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Meat quality of Santa Inês sheep fed forage palm (*Opuntia ficus-indica*, Mill) and water restriction

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Abstract

The aim of this study was to evaluate the physicochemical composition, fatty acids, and sensory properties of meat from Santa Inês sheep fed forage palm in the diet and with water restriction. They used 42 non-castrated male Santa Inês lambs, with about 180 days of age and an average weight of 21.6 ± 2.2 kg, distributed in a completely randomized design with seven treatments and six repetitions, and the data were submitted to regression analysis, factorial (level × water), and contrast between the control treatment and others. The treatments consisted of the inclusion of spineless cactus (0, 30, 50, and 70%). In treatments containing cactus pear (36 animals), half of the animals were placed under voluntary water consumption restriction. According to the physicochemical characteristics analyzed, lipids suffered an increasing linear effect (p<0.05) as they included spineless cactus in the diet of sheep. The control diet had the lowest percentage of lipids (2.44%). The inclusion of 50% cactus pear promoted a higher content of lipids (3.41), and restricting water intake resulted in higher lipid content (3.09). The inclusion of cactus pear and water restriction did not affect the profile of fatty acids in meat. In the studied sensory attributes (hardness, juiciness, flavor, color, aroma, and overall acceptability), only meat color suffered an increasing linear effect ($p < 0.05$). With the inclusion of spineless cactus in the diet, the meat from the lambs received good grades from the panelists, showing good acceptability. This demonstrates that the cactus pear provides sufficient water and nutrients for animals, resulting in the deposition of intramuscular fat, thus becoming a good-quality meat.

Keywords: cactus; color; lipids; water restriction; sensory.

Practical Application: The use of spineless cactus in animal feed does not alter the quality of the meat and meets the animal's water needs with up to 70% inclusion.

1 INTRODUCTION

Semi-arid regions have a limiting factor, which is the lack of water for animal production. In some areas, water scarcity is common, especially during the dry seasons, when animals have less access to water sources (Cordova-Torres et al., 2022). One alternative to get around this problem and reduce the cost of lamb production systems in the semi-arid region is to include raw materials adapted to the production region in the diets, reducing the cost of feeding the lambs and providing the animals with water.

The animals can obtain water through feed, especially feed with high water content, including succulent plants such as spineless cactus (Araújo et al., 2010). The spineless cactus contains 7–16% dry matter (DM, as fresh matter), and as DM-basis, the cacti contain 4–7% crude protein (CP), 2–3% ether extract (EE), and 15–25% minerals, depending on the species and the variety, but a small amount (neutral detergent fiber-25% and acid detergent fiber (ADF)-15%) of fibrous content (Abidi et al., 2009; Tosto et al., 2015). The digestibility of the dry matter of spineless cactus varies from 60 to 75% because of the abundance of non-structural carbohydrates and total digestible nutrients.

Previous studies that investigated water intake by animals fed a diet supplemented with spineless cactus have reported a reduction in voluntary water intake (Bispo et al., 2007; Cordova-Torres et al., 2022).

In addition, the inclusion of spineless cactus in the finishing diets for sheep affected the fatty acid (FA) profile, decreasing the saturated FA content and improving the monounsaturated and

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polyunsaturated FA amounts (Costa et al., 2017). However, data about the influence of including spineless cactus in the finishing diets of lambs on meat quality are scarce (Abreu et al., 2018; Costa et al., 2012; Lima et al., 2019). The aim of this study was to evaluate the physicochemical composition, fatty acids, and sensory properties of meat from Santa Inês sheep fed forage palm in the diet and with water restriction.

2 MATERIALS AND METHODS

2.1 Experiment site

The experiment was conducted at the Goat and Sheep Production Sector of the Universidade Federal da Paraíba (UFPB), located in Bananeiras, Paraíba State, Brazil, microregion of Brejo Paraibano, 6°45′00″ S latitude and 35°38′00″ W longitude, at an altitude of 520 m above sea level. This study was approved by the Animal Ethics Committee of the UFPB, Brazil (protocol no. 2,305/14).

2.2 Animal and diet

We used 40 male uncastrated Santa Inês lambs, around 180 days old, with an average initial body weight of 21.6 ± 2.2 kg. The animals were randomly allocated to collective stalls (two animals per stall) (3.0 m^2) with slatted and suspended floors and free access to feeders and drinkers, where they were kept in confinement until they reached an average weight of 32 kg. At the start of the experiment, the animals were weighed, wormed, and, after this process, identified and separated by similar weights for each stall. The adaptation period lasted 14 days, and the animals were weighed weekly until the end of the study.

The feedstuffs used were Tifton hay (*Cynodon* sp.), soybean meal, corn meal, mineral supplements, and spineless cactus. The diets were formulated to meet the requirements of sheep for a gain of 250 g/day (NRC, 2007) (Table 1). The treatments consisted of the inclusion of spineless cactus (*Opuntia fícus-indica* Mill) at increasing levels (0% (control), 30% with water, 30% without water, 50% with water, 50% without water, 70% with water, and 70% without water), six animals per treatment. In the treatments containing spineless cactus (36 animals), half of the animals were induced to restrict their voluntary water consumption. The experimental rations were offered twice a day (morning and afternoon) in the form of a complete mixture to induce the greatest consumption by the animals, and the total dry matter consumption was determined by the daily control of the food provided and that rejected, in order to provide daily leftovers of approximately 20%.

When the lambs reached a live weight of approximately 32 kg, they underwent a period of solid fasting and a 16-h water diet. The slaughter method adopted was stunning in the atlanto-occipital region, followed by bleeding, skinning, and evisceration.

2.3 Physicochemical analysis of meat

Cooking losses were evaluated according to the methodology described by Wheeler et al. (1993). Briefly, one steak of 2.5 cm thickness was obtained from the *Longissimus dorsi* muscle, with the cut being performed transversely in the direction of the muscle fibers. The steaks were individually wrapped in aluminum foil and cooked in a convection oven (FISCHER, Star model) at 150 °C until the internal temperature of 71 °C was monitored by K-type thermocouples (Comark, PK23M, Vienna Court, UK) (inserted in the geometric center of the sample). Then, the samples were cooled at room temperature until reaching the internal temperature of 24°C with an insertion thermometer (TESTO, model 106, Melrose, MA, USA). The initial and final weight (SHIMADZU, model TX3202L, Kyoto, Japan) of each steak was recorded and used to calculate the cooking loss.

The water retention capacity was measured by pressure using a 2.0 g sample of muscle. A sheet of Whatman No. 1 filter paper with an area of 10×10 cm^2 was placed on an acrylic plate,

Table 1. Percentage composition of ingredients in diets (% DM) and in feed according to forage palm levels.

Ingredients (g kg^{-1})	Inclusion levels (%)			
	0	30	50	70
Spineless cactus	0.0	300.0	500.0	700.0
Ground corn	275.0	153.0	148.0	85.0
Soybean meal	95.0	115.0	125.0	143
Tifton hay	600.0	400.0	200.0	50.0
Mineral supplement[1]	20.0	17.0	17.0	17.0
Vegetable oil	10.0	15.0	10.0	5.0
Chemical composition				
Dry matter, DM (g kg^{-1} as fed)	949.8	244.1	163.4	122.7
Crude protein, CP (g kg^{-1} DM)	118.6	117.1	116.2	116.7
Ethereal extract, EE (g kg^{-1} DM)	49.6	37.7	40.1	34.47
Neutral detergent fiber, NDF (g kg^{-1} DM)	685.4	547.8	446.7	350.8
Fiber in acid detergent, FAD (g kg^{-1} DM)	305.6	268.4	221.9	191.5
Total carbohydrates, TC (g kg^{-1} DM)	797.7	804.5	803.1	808.5
Nonfibrous carbohydrates, NFC (g kg^{-1} DM)	118.0	265.3	362.1	460.5
Metabolizable energy, ME (Mcal kg^{-1} DM)	2.39	2.38	2.44	2.45

[1]Mineral supplement: Ca-140 g; P-65 g; S-15 g; Mg-15 g; Zn-3.500 mg; Mn-3.000; I-60 mg; Se-10 mg; Co-100 mg; Vit A-50.000 UI/kg; Fluor (máx)-650 mg.

and another filter paper with the same area and another acrylic plate was placed on top of the sample; a 10 kg weight was placed on this set for 5 min, and after this time had elapsed, the sample was weighed again. The loss of water by pressure was given as a percentage of the initial weight (Sierra, 1973).

A sample of 100 g obtained from the right *Longissimus dorsi* of each animal was trimmed for connective tissue and external fat and then ground (in a domestic blender) prior to chemical composition assays. The moisture, ash, lipids, and protein contents were determined according to Association of Official Analytical Chemists (AOAC) methods (AOAC, 2005).

2.4 Fatty acids

The fatty acids present in the lipid extract were characterized using the method of Folch et al. (1957), following the methodology described by Hartman and Lago (1973). The fatty acid esters were identified and quantified using a gas chromatograph (VARIAN 430-GC, California, USA), coupled with a flame ionization detector and a fused silica capillary column (CP WAX 52 CB, VARIAN). Helium was used as the carrier gas (flow rate: 1 mL/min). The initial temperature of the oven was 100°C, and it was programmed to reach 240°C, increasing by 2.5°C per minute for 20 min. The injector and detector temperatures were maintained at 250 and 260°C, respectively. The chromatograms were recorded using the Galaxie Chromatography Data System software. The fatty acids were identified by comparing the retention times of the methyl esters in the samples with Supelco ME19-Kit standards (Fatty Acid Methyl Esters C6-C22). The fatty acid results were quantified by normalizing the areas of the methyl esters and expressed as a percentage of the area.

2.5 Sensory analysis

A descriptive sensory analysis was performed at the Laboratory of Product Performance and Sensory Analysis at the UFPB. The *Longissimus dorsi* muscle was wrapped in aluminum foil and cooked on a single plate grill at a controlled temperature of 180°C until the internal temperature reached 70°C. There was no addition of salt or seasonings. After cooking, the subcutaneous fat and external connective tissue were removed, and the muscle was cut into ten 2 cm^3 portions, which were individually wrapped in foil and marked with a random three-digit code. The samples were kept warm in a heater at 55°C until the time of testing (30 min).

To avoid the possible effects of the order of presentation, the samples were presented to panel members in different orders (Macfie et al., 1989). Sensory analysis was performed in individual booths that had controlled environmental conditions at a temperature of around 23°C (ISO, 1998). For this study, a trained sensory panel composed of eight UFPB agricultural science students was used. The selection of panelists started by recruiting habitual consumers of lamb meat who had an interest in participating in the study and were available to participate in the selection, training, and test sessions. After the first screening, the selection was carried out following the recommendations of ISO 8586:2012 through a discrimination test using samples similar to those used in further stages of sensory evaluation.

Assessors were trained (ISO, 2012) in sensory profiling of lamb meat during 10 training sessions where they developed a common vocabulary to evaluate sensory characteristics of lamb meat and agreed upon a list of descriptors and their definitions. The sensor analysis was conducted using an incomplete block design that included 20 dishes containing 2 samples each. The tests took place in four sessions, with five courses per session. Thus, the sensorial analysis included the meat of 40 animals (8 in each treatment), totaling 320 samples. The analysis was based on four sensorial descriptors, using a semistructured and continuous nine-point scale anchored at extremities with terms that express the intensity.

Regarding the reproducibility and performance of the selected panel, the identification of variations within and among panelists was assessed by an analysis of variance (ANOVA) following the approach described by Tomic et al. (2007). The reproducibility and performance of panelists were examined by ANOVA with one factor using Fisher's test (F) as the discriminant power index. The F-values obtained for all panelists in all sensory descriptors displayed values (between 0.02 and 2.98) below the F-value index (5.20) due to the similarity of tested samples. Panel performance was assessed using ANOVA with three factors (diet, panelists, and session) and the Equation 1:

$$Y_{iks} = \mu + \alpha_i + \beta_k + \gamma_s + \alpha\beta_{ik} + \beta\gamma_{ks} + \alpha\gamma_{is} + e_{iks} \quad (1)$$

Where:

Yiks: the result of the panelist i for the session s in the diet k;

μ: the overall mean;

αi: the diet effect;

βk: the panelist effect;

γs: the session effect;

αβik: the diet interaction per panelist;

βγks: the panelists interaction per session;

αγis: the diet interaction per session;

eijk (≈ N (0, σ2)): the error of the model.

No significant differences were obtained for the main factors or interactions of the model (Nobre et al., 2020).

2.6 Statistical analysis

The physical–chemical, fatty acid, and sensory data were subjected to ANOVA. The averages of the physical–chemical variables and fatty acids were compared by regression analysis using PROC REG of SAS (SAS Institute, 2001), as a function of the increasing levels of spineless cactus in the diets, and factorial analysis to evaluate the effect of water restriction as a function of the levels of spineless cactus using PROC GLM of SAS (SAS Institute, 2001) using the Tukey's test at the 5% probability level.

For the sensory analysis, the mathematical model was Equation 2:

$$yijk = \mu + Ti + eijk \quad (2)$$

where:

yijk: the dependent variable;

μ: the mean;

Ti: the fixed effect of the treatment with i levels from 1 to 5;

eijk: the error.

In this model, diet composition and panelist were included as fixed effects, whereas sessions were included as random effects. The mean values obtained from the sensorial analysis were compared by the Ryan-Einot-Gabriel-Welsch test at 5% probability.

3 RESULTS

The moisture, ash, and protein contents were similar ($p > 0.05$) for both spineless cactus inclusion and water restriction (Table 2). There was an increasing linear effect for lipid content ($p < 0.05$) as forage spineless cactus was included in the sheep's diet, while water restriction influenced lipid content ($p < 0.05$), promoting an increase in the percentage of lipids in sheep meat. The physical parameters of water retention capacity and weight loss due to cooking were similar for both spineless cactus inclusion and water restriction ($p > 0.05$) (Table 2).

The fatty acid c ontents were similar between the diets and for water restriction ($p > 0.05$), except for the monounsaturated acids palmitoleic (C16:1n7) and heptadecanoic (C17:1n7), in which there was a significant interaction between spineless cactus levels and water restriction ($p < 0.05$) (Table 3). It can therefore be seen that, with the inclusion of spineless cactus, the polyunsaturated fatty acids–saturated fatty acid (PUFA–SFA) ratio was higher (Table 3), probably due to the characteristic of spineless cactus having a higher rate of passage, with the food remaining in the rumen for less time, enabling a lower conversion of polyunsaturates into saturates and consequently a better ratio between them.

With regard to the sensory properties of sheep meat (Table 4), the inclusion of spineless cactus in the lambs' diet had no influence ($p > 0.05$) on the parameters of hardness, juiciness, flavor, aroma, and overall acceptability. This, therefore, reflects the consistency with the chemical and physical values of the meat, which were also not influenced, with the exception of lipids. The color of meat is an important sensory attribute in its processing and marketing, as it is one of the first characteristics observed by consumers. In the present study, as spineless cactus was included in the sheep's diet, the intensity of the meat color assessed by the tasters increased ($p < 0.05$). Water restriction did not influence the sensory characteristics of the meat of sheep ($p > 0.05$) fed spineless cactus, but the animals with restricted voluntary water consumption obtained better scores than the animals with voluntary water supply (Table 4). This shows the importance of spineless cactus both as a source of water and nutrients and as an alternative feed in times of food and water scarcity, especially in semi-arid regions.

4 DISCUSSION

Lima et al. (2019) evaluated the meat of sheep with no defined breed pattern receiving spineless cactus in the diet at increasing levels (0, 150, 300, and 450 g kg^{-1} DM) and observed that humidity increased but protein decreased from the 150 g kg^{-1} level and cooking losses increased. Beriain et al. (2000) stated that diets with a higher energy intake lead to a higher concentration of intramuscular fat (IMF). Therefore, the increase in the amount of lipids in the meat as the spineless cactus was included in the diet may have been due to the increased consumption of nonfibrous carbohydrates present in the spineless cactus, since according to Van Soest (1994), nonfibrous carbohydrates are an important source of energy for ruminants.

However, Madruga et al. (2005), evaluating the qualitative aspects of the meat of Santa Inês sheep fed four different diets, found a reduction in lipids in the meat of animals fed spineless cactus. It is worth noting that these animals had a much lower slaughter weight (16.7 kg) than the other treatments (29.3 kg), which may influence the amount of IMF (Abdullah & Qudsieh, 2008, Martínez-Cerezo et al., 2005). The results of this study on lipids suggest that the meat from animals fed spineless cactus had better marbling (Sañudo et al., 1999), which is an important aspect of meat quality, especially when it comes to consumers' purchasing decisions.

Current results showed that cooking losses were not influenced by the inclusion of spineless cactus in the finishing diet

Table 2. Physicochemical characteristics of meat from Santa Inês sheep fed palm and water restriction.

Variable	Inclusion level—C (%)				Water—W		SEM	*p*-value			
	0	30	50	70	With	Without		Water	C*W	Linear	Quadratic
Humidity (%)	74.45	74.75	73.96	74.57	74.45	74.40	0.93	0.814	0.155	0.596	0.622
Ash (%)	1.00	1.01	1.00	1.01	1.02	0.99	0.04	0.012	0.276	0.736	0.941
Protein (%)	22.33	22.59	22.33	22.89	22.82	22.35	1.62	0.193	0.000	0.426	0.658
Lipids (%)	2.44	2.60	3.41	2.93	3.09	2.76	0.56	0.044	0.037	0.004[1]	0.117
Water retention capacity	37.14	38.52	37.67	37.40	37.39	38.06	4.47	0.701	0.666	0.944	0.650
Cooking losses (%)	55.99	57.96	56.93	56.31	56.49	57.09	3.27	0.732	0.565	0.992	0.444

SEM = standard error of the mean; [1] $Y = 2.4879 + 0.0097x$ ($R^2 = 0.98$).

Table 3. Fatty acid averages of Santa Inês sheep fed palm and water restriction.

Variable	Inclusion level—C (%)				Water—W		SEM	*p*-value			
	0	30	50	70	With	Without		Water	C*W	Linear	Quadratic
AGS	47.44	65.05	63.79	59.35	64.85	58.83	19.09	0.470	0.690	0.762	0.256
C10:0	0.12	0.34	0.17	0.18	0.27	0.19	0.24	0.506	0.281	0.621	0.374
C11:0	0.00	0.08	0.02	0.09	0.07	0.01	0.12	0.325	0.225	0.584	0.417
C12:0	0.24	0.49	0.31	0.28	0.37	0.34	0.02	0.814	0.110	0.516	0.238
C14:0	1.79	3.01	2.89	2.47	2.82	2.60	1.03	0.624	0.485	0.886	0.106
C15:0	0.26	0.46	0.31	0.45	0.37	0.41	0.16	0.583	0.141	0.419	0.795
C16:0	22.74	33.20	34.05	30.68	33.22	30.61	9.91	0.550	0.491	0.593	0.173
C17:0	0.96	1.54	1.43	1.78	1.70	1.42	0.82	0.239	0.816	0.091	0.793
C18:0	19.53	23.05	21.94	19.88	23.26	20.15	7.01	0.308	0.911	0.722	0.406
C19:0	0.00	0.40	0.32	0.86	0.36	0.58	0.80	0.561	0.428	0.176	0.762
C20:0*	0.00	0.12	0.11	0.13	0.08	0.13	0.07	0.069	0.350	0.073	0.225
C21:0	1.79	2.28	2.16	2.41	2.30	2.20	0.78	0.792	0.128	0.432	0.813
C23:0	0.00	0.04	0.03	0.04	0.02	0.04	0.08	0.459	0.353	0.621	0.836
C24:0	0.00	0.05	0.03	0.16	0.02	0.12	0.21	0.305	0.359	0.283	0.637
AGMI	47.19	29.46	26.79	28.90	28.26	31.48	18.49	0.697	0.330	0.350	0.325
C14:1n5c	0.00	0.02	0.01	0.01	0.01	0.01	0.02	0.785	0.191	0.772	0.536
C16:1n7c	1.47	1.93	2.24	1.70	1.90	1.90	0.65	0.981	0.041	0.878	0.124
C17:1n7c	0.53	0.49	0.22	0.37	0.38	0.38	0.33	0.965	0.025	0.363	0.629
C18:1n9c	42.79	25.04	22.58	23.50	24.07	26.47	18.08	0.768	0.312	0.298	0.352
C18:1n9t	2.33	1.58	1.47	1.56	1.63	1.60	1.04	0.950	0.824	0.484	0.469
C18:1n11c	0.07	0.38	0.23	1.75	0.25	1.09	2.37	0.427	0.481	0.293	0.542
C20:1n9c	0.00	0.01	0.03	0.01	0.02	0.01	0.03	0.747	0.087	0.597	0.496
AGPI	5.37	5.49	9.42	11.74	6.88	9.69	7.08	0.394	0.156	0.110	0.634
C18:2n6c	4.31	4.50	8.74	10.78	6.17	8.66	6.95	0.443	0.179	0.099	0.662
C18:2n6t	0.00	0.02	0.05	0.03	0.04	0.03	0.04	0.719	0.182	0.238	0.431
C18:3n6	0.00	0.06	0.06	0.03	0.05	0.04	0.05	0.873	0.560	0.985	0.110
C18:3n3	0.56	0.30	0.18	0.40	0.16	0.44	0.60	0.297	0.695	0.881	0.442
C20:2n6c	0.50	0.51	0.32	0.35	0.42	0.39	0.19	0.705	0.114	0.108	0.962
C20:3n6c	0.00	0.06	0.06	0.14	0.04	0.11	0.16	0.327	0.155	0.272	0.838
C20:4n6c	0.00	0.03	0.01	0.01	0.00	0.02	0.03	0.266	0.213	0.658	0.385
TAGPI	52.56	34.95	36.20	40.64	35.14	41.17	19.00	0.470	0.690	0.762	0.256
w6	4.81	5.19	9.24	11.34	6.72	9.25	6.83	0.428	0.161	0.096	0.670
w3	0.56	0.30	0.18	0.40	0.16	0.44	0.60	0.297	0.695	0.881	0.442
AGMI/AGS	1.00	0.57	0.57	0.59	0.55	0.66	0.44	0.593	0.481	0.443	0.355
AGPI/AGS	0.11	0.09	0.18	0.23	0.11	0.20	0.16	0.237	0.329	0.152	0.565
TAGPI/AGS	1.11	0.66	0.75	0.82	0.66	0.86	0.53	0.399	0.821	0.847	0.336
n6/n3	8.94	8.34	18.14	10.95	9.38	10.70	4.01	0.719	0.057	0.357	0.933
DFA	0.37	1.21	1.02	0.76	1.12	0.82	0.93	0.457	0.927	0.942	0.226
IA	0.41	4.80	2.15	1.66	2.98	2.47	3.67	0.752	0.246	0.569	0.155

SEM: standard error of the mean.

Table 4. Sensory characteristics of meat from Santa Inês sheep fed palm and water restriction.

Variable	Inclusion Level—C (%)				Water		SEM	p-value		
	0	30	50	70	With	Without		Cactus	Water	C*W
Tenderness	2.52	2.59	2.83	2.15	2.46	2.58	1.77	0.534	0.659	0.627
Juiciness	4.26	3.93	3.78	3.88	3.93	3.91	2.11	0.435	0.945	0.694
Flavor	5.78	5.89	6.53	5.84	6.18	5.93	1.54	0.234	0.283	0.421
Color	4.76	4.76	5.39	5.55	5.18	5.16	1.88	0.389	0.930	0.735
Aroma	5.83	5.64	5.84	5.63	5.88	5.60	1.46	0.654	0.204	0.134
Global acceptance	6.56	6.29	6.40	6.40	6.45	6.35	1.48	0.786	0.650	0.479

SEM: standard error of the mean.

for lambs, agreeing with data reported by De Abreu et al. (2018), who found similar cooking loss values in lambs fed diets containing different replacement levels of wheat bran by spineless cactus (0, 330, 660, and 1,000 g kg^{-1}). Since increased slaughter body weight generally produces greater contents of IMF and, in consequence, lower values of cooking losses, current results might be expected because of the similarity of the slaughter body weight (and age) of animals.

The C16:0, C18:0, and C18:1 accounted for 79.7% of the total fatty acids, with C16:0 being the SFA that contributed most to the profile, followed by C18:1n9 cis, which accounted for 86.09% of the monounsaturated fatty acid and 28.5% of the fatty acid profile of the meat. The predominance of these acids has been reported in previous studies (Abidi et al., 2009; Atti et al., 2006; Bessa et al., 2008; Costa et al., 2017; Madruga et al., 2008).

Considering that the plasma concentration of cholesterol is influenced by the composition of fatty acids in the diet and knowing that palmitic acid (C16:0) increases the level of blood cholesterol while oleic acid (C18:1) decreases it and stearic acid (C18:0) has no influence (Madruga et al., 2005), it was observed that the inclusion of spineless cactus and the restriction of voluntary water consumption did not significantly influence the concentration of these three main acids.

As the spineless cactus was included, there was an increase in SFA and PUFA, as reported by Madruga et al. (2005) with sheep spineless cactus. The most representative SFAs evaluated were C16:0 (palmitic acid) and C18:0 (stearic acid). According to Micha and Mozaffarian (2010), a meta-analysis showed that palmitic acid (C16:0) is the saturated fatty acid that has the least influence on the increase in unwanted cholesterol, the most important being lauric (C12:0), followed by myristic (C14:0), which accounted for only 0.6 and 4.4%, respectively, of the SFA present in meat. On the contrary, C18:0 is neutral in its effects on cholesterol, and several mechanisms have been proposed for this alteration, including the reduction of hepatic low-density lipoprotein (LDL) receptors (Daumerie et al., 1992).

Oleic acid was the most representative of the monounsaturates, while linoleic acid (C18:2n6c) was the most representative of the polyunsaturates. This, in turn, was the one that showed levels of 4.31 and 11.74 in animals on the control diet (without spineless cactus) and with 70% spineless cactus, respectively. According to Valsta et al. (2005), monounsaturated and polyunsaturated fatty acids are considered hypocholesterolemic because they are effective in reducing blood cholesterol concentrations.

Therefore, the inclusion of spineless cactus in the diet of sheep can improve the nutritional quality of the meat due to its fatty acid profile, since the more expressive saturated fatty acids present in the meat have less hypercholesterolemic action, while the higher mono- and polyunsaturated fatty acids promote the reduction of unwanted cholesterol.

Wood et al. (2004) recommended that the PUFA–SFA ratio of a food's lipid profile should be above 0.4 to avoid diseases associated with the consumption of saturated fats. Similar results were found by Atti et al. (2006) feeding goats with spineless cactus and also observed by Nefzaoui (2010) in sheep and goats fed with spineless cactus.

According to Lopes et al. (2012), the meat of ruminant animals has a higher amount of saturated fatty acids and lower concentrations of monounsaturated and polyunsaturated fatty acids. This is due to the process of biohydrogenation, which involves the addition of a hydrogen ion to a double bond, resulting in the conversion of unsaturated fatty acids into their corresponding saturated fatty acids. However, the biohydrogenation process is not 100% complete for all polyunsaturates, some of which reach the duodenum and are absorbed (Holanda et al., 2012).

The inclusion of spineless cactus in the finishing diets for lambs did not modify the sensory quality of the meat. Therefore, results from sensory analysis indicate good meat acceptance, regardless of the inclusion level of the spineless cactus as an alternative ingredient, in accordance with findings reported by Abreu et al. (2018) and Costa et al. (2017). In general, consumers prefer meat with low odor intensity and flavor. The overall acceptability was correlated with the flavor intensity and juiciness, demonstrating that these factors can lead to the acceptance or rejection of the meat by consumers. Sensorial results obtained in the current study represent an important point since spineless cactus is widely used as forage in arid and semi-arid regions. In fact, the use of spineless cactus in the finishing diets for lambs could be especially important in semi-arid regions where the lack of standardized and quality lamb meat throughout the year affects the local economy and the consumer market (Lima et al., 2019).

5 CONCLUSIONS

The inclusion of spineless cactus in the diet of sheep increases the lipid content and intensifies its color, without interfering with the other chemical, physical, and sensory characteristics. It is possible to indicate the inclusion of 50% spineless cactus in sheep feed.

The spineless cactus in the sheep's diet does not affect the lipid profile of the meat; however, when combined with water restriction, it promotes sheep meat with a higher percentage of lipids, without altering other chemical, physical, and sensory characteristics, indicating that this management can be used in the semi-arid region.

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