final, and  $\Delta TG$  data for RA and BF thickness

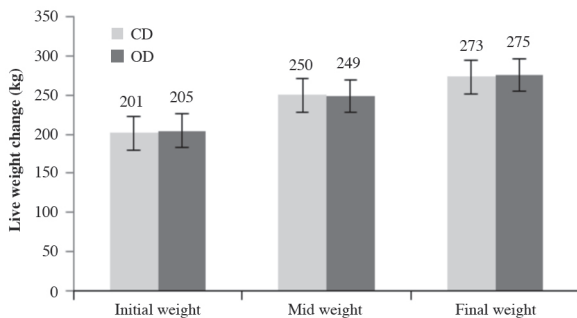
**Table 3. Daily nutrient intake, performance and predicted intake values for steers fed diets based on whole grain oats or corn.**

Item	Dietary treatment		SEM	P-value
	OD	CD		
<b>Intake</b>				
DM, kg	6.39	6.58	0.13	0.5096
CP, g	946	921	19.20	0.5474
ADG, kg	1.18	1.19	0.05	0.9155
F/G ratio, kg $kg^{-1}$	5.48	5.64	0.24	0.7618
<b>Predicted values<sup>1</sup></b>				
ME, Mcal	14.76	17.10	0.50	0.0073
MP, g	486	602	20.40	<0.0001
DIP, g	700	541	21.60	0.0005
DIP balance, g	169	-75	40.80	<0.0001

<sup>1</sup>Calculated from the NRC (1996) model.

OD: diet based on whole oats grain; CD: diet based on whole corn grain; SEM: standard error of the mean; DM: dry matter; CP: crude protein; ADG: average daily gain; F/G: feed to gain ratio; ME: metabolizable energy; MP: metabolizable protein; DIP: degradable intake protein.

Within a row, means differ when  $p < 0.05$ .



OD: diet based on whole oats grain; CD: diet based on whole corn grain.

**Figure 1. Live weight change of steers fed diets based on whole grain oats (OD) or corn (CD).**

are reported in Table 5. Differences between treatments were apparent only for  $\Delta TG$  in RA, which was 40% greater on a daily basis for animals receiving OD than those on the CD diet. Conversely, a larger trend ( $P = 0.0787$ ) for BF deposition was found for CD compared to OD treatment. Observed HF values resulted almost identical at the beginning as well as at the end of both treatments averaging 1.46 and 2.77 mm, respectively.

### Rumen parameters and DM degradability of grains

The rumen pH for both diets decreased linearly after the first daily meal following a similar pattern, as shown by the regression in Figure 2a where  $R^2 = 0.377$  and 0.874 for OD and CD respectively ( $P \leq 0.05$ ). Neither treatment effect nor interaction treatment by sampling hour was found. The pH values ranged from 7.05 to 6.13 and 7.11 to 6.37 for OD and CD, respectively, within the 24 h interval. As shown in Figure 2b rumen  $NH_3-N$  changed with sampling time. It was described by a quadratic regression for both diets where  $R^2$  was 0.6718 and 0.7912 for OD and CD, respectively ( $P > 0.05$ ). Treatment had no effect on rumen  $NH_3-N$ ; however, concentration varied with sampling hour as expected. Thus, minimum  $NH_3-N$  concentrations were reached 12 and 18 h after morning meal for OD (7.10 mg  $dL^{-1}$ ) and CD (5.82 mg  $dL^{-1}$ ) respectively.

In Table 6 are reported the degradation constants as well as values for DMED for oats and corn grains, as main components of the experimental diets. Thus, oats showed

**Table 4. Blood parameters in steers fed diets based on whole grain oats or corn.**

Item	Dietary treatment		SEM	P-value
	OD	CD		
Glucose, g $L^{-1}$	0.86	0.85	0.02	0.9065
NEFA, mEq $L^{-1}$	0.38	0.38	0.01	0.7834
Total protein, g $dL^{-1}$	6.85	7.06	0.08	0.1755
Ca, mg $dL^{-1}$	9.72	10.44	0.23	0.1152
P, mg $dL^{-1}$	9.12	9.64	0.50	0.6292
Mg, mg $dL^{-1}$	1.60	1.36	0.06	0.0564
Na, mEq $L^{-1}$	137.80	137.80	0.36	0.9999
K, mEq $L^{-1}$	5.16	4.88	0.16	0.4127

OD: diet based on whole oats grain; CD: diet based on whole corn grain; SEM: standard error of the mean; NEFA: non-esterified fatty acids.

**Table 5. Live animal ultrasound measurements of the carcass of steers receiving diets based on whole grain oats or corn.**

Item	Initial <sup>1</sup>		Final <sup>2</sup>		$\Delta TG$ <sup>3</sup>	
	RA	BF	RA	BF	RA	BF
	$cm^2$	mm	$cm^2$	mm	$cm^2 d^{-1}$	mm $d^{-1}$
Dietary treatment						
OD	33.30	1.12	42.02	1.58	0.15	0.01
CD	34.54	1.06	39.72	2.54	0.09	0.03
SEM	1.02	0.05	1.47	0.28	0.02	0.01
P-value	0.5731	0.5447	0.4673	0.0787	0.0316	0.0729

OD: diet based on whole oats grain; CD: diet based on whole corn grain; SEM: standard error of the mean.

<sup>1</sup>Measurements at the beginning of the experiment: RA: rib eye area; BF: back fat depth at 12<sup>th</sup> rib.

<sup>2</sup>RA and BF measurements made at the end of the experiment.

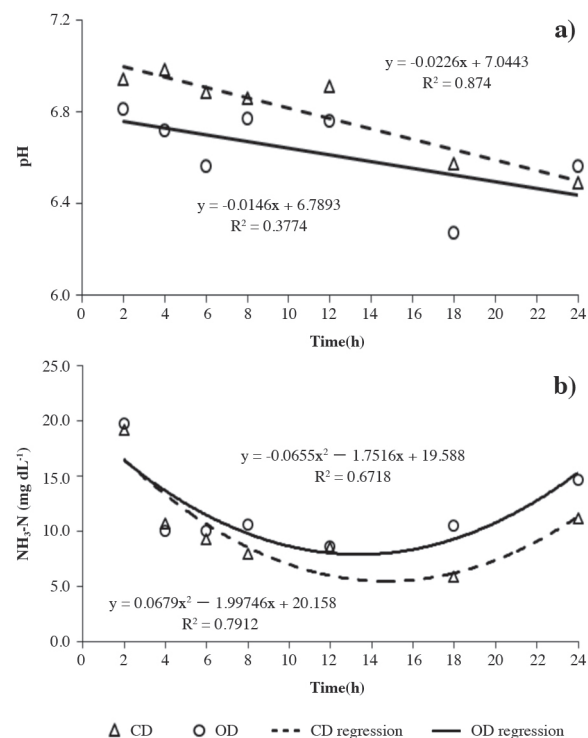
<sup>3</sup> $\Delta TG$ : rate of daily growth for RA and BF in a 60 d period.

a larger soluble fraction *a* with a mean value of 69.14% and a smaller potential degradable fraction *b* with a mean value of 30.83%. Instead corn grain exhibited a smaller *a* and larger *b* fractions with mean values of 19.83% and 79.81%, respectively. The rate of degradation *c* for fraction *b* resulted 4.5 times larger for corn than oats (*P* < 0.05). No differences were detected for DMED.

## DISCUSSION

### Animal performance

Distinctive animal response, feed efficiency and carcass



<sup>1</sup>pH regression: *P* values were 0.0029 and 0.0500, and means 6.8 and 6.6 for CD and OD, respectively.

<sup>2</sup>NH<sub>3</sub>-N regression: *P* values were 0.3979 and 0.4033, and means 10.3 and 12.0 mg dL<sup>-1</sup> for CD and OD, respectively.

**Figure 2. Regressions for (a) rumen pH (linear)<sup>1</sup> and (b) NH<sub>3</sub>-N concentration (quadratic)<sup>2</sup> at different time intervals in ruminally cannulated animals receiving OD or CD.**

**Table 6. *In situ* degradation parameters, effective and potential degradability of energy feed components of experimental diets CD and OD<sup>1</sup>.**

Item	Substrate		SEM	P-value
	Oats	Corn		
Degradability parameters <sup>1</sup>				
<i>a</i> , %	69.14	19.83	9.34	0.0010
<i>b</i> , %	30.83	79.81	9.28	0.0016
<i>c</i> , %/h	0.02	0.09	0.01	0.0222
DMED, %	77.06	71.35	1.42	0.1636

CD: based on whole corn grain; OD: based on whole oats grain; SEM: standard error of the mean.

<sup>1</sup>*a*, *b*, *c* are constants in the equation DMED: dry matter effective degradability =  $a + [bc/(c + k)]$ , where *a* = the rapidly soluble fraction, *b* = the potentially degradable fraction, *c* = the rate of degradation of fraction *b*. Fractional dilution rate (*k*) = 0.05.

characteristics could be expected from different grain sources added to the ration. Furthermore grain processing and inclusion level of other dietary components could interact affecting in different ways these parameters (Mathison, 1996; Owens et al., 1997; Corrigan et al., 2007).

Calculated ME and MP daily intake was higher for CD than OD, being DIP values high for OD but exhibited a negative balance for CD. Therefore, differences in animal performance arising from these diets should have been expected. In fact when required inputs for each individual, as described in Materials and Methods, were inserted in the NRC computer model (NRC, 1996), calculated MP would support ADG's of 1.09 and 1.55 kg animal<sup>-1</sup>, but the ME supply would limit them to 0.97 and 1.35 kg animal<sup>-1</sup> for OD and CD, respectively. However, the observed mean ADG values resulted almost identical: 1.18 and 1.19 kg animal<sup>-1</sup> d<sup>-1</sup>, for both diets. The accuracy of NRC model (NRC, 1996) to predict ADG could be affected by different aspects. Prediction discrepancies with actual data were found particularly at low rates of gain, biases could appear by estimating NE content from TND related to nutrient composition and different feed sources among others (Block et al., 2006). However, for the purposes of this study the NRC program was considered a suitable standard to contrast with observed ADG data, particularly to establish potential differences between corn and oats grains. In this study, the moderate level of unprocessed grain inclusion in the diet, high NDF content and DIP availability could have been involved in reducing the nutritional gap and consequently productive performance between oats and corn based diets.

Besides, a faster rumen degradation rate and extent of starch from oats compared with corn (Ørskov, 1986; Owens et al., 1997) are in agreement with the findings of this study. Since the largest portion of the DM is starch in both grains (NRC, 1996; Huntington, 1997), then DM degradability could be expected to resemble starch degradation. Even more, oats starch degrades faster than the other DM components (Cerneau and Michalet-Doreau, 1991). The synchronous supply of carbohydrate and protein could benefit efficiency of nutrient utilization. The faster ruminal degradation rate for oats would provide available carbohydrates to increase protein synthesis for the largest DIP supply in OD, compared to the negative DIP balance for CD. A synchronous diet could improve microbial protein synthesis and VFA production, utilization of recycled N, and decrease N output which would benefit animal performance and decrease environmental impact (Cole and Todd, 2008; Seo et al., 2010). Conversely, the comparatively higher ME associated to a negative DIP balance for CD was probably limiting NDF rumen digestion in this diet. DIP balance becomes more critical with high dietary NDF.

Waldo (1973) suggested that rumen fermentation of starch is 94% and 74% for oats and corn respectively. Then

higher starch escape to duodenum would be expected from corn but it minimizes with the inclusion of 40% to 60% corn in the diet. The substitution of corn for oats up to 40% of total diet with cattle of similar initial weight did not show significant changes in rumen fermentation or effective nutrient utilization (Dutta and Thakur, 1992). For 54% inclusion of dry processed corn, oats, wheat or barley grains the ADG ranged from 1.09 to 1.17 kg d<sup>-1</sup>, with no differences for ADG or F/G ratio between oats and corn (Dion and Seoane, 1992). Although grain was processed rather than whole, ADG resulted similar to the observed values in this study. When a 60% oats or corn pelleted diet was fed to similar weight steers as in this study, again no differences in F/G were found, but ADG was higher for corn, being 1.23 vs. 1.41 kg animal<sup>-1</sup> daily for oats and corn based diets respectively (Arelovich et al., 2012).

Inter and intra-species variability in grain composition and degradation is other aspect that many times is overlooked when considering grain nutritional value and animal response. An important variability among various oats genotypes was found by Martínez et al. (2010). Waldo (1973) reported cultivar variability in starch escape for different corn grains. For distinct fractions of the grain, differences detected within exceeded those between species for cultivars of oats and corn (Micek and Kowalski, 2010).

#### Blood profile and rumen parameters

All blood data except NEFA were contrasted with reference values as suggested by Boyd (1985). Total protein, Ca, Na, and K were within normal ranges for blood serum. Glucose values resulted identical across treatments but somewhat higher than reference values (0.42-0.75 g L<sup>-1</sup>). Glycogenic stimuli can be induced by a larger propionate production (Raun et al., 1976; Cinar and Sulu, 1995) expected from grain feeding. Since monensin was included in both diets, which in turn modify fermentation favoring propionate production, increased blood glucose could also be expected with monensin supply (Debasis and Singh, 2002; Broderick, 2004). A shift of starch digestion to duodenum from where it is absorbed as glucose (Haimoud et al., 1995) could also be a factor increasing glucose level. The last would be occurring particularly with CD because of the comparatively lower starch degradation of corn grain, as discussed above.

NEFA concentrations can be used as a measure of adequate energy intake (Rudik et al., 2004), and low NEFA values are found in the blood of healthy animals with positive energy balance. Meanwhile high concentrations (> 40 mEq L<sup>-1</sup>) indicate adipose tissue lipolysis, which occurs in response to increased energy demand.

The average P concentration in blood is over the reference interval (4.3-7.8 mg dL<sup>-1</sup>) with no treatment effect. Erickson et al. (2002) found values of 8.0 mg dL<sup>-1</sup>

with different levels of P in the diet (0.22%, 0.28%, and 0.24%) for feedlot steers, but levels changed significantly over time. The increased blood Mg for OD ( $p = 0.0564$ ) could be attributed to the much larger content of Mg in oats (0.42%) than in corn (0.11%) as reported by NRC (1996). Reference values range from 1.7 to 3.0 mg dL<sup>-1</sup>, thus, animals with blood values of 1.36 mg dL<sup>-1</sup> in CD could be considered as marginal in Mg. Thus, Mg availability in CD could have diminished efficiency of energy utilization, mainly because the role of Mg as required cofactor in glycolysis regulation, which might have been an additional negative aspect contributing on overall performance for animals receiving CD.

The pre and postprandial variations in pH and NH<sub>3</sub>-N traits were affected by the time of the day. A significant linear decrease was observed for rumen pH with both diets; however, the mean values were over 6.5 along the 24 h period. Since subacute acidosis was defined for a rumen pH < 5.6 for more than 12 h (Owens et al., 1998), there was no risk of rumen acidosis. Besides, sustaining pH > 6.0 is critical for efficiency of microbial attachment and fiber digestion in the rumen (Sung et al., 2007).

Ørskov (1986) indicated that depression in fiber digestion from feeding cereal grains can be obviated by reducing the extent that cereal grains are processed. So feeding both grains in the whole form and the high amount of effective NDF from forage in the diet would contribute to a ruminal pH sufficiently high to maintain fiber digestion and avoid acidosis.

The ruminal NH<sub>3</sub>-N concentration followed a typical pattern with a quadratic response to time; it was highest 2 h after the meal, then gradually decreased to reach a minimum between 12 and 14 h later, after, which it rose up again to their pre-feeding level for both diets. This is a typical pattern for ruminal NH<sub>3</sub>-N rumen pool. It fits the model which usually peaks after feeding followed by a decrease in NH<sub>3</sub>-N and pH, increase in ruminal VFA and CO<sub>2</sub> associated with starch fermentation, accompanied by a decrease in NH<sub>3</sub> absorption and a later increase in urea transfer across the ruminal wall (Rémond et al., 2002; Abdoun et al., 2006). The consistently lower NH<sub>3</sub>-N concentration 2 h after feeding can be linked to the negative DIP balance for CD. A universal constant of 5 mg dL<sup>-1</sup> for NH<sub>3</sub>-N (Satter and Slyter, 1974) determined *in vitro* is widely accepted as the minimum concentration at which maximum microbial growth and activity would take place. However optimal concentrations of 17 to 25 mg dL<sup>-1</sup> for several *in vivo* and *in situ* studies were suggested as reviewed by Kertz (2010). The average NH<sub>3</sub>-N was over 5 mg dL<sup>-1</sup> most of time for both diets with OD much closer to the highest suggested levels.

Degradability constants *a*, *b*, and *c* could be considered typical for oats and corn grains, showing a rapid faster rumen availability from the oats in OD compared to corn grain in CD. The DM degradation pattern for corn closely resembles starch rumen degradation. A study

from Philippeau et al. (1999) showed that corn DM degradation parameters and effective degradability were linked to starch degradation, with 98% of the variation in the extent of starch degradability accounting for that of DM degradability. Less data are available for oats grain. Oats rumen degradability was reported to be 87% and 98% for DM and starch respectively (Herrera-Saldana et al., 1990). Because of the greater fiber content in oats than corn grain, degradation patterns might be expected to be different between starch and non starch components. This is illustrated by the differences observed among degradation parameters. However, DMED of both grains remain statistically unchanged. Large differences could exist in the proportion of nutritional fractions of oats grain (Martínez et al., 2010) that may affect their relative ruminal availability.

### Ultrasound measurements

Live ultrasound is an adequate option to predict carcass composition before slaughtering (May et al., 2000). The differences found in ultrasound measurements for the rate of growth in RA and BF between CD and OD are remarkable. While BF is an important commercial trait, the RA is mostly healthy lean beef. Published data contrasting carcass characteristics between oats and corn based rations was not found. Oats grain supplementation on pasture increased RA in a recent study (Ferradás et al., 2012). Processing of oats (whole vs. ground grain) failed to change RA, or dressing percentage, or animal performance (Rojas et al., 2011). The DIP balance and energy availability should have favored a greater microbial protein synthesis in the rumen for OD, thus the microbial protein outflux should promote a larger amino acid availability at the duodenum. This may explain to some extent the differences in fat and protein deposition between both diets.

### CONCLUSIONS

Our results indicate that total mixed rations based on either corn or oats fed up to 55% of total DM to growing animals do not change blood profile or modify rumen environment. Moreover, compared with whole corn, whole oats increased rate of protein deposition as measured by ultrasound RA with no negative impact on animal performance. Under the conditions of our experiment whole oats appeared to substitute equally for whole corn. As additional implications, these results may be useful for small producers that harvest their own grain, particularly in areas where corn production is limited by environmental conditions. Other considerations such as higher cost of corn than oats, regional availability and transportation add to the potential benefits of feeding oats as a substitute for corn on animal performance and beef quality, which deserves further research. Tabular nutritional values of oats and corn are useful practical

guide in many situations. However, animal performance cannot always be satisfactorily predicted from these values. When whole grains are supplied with an inclusion level of 50% to 60% of total diet for both grains, then animal performance seems to get closer than expected.

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