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Ruminants

Performance and carcass characteristics of lambs fed a solution of cheese whey during feedlot and pre-slaughter lairage

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ABSTRACT - The objective of this study was to evaluate performance and carcass and meat characteristics of lambs fed a solution of cheese whey plus water (100 g kg^{-1} dry matter) (CW) during feedlot and pre-slaughter lairage. Data were analyzed as a 2 × 2 factorial (place – feedlot and slaughterhouse, food – water or CW). We evaluated the following treatments (feedlot/slaughterhouse): CW/CW, CW/water, water/CW, and control (water/water). The lambs were given a balanced diet for 70 days in the feedlot. Slaughter started 12 h after the animals arrived at the slaughterhouse. Dry matter intake, gain-to-feed ratio, average daily gain, and body weight of lambs fed CW were similar to those of control lambs. The water/CW group consumed less of this solution than the CW/CW group in the slaughterhouse. The CW supplied as a pre-slaughter supplement reduces the drip losses of lamb carcasses provided that the animals also consume it during the feedlot period. The other carcass characteristics (carcass weight, pH, subcutaneous fat thickness, and ribeye area) were similar among treatments. The meat characteristics (color, water holding capacity, cooking losses, and shear force) were similar among treatments. Whey cheese added to water can be used as an ingredient of the diet for lambs and as pre-slaughter supplement, since it does not change performance and improves carcass characteristics.

Key Words: carcass quality, meat characteristics, sheep, slaughterhouse, welfare

Introduction

Cheese production in Brazil was 1.03 million tons in 2013 (ABIQ, 2014) and the estimated production of whey was 9.27 million tons. Some characteristics of whey are its polluting potential and its biochemical oxygen demand (BOD) of around 30 to 45 g L^{-1} (Mizubuti, 1994). Generation of biogas, ethanol, and other salable products have made it possible to reduce BOD by 75%; thus, half of the milk produced is not a pollutant, but rather a resource (Siso, 1996). However, in Brazil, 50% of the whey is not used (Siqueira et al., 2013), becoming a pollutant to rivers and streams.

Whey is composed of 550 g kg^{-1} of milk nutrients (Almeida et al., 2001) and has a digestible energy content of 15.9 MJ kg^{-1} (Brooks and McGill, 1995); therefore, it may be an alternative to animal feed. Researchers commonly recommend quantities of whey equal to or above 100 g kg^{-1} dry matter (DM) of the diet for satisfactory weight gain (Fontes et al., 2006; Costa et al., 2010). No studies were found in the literature in which whey was supplied in solution with water, which may produce different results. In addition to feedlot, the short-term effects of feeding whey pre-slaughter can cause changes in both responses to stress and muscle metabolism and may result in undesirable effects on animal carcasses and meat. Some supplements have been developed and investigated for their effectiveness in lessening the impacts of pre-slaughter stressors (Ferguson and Warner, 2008). Providing easily assimilated feed to animals can be an alternative to improve meat quality. A higher circulating energy concentration may spare part of the glycogen in a moment of pre-slaughter stress (Lawrie, 2005).

In view of the above, the objective of this study was to evaluate performance and carcass and meat characteristics of lambs fed a solution of cheese whey and water during feedlot and pre-slaughter lairage.

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Material and Methods

The procedures performed in this experiment were approved by the local Ethics Committee for Animal Experimentation under registration CETEA 185/2011.

The experiment was conducted in Igarapé - MG, Brazil (20º 04' 13" S, 44º 18' 06" W, and 786 m). This experiment used 24 intact male 1/2 Dorper × Santa Inês lambs, with an initial body weight and standard error of 25.91±0.60 kg and an average age of 90 days. In the feedlot, lambs were randomly assigned to two groups: animals that received solution of cheese whey and water (100 g kg^{-1} of dry matter) (CW) (n = 12) and animals that did not receive CW (n = 12). At the slaughterhouse, lambs were divided into animals receiving CW or animals receiving water. Minas Frescal cheese whey was added to water at both the feedlot and the slaughterhouse. Data were analyzed as a 2 × 2 factorial (place – feedlot and slaughterhouse; food – water or CW) with six replicates. The treatments evaluated were (feedlot/slaughterhouse): CW/CW, CW/water, water/CW, and control (water/water).

To determine the proportion of CW in the diet, intake and nutrient digestibility testing was previously performed with different levels of this ingredient in solution. In this experiment, the inclusion of 100 g kg^{-1} CW was determined to produce the best results (Martins, 2013).

Lambs were given a balanced diet for 70 days in the feedlot (Tables 1 and 2). The animals were supplied with the protein and metabolizable energy requirements required for a gain of 200 g d^{-1} during the feedlot.

The period of feedlot included 14 days for adaptation of animals to the experimental diets and to the facilities. Lambs were placed in individual stalls. The animals were weighed at the beginning and end of the adaptation period and every 14 days during the experimental period, after fasting from solids for 16 h. Based on the weight of animals, the average daily gain (ADG) was estimated and at the end of the experiment, the gain-to-feed ratio (G:F) was calculated. Diets were supplied daily at 7:00 and 16:00 h in excess by 10% to ensure leftovers.

Half of the lambs received 7 kg of water each; this value was estimated so that the animals did not lack water during the day. For the other half of the animals, the desired percentage of whey was placed in a plastic bucket and water was added until a mass of 6 kg was reached. This procedure was performed at 7:00 h for each animal. Animals that consumed CW received their cheese whey percentage plus 20% extra. Water or CW was individually supplied in plastic buckets.

The feed supplied and the leftovers were weighed daily for each treatment. To determine cheese whey intake, the mixture of this ingredient and water was considered homogenous. Samples of the feed, leftovers, and ingredients were collected weekly. Determinations of the nutrients in the feed were performed according to the procedures described by Horwitz (2000). Neutral detergent fiber was determined following the recommendations of Van Soest et al. (1991). Whey analysis was performed according to the procedures described by Teixeira and Fonseca (2008).

At the end of the feedlot, lambs were transported to the slaughterhouse, where the second phase of this experiment was conducted. There were no stops during the journey and the lambs did not have access to water or feed during the transfer. The travelled distance was 160 km, 6 km of which were travelled on unpaved roads. The shipment, transport, and unloading were conducted following the recommendations of Paranhos da Costa et al. (2010, 2011).

Table 1 - Compositions of the experimental diets (g kg^{-1} of dry matter)

Item	Diet	
	Control	Cheese whey
Ingredient		
Tifton Hay 85	415.90	391.90
Corn meal	254.70	192.00
Extruded soybean	275.40	264.40
Cheese whey	-	100.00
Megalac	21.80	22.00
Urea + ammonium sulfate	3.00	3.00
Mineral salt	25.00	25.00
Dicalcium phosphate	4.20	1.70
Chemical composition		
Dry matter	741.50	684.30
Crude protein	185.00	185.00
Metabolizable energy (MJ kg^{-1})	11.46	11.46
Neutral detergent fiber	367.40	343.10
Ca	6.40	6.50
P	4.10	4.10

Table 2 - Analysis of the concentrate, Tifton 85 hay, and cheese whey (g kg^{-1} of dry matter)

Item	Control concentrate	Whey concentrate	Hay	Cheese whey
Chemical composition				
Dry matter	717.40	740.00	770.00	65.00
Crude protein	280.06	300.45	79.80	121.50
Ether extract	57.75	61.37	50.00	-
Minerals	93.94	99.86	59.60	76.90
Neutral detergent fiber	131.77	130.96	590.10	-
Fat	-	-	-	49.20
Lactose	-	-	-	490.80
Titratable acidity (ºD)	-	-	-	11.40

After unloaded, sheep were placed into four collective pens according to the previously described treatments. Each collective pen was subdivided by means of iron grids, each with plastic buckets. The methodology used to supply CW and water was the same as the feedlot.

Slaughter began 12 h after the animals arrived at the slaughterhouse. Animals were stunned with an electro narcosis system, consisting of two electrodes placed on their head, which was immediately followed by bleeding in accordance with the Brazilian Federal Meat Inspection Regulations (Brasil, 1997).

Approximately 45 min after bleeding, the pH (pHi) was measured in the loin (*LM thoracis et lumborum*), as described by Pearce et al. (2010). The forestomaches, stomachs, and intestines were weighed full; after washing, they were also weighed empty. The hot carcasses were weighed, washed, and taken to a cooling chamber with a temperature ranging from 2 to 4 ºC for 24 h. After cooling, the carcasses were weighed again and the pH was measured (pHu). In the cold carcasses, using a measuring tape, the internal length and the perimeters of the thorax and leg were measured according to Sañudo and Sierra (1986). Subcutaneous fat thickness and the ribeye area were evaluated using the United States Standards for Grades of Carcass Beef (1997), as described by Gomide et al. (2006).

A 10-cm section of deboned *longissimus* muscle was removed from the carcass after 24 h cooling. This muscle was then vacuum-packed and subjected to analysis. Meat color, water loss by cooking, water holding capacity, water activity, and shear force were assessed on this portion of the loin.

Lightness (L*), redness (a*), and yellowness (b*) values were measured according to the description of Devine et al. (2002) using the Hunter lab Miniscan, model Miniscan EZ.

To determine water loss by cooking, the meat was weighed (67.00±1.83 g) and placed on an electric grill. When the temperature at the coldest point on the steaks reached 40 ºC, they were turned over, and the other side was grilled until it reached 71 ºC. The sections of meat were then cooled to room temperature and weighed again (Ramos and Gomide, 2007).

Cylindrical samples were then taken from the meat sections that underwent cooking. The samples had a diameter of 1.27 cm and were used to perform the objective analysis of shear force, which was measured using a Warner-Bratzler device (Wheeler et al., 2001).

The part of the raw *longissimus* muscle that remained after the steaks were removed for cooking was used to evaluate the water holding capacity. These samples were centrifuged (4 min/1500 rpm) and placed in an oven (18 h/70 ºC). The water holding capacity was calculated by the difference in weight (Nakamura and Katoh, 1981). Other raw samples were used to measure water activity by means of the Aqualab® series 3TE instrument. The experiment was performed in a completely randomized design and each animal was an experimental unit. The dependent variables, dry matter intake (DMI), water intake, gain-to-feed ratio (G:F), average daily gain (ADG), and body weight (BW) were only assessed while the animals were in the feedlot (t test), $P<0.05$). The other dependent variables were assessed under the effect of feedlot and pre-slaughter (2 × 2 factorial). Data were tested by ANOVA and whenever significant, the mean values were compared by the Tukey test ($P<0.05$). Adjustment of the dependent variables was performed by analyzing the covariable "initial BW", when significant ($P<0.05$). For the variable "CW or water intakes", which was determined in the slaughterhouse, the assumption of normality for the residue and the homogeneity of variances were not accepted; therefore, a Kruskal-Wallis test was performed ($P<0.05$).

The mathematical model used was:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \alpha_i\beta_j + e_{ijk},$$

in which y_{ijk} = observed value of the variable that received whey in feedlot i, that received whey in slaughterhouse j, and repetition k; μ = overall mean; α_i = feedlot – control diet or diet with CW; β_j = slaughterhouse – water or CW; $\alpha_i\beta_j$ = effect of interaction; and e_{ijk} = random error associated with each observation.

Results

The values of DMI, G:F, ADG, and BW of lambs were similar between the animals receiving CW and the control animals. The lambs receiving CW ingested less water during the feedlot (Table 3). At the slaughterhouse, water/CW animals ingested less CW (Table 4).

Table 3 - Performance of lambs finished on diets with or without cheese whey

Item	Treatment[1]		SEM	P-value
	Control	Cheese whey		
Dry matter intake (kg day^{-1})	0.78	0.83	0.04	0.305
Water intake[2] (kg day^{-1})	3.35	2.29	0.12	<0.001
Gain-to-feed ratio (weight weight^{-1})	0.29	0.29	0.14	0.810
Average daily gain (g day^{-1})	227.90	250.80	11.45	0.156

SEM - standard error of the mean.
[1] Control: no cheese whey; cheese whey: 100 g kg^{-1} of dry matter.
[2] Water of the feed not taken in consideration.

The initial and ultimate pH and the hot and cold carcass weights were similar among treatments (Table 5). Carcass measurements were similar among treatments. Lambs presented similar values for subcutaneous fat thickness, body length, perimeters of the thorax and leg, and ribeye area. The weights of the forestomaches, stomachs, and intestines of lambs were similar among treatments.

Lambs in treatment CW/CW showed lower drip loss. Animals in water/CW treatment showed higher drip loss.

Table 4 - Intake of cheese whey and water or water and intake of cheese whey in the slaughterhouse

Treatment[1]	CW or water (kg lamb^{-1})	25th and 75th percentiles	Cheese whey (g DM lamb^{-1})	25th and 75th percentiles
CW/CW	1.34b	0.49-2.04	21.39	7.82-32.57
CW/water	1.30b	0.55-1.92	-	-
Water/CW	0.42a	0.29-0.55	6.70	4.63-8.78
Control	1.16b	0.41-1.92	-	-

CW: solution of cheese whey and water.
DM - dry matter.
[1] Treatments (feedlot/slaughterhouse): CW/CW, CW/water, water/CW, and control (water/water).
Medians within a column with different letters differ by the Kruskal-Wallis test (P<0.05).

Meat color (Hunter L*, a*, and b*), water holding capacity, water activity, water loss by cooking, and shear strength were similar among treatments (Table 6).

Discussion

The DMI of growing lambs in this experiment was close to values recommended by the NRC (2007). Because the nutrient intake was satisfactory, the other performance-related variables were similar. According to King and Schingoethe (1983) and David et al. (2010), cattle have the ability to consume large amounts of cheese whey without having their weight gain rates reduced. Costa et al. (2010) recommended proportions larger than those of the present trial (up to 450.00 g kg^{-1} of dry matter) for goats without changes in G:F.

No reports of low acceptability of liquid cheese whey have been found in the scientific literature. Lana (2005) drew attention to the problems caused by water shortage, including performance loss. However, in the present study,

Table 5 - Carcass characteristics of lambs fed a solution of cheese whey during feedlot and pre-slaughter lairage

Item	Feedlot (F)		Pre-slaughter (PS)		SEM	P-value		
	CW	Control	CW	Water		F	PS	F × PS
Initial pH	6.75	6.73	6.66	6.83	0.07	0.730	0.088	0.861
Hot carcass weight (kg)	17.35	16.84	16.92	17.27	0.84	0.380	0.987	0.784
Ultimate pH	5.95	5.95	5.90	6.00	0.08	0.549	0.092	0.552
Cold carcass weight (kg)	16.85	16.19	16.36	16.68	0.77	0.268	0.981	1.007
Drip loss[1] (g/100 g)	2.21a	3.59b	4.72c	3.20b	0.50	0.060	0.910	0.014
Subcutaneous fat thickness (mm)	2.23	1.96	2.02	2.17	0.28	0.233	0.727	0.944
Total length (cm)	55.50	55.33	55.20	55.63	1.07	0.665	0.930	0.934
Perimeter of thorax (cm)	78.33	78.74	78.76	78.31	1.41	0.739	0.745	0.844
Perimeter of leg (cm)	47.50	44.00	44.90	46.60	1.69	0.067	0.355	0.355
Ribeye area (cm^2/kg of BW)	0.31	0.32	0.30	0.33	0.03	0.842	0.166	0.836
Full stomach (kg)	6.19	6.15	6.22	6.12	0.45	0.931	0.829	0.994
Empty stomach (kg)	1.28	1.26	1.24	1.30	0.06	0.832	0.330	0.564
Full intestines (kg)	2.78	2.61	2.73	2.66	0.13	0.142	0.433	0.290
Empty intestines (kg)	1.33	1.36	1.35	1.33	0.05	0.724	0.794	0.298

CW: solution of cheese whey and water; Control: no cheese whey.
BW - body weight; SEM - standard error of the mean.
[1] Treatments (feedlot/slaughterhouse): CW/CW, CW/water, water/CW, and control (water/water), respectively.
Means in the same row with different letters differ by Tukey test (P<0.05).

Table 6 - Meat characteristics of lambs fed a solution of cheese whey during feedlot and pre-slaughter lairage

Item	Feedlot (F)		Pre-slaughter (PS)		SEM	P-value		
	CW	Control	CW	Water		F	PS	F × PS
Hunter L*	35.06	35.02	36.16	33.92	1.45	0.981	0.156	0.977
Hunter a*	11.43	11.63	11.31	11.74	0.35	0.595	0.260	0.575
Hunter b*	11.75	12.20	12.33	11.62	0.66	0.522	0.319	0.556
WHC (g/100 g)	63.4	62.60	61.19	64.84	1.84	0.190	0.705	0.316
WA[1]	0.99	0.99	0.98	0.99	0.00	0.969	0.358	0.048
CL (g/100 g)	46.45	45.23	45.95	45.73	3.35	0.736	0.955	0.363
SF (kg)	2.98	2.33	2.56	2.75	0.37	0.243	0.723	0.947

CW: solution of cheese whey and water; Control: no cheese whey.
WHC - water holding capacity; WA - water activity; CL - cooking losses; SF - shear force; SEM - standard error of the mean.
[1] Treatments (feedlot/slaughterhouse): CW/CW, CW/water, water/CW, and control (water/water), respectively.
Means in the same row with different letters differ by Tukey test (P<0.05).

despite the lower amount of water consumed by the lambs fed CW, their DMI and ADG were not affected.

In the slaughterhouse, for water/CW treatment, the environment was possibly less familiar when the CW was supplied because the animals did not know this solution. As stated by Broom (1986), the welfare of an individual is its state concerning the attempts made to deal with the environment.

Despite the CW intake, the pH of the carcasses was similar. Ferguson and Warner (2008) stressed that a larger number of variables are necessary to evaluate meat quality, because some changes may occur irrespective of the pH. Ferguson and Warner (2008) asserted that magnesium intake may decrease drip losses. Schingoethe et al. (1980) reported greater magnesium absorption by steers fed cheese whey.

The similarity between most carcass traits herein was due to the similarity among treatments for DMI and performance in the feedlot, as also reported in an analogous situation by Beserra et al. (2003), Lima et al. (2013), and Van Cleef et al. (2014). As the loin eye area and fat thickness were similar among treatments, it is suggested that the carcass edible portion and the physiological age of the animals were also similar (Luchiari Filho, 2000). Lima et al. (2012), evaluating the performance of calves fed whey in association with colostrum, also found no changes in body measurements.

Feed restriction was adopted to avoid risk of carcass contamination during slaughter (Fisher et al., 2011), since larger gastrointestinal volumes may facilitate its rupture during evisceration. Nevertheless, in this experiment, evaluating the weight of the stomachs and intestines, there were no problems in emptying the gastrointestinal tract.

The pH of a meat is important because it affects many quality factors, including color, texture, and flavor (Lawrie, 2005). Possibly because there were no changes in pH in this experiment, the variables related to color, texture, water holding capacity, water activity, and cooking losses did not change. Warner et al. (2007) reported lower water holding capacity in meat after subjecting cattle to pre-slaughter stress.

Meat color values were within the range determined by Sañudo et al. (2000) for sheep. The mean values for shear force in all treatments were below those considered by Souza et al. (2004) as the upper limit for considering the meat as tender.

Conclusions

Whey cheese added to water can be used as an ingredient in the diet for lambs and as pre-slaughter supplement since it does not change performance and improves carcass characteristics.

Acknowledgments

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