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Feeding Systems and the Physicochemical and Sensory Quality of Lamb Meat: Can Feeding Systems Affect Lamb Meat Quality?

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Abstract

This study aims to evaluate the physicochemical characteristics, fat composition, and sensory attributes of lamb meat produced in two feeding systems: (1) Unweaned and unsupplemented lambs in the pasture and (2) early weaned lambs in the pasture with concentrate supplementation post-weaning. The experiment was performed in the winter–spring pastures in the subtropical region of Brazil. The experimental design was completely randomized with two treatments (feeding systems), four paddocks per treatment and twenty lambs (experimental units) per paddock. Carcass weight, dressing percentage, pH, rib eye area, subcutaneous fat thickness, and visual fatness were determined. Loin samples were used for instrumental color, thawing and cooking loss, shear force, water holding capacity, fat and sensory analyses. Carcass pH did not differ between the systems ($p > 0.05$). Supplemented weaned lambs showed a higher body condition score, carcass weight, dressing percentage and fatness ($p < 0.001$). They also showed higher ($p < 0.05$) total fat and long chain fatty acid (FA) content than unweaned lambs. Lamb meat from both systems showed similar and high sensory acceptance. Early weaning and supplementation proved to be a better choice for producing lambs in the winter–spring pasture, under subtropical conditions, because it promoted better carcass and meat traits and good sensory attributes, which could improve payment to the farmers.

Keywords: fatty acids, lamb production, sensorial analysis, pasture, ruminant

1. Introduction

The consumption of ruminant meat products has greatly increased in developing countries such as Brazil. Some aspects of lamb meat production may be considered such as the profitability to the farmer, safety to human consumption and the high quality with low environmental impact.

Different sheep production systems are used worldwide, which offer different types of handling and determine differences in the characteristics of lamb meat (Sañudo *et al*., 2007). In countries with the greatest commercial lamb production, such as New Zealand, sheep are produced almost exclusively on cultivated pastures, with very few concentrates (Morris and Kenyon, 2014). In Brazil, lamb meat is mainly produced using pastoral production systems in commercial herds, made up of dual-purpose and specialized breeds for meat production (Ricardo *et al*., 2015).

Most of the Brazilian sheep herds are in the Southern and the Northeast biomes, in extensive areas. However, in agricultural and integrated livestock crop production areas, farmers have intensified lamb production to slaughter younger animals. In this case, intensive grazing systems, concentrate supplements, and feedlot strategies are used.

One of the intensive systems is a very simple technology: No weaning lambs in pastures until the slaughter weight and considering high herbage allowance for the lactation ewes. In this case, it was noted that favorable profitability and animal welfare (Fernandes *et al*., 2014). Another production strategy in intensive livestock areas is early weaning of lambs (60 days old) and feeding them post-weaning concentrate supplements in pastures until slaughter. In this case, because of a higher protein intake (Houdijk, 2012), the ewes are ready for new mating and earlier and rapid lamb growth cycle takes place (Fernandes *et al.*, 2010; Ribeiro *et al*., 2009), with lower parasitological challenges (Salgado and Santos, 2016).

Feeding systems that promote adequate fat levels, lower concentrations of saturated fatty acids, and acceptable sensory characteristics of meat are of great interest to farmers, industries, and consumers (Montossi, 2007).

Thus, we aim to study the physicochemical characteristics, the FA profile, and the sensory attributes of the carcass and meat of lambs produced in two feeding systems in an integrated livestock crop production area, in the subtropical region of Brazil. We hypothesized that different feed sources can modify the quality of the lamb's meat, including the profile of FA, towards greater commercial quality and higher nutritional value.

2. Material and Methods

Ethics statement

The animal handling procedures were approved by the Ethics Committee on Animal Use, Federal University of Paraná (UFPR), Brazil, protocol number 052 / 2011.

The ethical and biosafety aspects of the sensory analysis were approved by the Research Ethics Committee (CEP) of PUCPR (Pontifícia Universidade Católica do Paraná, Brazil) under protocol number 1.072.008.

Experimental area, treatment, and animals

This study was performed at the Tangará Commercial Farm, in the Southern Region of Brazil (24° 38′ 58″ S, 50° 51′ 03″ W), 833 m above sea level. The climate is subtropical Cfb, according to the Köppen-Geiger climate classification. The experiment lasted 81 days in the winter–spring season.

Forty Ile de France male lambs were allocated to two feeding systems (20 lambs for each feeding system): (1) Unweaned and unsupplemented lambs in pastures until slaughter (n = 20) and (2) early weaned lambs from pastures with concentrate supplementation post weaning, at 2% body weight per day, until slaughter (n = 20). Thus, lambs were milk-fed (suckling lambs) with free access to the pasture in system 1; the weaned lambs had pasture-grazing and concentrate as sources of nutrients, in system 2.

Sixteen lambs were twins and four lambs were single birth, in each treatment. Unweaned lambs presented a mean (±SD) initial body weight (BW) of 21.7±3.23 kg and weaned lambs, a mean (±SD) initial BW of 19.6±5.45 kg. The mean (±SD) initial age of the lambs was 61.0±4.7 days. Ewes presented a mean initial BW of 67.0±1.8 kg and were not supplemented during the experiment.

The pasture was of annual ryegrass (*Lolium multiflorum* Lam.) overseeded on perennial Tifton-85 (*Cynodon spp*). The grazing method was continuous and variable stocking according to the "put and take" technique (Mott and Lucas, 1952), adjusted every 21 days to keep the herbage allowance of 12 kg dry mass (DM) / 100 kg body weight (BW) / day (12%). A 6.0 ha area of cultivated grassland was subdivided into eight grazing paddocks. For weaned and supplemented lambs, the paddock area was 0.35 ha and for unweaned lambs and ewes was 1.1 ha.

The concentrate feed for weaned lambs (Golden Sheep Cordeiros e Borregos®; Agraria Ovinos; 20 g / kg Crude Protein) was offered *ad libitum*, daily in the afternoon (4:30 pm) at 2% of BW (body weight) in DM / day. The diet was formulated to meet the requirements of weaned lambs with fast growth potential (NRC, 2007). The adjustment of concentrate was performed every 21 days, when the animals were weighed after 12 hours of solid fasting. The mean concentrate intake during the experiment was 520 g / day.

Forage and concentrate analysis and nutritive value

Hand plucking method (Burms *et al*., 1989), that simulates the animals grazing, was used to collect the forage from pasture for chemical analysis every 21 days. The concentrate sampling was also done every 21 days. Samples of the pasture and the concentrate were analyzed at the Laboratory of Animal Nutrition in the Department of Animal Science of the Federal University of Paraná, Brazil. For the estimation of the total digestible nutrients (TDN), the formulas described by Kearl (1982) for the concentrate and Weiss *et al.* (1992) for the forage were applied. Total nitrogen was determined by the Kjeldahl method (AOAC 1984) and crude protein (CP) was obtained by multiplying the total nitrogen concentration by 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest *et al.* (1991). The proximate composition of pasture and concentrate is presented in Table 1.

Tabela 1. Dry matter (%) and proximate composition (% DM) of pasture and concentrate in lamb feeding systems

	Unit	Tifton-85	Annual Ryegrass	Concentrate*
DM	(%)	31.5	23.8	89.4
TDN	(% DM)	64.0	74.0	83.0
CP		12.6	17.9	19.8
NDF		59.0	58.0	20.9
ADF		23.3	23.4	5.54
Fat		3.7	4.1	2.7
Ash		8.1	12.1	4.7

*Concentrate ingredients: corn meal (40% DM); soybean meal (40% DM); wheat bran (15%), $CaCO_3$ (2.5% DM), common salt (0.5% DM) and mineral salt (2% DM).

DM: dry matter; TDN: total digestible nutrients; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber.

Carcass and meat quality evaluations

The unweaned lambs were slaughtered (means ± SD) at 37.4 ± 3.97 kg and 143.8 ± 6.31 days old, whereas supplemented weaned lambs were slaughtered at 39.8 ± 5.49 kg and at 144.2 ± 7.58 days old. The lambs were fasted for 16 hours before slaughter, with free access to water. After that, the animals were weighed (slaughter weight - SLW) and the body condition score (BCS, 1–5 scale; Russel *et al.*, 1969) was determined.

The slaughter was carried out in a commercial abattoir according to the Parana State Inspection System (SIP), Brazil. The stunning was made by eletronarcosis and bleeding by the section of the jugular veins and carotid arteries. After evisceration, the hot carcass weight (HCW) was taken; they were left for 6 h at 21 ℃ ambient temperature and then transported to a cold room set to 4 ℃ for 24 h. Carcass characteristics were determined in 20 lambs from each treatment. Cold carcass weight (CCW) was determined and the dressing percentage (DP) was calculated as follows: Hot carcass weight (HCW)/slaughter weight (SLW) X 100.

The visual fatness (VF) was assessed after carcass cooling using a subjective five-point scale, according to Caneque and Sañudo (2000), which indicates the amount and distribution of external fat in the carcass from 1 (lean) to 5 (very fat).

Carcass pH was determined at 45 minutes ($pH_{45min.}$) and at 24 hours after slaughter (pH_{24h}) (AOAC, 2000), using a portable digital potentiometer with penetration probe (Hanna Instruments HI 99163) in *Longissimus thoracis and lumborum* muscle (LM) penultimate rib (AOAC, 2000).

The carcass subcutaneous fat thickness (SFT) was evaluated between the twelfth and thirteenth thoracic vertebrae, using portable digital calipers, according to Caneque and Sañudo (2000).

The measurement of the rib eye area (REA) was performed on a cold carcass, on the LM, between the twelfth and thirteenth ribs (at the insertion of the last thoracic vertebra to the first lumbar). The REA was determined following the methodology described by Huidobro *et al.* (2000).

The carcasses were divided lengthwise taking up the loins on the left and right side, from the transverse cut between the 13th thoracic vertebra and the 1st lumbar vertebra and the 6th lumbar vertebra and the 1st sacral vertebra, according to Colomer-Rocher (1988). The loin samples (~200g) were vacuum packed in ethylene vinyl alcohol (EVOH) packaging (permeability of 4 cm^3 O2/ m^2 per day at 1 ATM and 23 ℃) and kept frozen at -18 ℃ until analyses. 36 left loins were used for physicochemical parameter determination (18 from each treatment) and the 36 right loins were used for sensory and FA composition analyses.

After 90 days of frozen storage, the loin samples were thawed under refrigeration until they reached an internal temperature of 2 ℃ to 5 ℃, and the thawing weight loss (TWL) was determined by gravimetry and expressed in percentage (Muela *et al.*, 2010).

The meat instrumental color was determined after the total thawing of the loin samples. The analysis was performed through an average of five shots directly on the surface of the samples (approximately 3 cm thick), 30 min following the exposure of the sample surface to the atmosphere. The method specified by the American Society for Testing and Materials (ASTM) (2001) was used, with a portable spectrophotometer (Konica Minolta CM-600D, Tokyo, Japan), illuminant D65, and a 10 °observer.

The CIE Lab system for the reflectance of light was used in three dimensions: L* represented the lightness and a* and b* represented the intensity of the red and yellow colors, respectively.

Cooking weight loss (CWL) was determined in samples (previously weighed) cooked in heat-resistant polyethylene bags in a water bath at an internal temperature of 70 ℃ for 15 minutes (Morgan *et al*., 1993). After cooking, the samples were dried with absorbent paper and cooled at room temperature for reweighing. Cooking weight loss was expressed as a percentage related to the initial weight, determined by gravimetry (Pla, 2000).

The shear force (SF) was determined in cooked samples (n = 5 replicates), as previously described. They were cut in 1.27 cm cylindrical shapes, with a 2-cm length. The samples were sheared perpendicularly to the muscle fiber orientation by a Heavy Duty Platform (HDP) / 90 probe, in a texturometer TAXT2i (Stable Micro Systems, Surrey, England), equipped with a Warner-Bratzler blade. Shear force was taken with 1.5 mm / s test speed and 30 mm distance from the base.

Water holding capacity (WHC) was assessed in accordance with Barbut's (1996) study and calculated using the following formula:

WHC = 100 - [(Initial weight of sample - Final weight of sample / 100) x 100].

Fat content and fatty acid profile

For total fat content determination, 10 loins from each treatment were used. The samples were weighed in triplicate and subjected to extraction by the Soxhlet method (996.06) (AOAC, 2000). The FA composition was determined in accordance with Hartman and Lago (1973), in duplicate. The FA methyl esters (FAMES) obtained according to the method of Hartman & Lago (1973), using ammonium chloride solution and sulfuric acid in methanol, as esterifying agent, were analyzed on a Varian 3900 gas chromatograph (GC) flame ionization detector (FID). A workstation with STAR software, split injector, sample split ratio of 75:1, and the CP-SIL 88 capillary column were used. The chromatographic conditions were: Programmed column temperature starting at 120 ℃ for 5 minutes, raised to 235 ℃ at 3 ℃ per minute, and remaining at that temperature for 20 minutes. Hydrogen was used as the carrier gas at a flow rate of 1 mL / minute and nitrogen, make-up gas at 30 mL / minute, with injector temperature of 270ºC, detector temperature of 300ºC, and injection volume of 1 µL (Firestone, 1998).

The FAMES in the total lipids of each sample were identified by comparing retention times with those of a standard FAME mixture (SupelcoTM 37 Component FAME Mix). The results were expressed in g / 100 g meat.

For sensory analysis ten loins were used, five for each treatment. The loin samples were cooked as described previously for CWL and cut into cubes of ~2 cm^3 and kept warmed (approximately 55–60 ℃) for a maximum of 30 minutes. No flavoring was added to the meat at any evaluation time.

Sensory analysis

Sensory analysis was conducted only under the previous microbial innocuity evaluation of samples, according to the current Brazilian regulation (Brasil, 2001), related to the fecal coliform and *Escherichia coli* count and spoilage bacteria (count of psychrotrophic aerobic bacteria).

The samples were identified by three random digits and sensory assessed by a panelist of 133 untrained members (69 women and 64 men, from 18 to 50 years of age). Each panelist consumed four samples, two cubes of each treatment. The samples were presented to the panelists in a monadic order, to minimize the effect that the order would have on the responses (Sañudo Astiz, 2008). The sensorial tests were held in two days. Every day, in the morning, the samples followed the same pattern of preparation — an affective acceptance test with a nine-point hedonic scale (1 = ‘strongly disliked’; 2 = ‘disliked’; 3 = ‘moderately disliked’; 4 = ‘slightly disliked’; 5 = indifferent; 6 = ‘slightly liked’; 7 = ’moderately liked’; 8 = ‘liked’; 9 = ‘strongly liked’) was used to evaluate how the panelists liked or disliked the color, tenderness, flavor, and overall taste of meat samples (Dutcosky, 2014).

Experimental design and statistical analyses

A completely randomized design with two treatments (two feeding systems) and 20 replicates (lambs) per treatment was used.

The data normality was checked by the Shapiro-Wilk test (Shapiro and Wilk, 1965). Analysis of variance was performed using the F test at a 5% significance level for the carcass and meat characteristics.

The Pearson ́s correlation was estimated for the body condition score (BSC), subcutaneous fat thickness (SFT), dressing percentage (DP), rib eye area (REA), shear force (SF), and visual fatness (VF). These variables are used for selection of animals for slaughter (specifically body condition score) and bonus for sheep farmers in the Brazilian commercial cooperatives. For the sensory data, the Wilcoxon nonparametric test was performed.

Data were analyzed using R software version 3.1.2 (R Core Team, 2012).

3. Results and Discussion

The feeding systems had no influence on meat pH_{45min} and pH_{24h} ($p > 0.05$) (Table 3). Mean final pH (pH_{24h}) values varied from 5.50 to 5.56 for unweaned and supplemented weaned lambs, respectively, within the normal range reported by Young *et al*. (2004).

Table 2. Means and standard errors of lamb carcasses characteristics in two feeding systems

Parameters	Unit	Unweaned lambs	Supplemented weaned lambs	P *value*
SLW	kg	37.4 ±0.88	39.8 ±1.23	NS
BCS	1 to 5	2.5 ±0.03	2.8 ±0.02	*
VF	1 to 5	3.3 ±0.16	4.0 ±0.11	*
SFT	mm	2.3 ±0.14	3.1 ±0.13	*
HCW	kg	16.0 ±0.41	18.0 ±0.60	*
DP	%	42.3 ±0.74	46.4 ±0.61	*
REA	cm^2	12.0 ±0.41	13.2 ±0.29	**

SLW=slaughter weight; BCS=body condition score; VF=visual fatness; SFT=subcutaneous fat thickness; HCW=hot carcass weight; DP=dressing percentage; REA=rib eye area.

NS= not significant ($P>0,05$); *P value <0.05; **P value <0.01

Feeding systems influenced ($p < 0.05$) BCS, HCW, DP, VF, SFT, and REA of the lambs (Table 2) with similar ($p > 0.05$) SLW. Supplemented weaned lambs presented higher HCW and DP ($p < 0.05$) than suckling ones, indicating higher muscle and adipose tissue development. Also, Boughalmi and Araba (2016) noted that when pasture feeding systems were predominant, lamb carcass yields were lower because the digestive tract was filled to the highest degree.

Similarly, REA was also higher ($p < 0.01$) for supplemented weaned lambs, confirming a greater muscle development in these animals. Although the LM muscle had late development (Owens *et al*., 1995; Hashimoto *et al*., 2012), it was observed that concentrate supplementation provided higher muscle deposition for lambs (mean 143–144 days old), which corresponded to an increased yield of high value meat cuts (Safari *et al*., 2001). These results agree with the study of Carvalho *et al*. (2006) and Carvalho *et al*. (2007), who found that a daily supply of concentrate equal to or greater than 2% of body weight for lambs would be sufficient to override the lack of milk and improve the performance of the animals.

The correlation matrix showed a positive correlation ($p < 0.05$) between DP and REA (Table 3), reaffirming the possibility of using the REA measurement by pre-slaughter ultrasound to choose the lambs with the highest carcass yield, as these will be better paid.

The BCS, VF, and SFT were also higher in the carcasses of supplemented weaned lambs (Table 2; $p < 0.05$). Diet is a factor that affects the carcass fat content and quality as it is directly linked with the energy intake (NRC, 2007). When ruminants ingest excessive energy, it is metabolized and stored as adipose tissue (Arruda *et al*., 2012). In our study, the concentrate fed to lambs — at 2% of BW (body weight) in DM / day — probably provided more energy than the other sources of nutrients (pasture and milk) and this caused the carcasses to have higher fat in them.

Also, the fat thickness can be influenced by increased carcass weight (Table 3). According to Chestnutt *et al.* (1994), fat depth increased by 0.52mm / kg carcass weight on a high nutrition plane compared to 0.13 mm / kg on a low nutrition plane.

Table 3. Pearson ́s correlations for the lamb body condition score, carcass characteristics and meat quality in two feeding systems

Variables	SF	BCS	SFT	DP	REA	VF
SF	1					
BCS	-0.21	1				
SFT	-0.12	0.63*	1			
DP	0.01	0.57*	0.57*	1		
REA	-0.05	0.5*	0.58*	0.65*	1	
VF	-0.19	0.66*	0.72*	0.64*	0.66*	1

SF=shear force; BCS=body condition score; SFT=average subcutaneous fat thickness; DP=dressing percentage; REA=rib eye area; VF= visual fatness

*P value<0.05

Besides that, BCS, VF, and SFT were positively correlated ($p < 0.05$; Table 3) meaning that a higher BCS resulted in superior carcass visual fatness and subcutaneous fat thickness (Sañudo and Sierra, 1986). The cooperatives of sheep farmers in Southern Brazil chose better lambs for marketing according to the BCS, at the pre-slaughter stage, thinking about the future carcass subcutaneous fat and superior quality of the meat cuts.

The meat SF was not affected by feeding treatments ($p > 0.05$) (Table 4). However, lamb meat from both systems can be considered as tender meat, with values ranging from 3.6 kgf (supplemented weaned lambs) to 3.9 kgf (suckling lambs) (Shackelford *et al*., 1997). The young slaughter age of animals (mean 143 – 144 days) must have contributed to the tenderness of the meat. Tenderness of lamb meat was also confirmed in sensory evaluation, as the tenderness scores were higher than 7.0 for both treatments (Table 7).

Sañudo *et al.* (1996) suggested that shear force and tenderness were significantly affected by carcass weight, which was not confirmed in this case. The Pearson ́s correlation matrix (Table 3) showed that tenderness of lamb meat was apparently not influenced by the fat and muscle content, nor by dressing percentage and feeding system.

Considering the other physicochemical parameters, feeding systems influenced the WHC and TWL ($p < 0.05$). The suckling lamb meat presented lower WHC and higher TWL (Table 4). The higher fat thickness in supplemented lamb carcasses could have protected them against water loss on cooling, as stated by Sañudo *et al.* (1997) and Fonseca *et al.* (2012). However, those differences were not high enough to affect the CWL and SF (instrumental) or sensory tenderness (Table 7). Similarly, Rizzi *et al*. (2002) also reported no difference in CWL in lamb meat from six different feeding systems.

Table 4. Mean and standard errors of physicochemical parameters of lamb meat in two feeding systems

Parameter	Unit	Unweaned lambs	Supplemented weaned lambs	P *value*
$\text{pH}_{24\text{h}}$	-	5.50 ±0.03	5.56 ±0.27	NS
WHC	%	69.03 ±0.45	72.55 ±0.5	*
CWL	%	21.63 ±1.04	20.33 ±0.87	NS
TWL	%	4.89 ±0.37	3.80 ±0.34	*
SF	kgf	3.9 ±0.22	3.6 ±0.17	NS
L*	-	41.67 ±0.66	43.17 ±0.89	NS
a*	-	15.23 ±0.45	15.98 ±0.46	NS
b*	-	6.55 ±0.37	6.34 ±0.45	NS

WHC= water holding capacity; CWL= cooking weight loss; TWL= thawing weight loss; SF = shear force; L*=lightness; a*=redness; b*=yellowness

NS=not significant (P>0.05); *P value <0.05; **P value <0.01

The feeding system did not affect ($p > 0.05$) the instrumental meat color (Table 4) nor sensory color attribute (Table 7). The type of weaning (Sañudo *et al*., 1998a) and suckling can affect L*, redness a*, and hue in meat of light weight lambs (4 to 8 kg; Panea *et al*., 2011). This effect was not observed in the lambs of the present study probably due to the higher slaughter weight and age of the lambs. Our lambs were 60 days old when sheep's milk production may be declining (Hentz *et al*., 2012). We must also take into account that the lambs in sucking system were milk-fed but with free access to the pasture as well. Osório *et al*. (2014) stated that in ruminants, the type of solid feed (pasture, cereals, grains) has low influence on meat color, possibly due to ruminal digestion.

The fatness characteristics of the carcasses (BCS, VF, SFT) were higher for supplemented lambs (Table 2) as the total FA content (Table 5). Meat from animals of both feeding systems can be considered "lean" according to the Food Advisory Committee (1990), as fat content is lower than 5%.

Table 5. Means and standard errors of the fat composition (mg/100 g meat) of lamb meat in two feeding systems

Composition	Unweaned lambs	Supplemented weaned lambs	P *value*
Total fat content	1087,00 ±160,82	1638,00 ±227,58	*
Saturated FA	607,00 ±83,39	858,00 ±122,24	NS
Monounsaturated FA	443,00 ±71,52	713,0 ±108,21	NS
Polyunsaturated FA	41,00 ±6,90	44,00 ±6,18	NS

NS= not significant (P>0.05); *P value <0.05; **P value <0.01

The content of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) FA (Table 4) were similar (p > 0.05) in both treatments. Sañudo *et al.* (1998b) found higher polyunsaturated FA for suckling lambs than for weaned lambs, which was not confirmed for these feeding systems, but similar amounts of total unsaturated and total saturated FA.

In the present study, the MUFA content had no significant difference (p > 0.05) between the feeding systems. It would normally be expected that lambs receiving concentrated supplementation would present meat with higher MUFA content, considering that the concentrate has a higher content of MUFA compared to pasture. However, in both treatments lambs have grazed the same pasture (grasses) and the effect of grazing on meat FA composition depends on the forage species, as is the case of legume pastures (Lee *et al.*, 2009). A MUFA content of 50% was observed, while Alvarez *et al* (2013) reported 43.28% in lamb meat. The presence of this type of FA in the meat is important for consumers who aim to improve the lipid profile of the blood through the diet (Santos *et al.*, 2013).

The concentrate feed (which is usually rich in linoleic acid) and ewes' milk absence did not affect (p > 0.05) the PUFA content of the supplemented weaned lamb meat. This result was expected because in ruminants a little portion of PUFA is available for incorporation into the tissues, because of the extensive biohydrogenation in the rumen, as detailed by Chikwanha *et al.* (2018).

Santos-Silva *et al.* (2002) stated that the FA profile of meat from lambs fed on pasture shows a better nutritional balance than of the lambs fed with concentrate because of the higher amount of n-3 polyunsaturated FA, higher concentration of conjugated linoleic acid (C18:2 n-6) and lower ratio n-6: n-3. In this case, the influence of feeding systems in the SFA composition was significant only for stearic acid (C18:0) content (Table 6). Stearic acid (C18:0) was greater in supplemented weaned lamb´s meat. Enser *et al.* (1996) reported that high muscle concentrations of C18:0 are common in grazing animals, reflecting high levels of rumen biohydrogenation. However, despite being an SFA, this FA can promote a small reduction in low-density lipoprotein cholesterol (LDL-c) (Santos *et al.*, 2013). Interestingly, Hunter *et al*. (2010) reported that increased intake of stearic acid (18:0) may have neutral or protective effect against cardiovascular diseases.

Table 6. Means and standard errors of FA profile (mg/100 g meat) of lamb meat in two feeding systems

Fatty acids	Unweaned lambs	Supplemented weaned lambs	P value
Myristic (C14:0)	63,74 ±9,64	55,60 ±8,82	NS
Palmitic (C16:0)	313,26 ±46,07	442,10 ±66,60	NS
Stearic (C18:0)	229,83 ±29,66	360,30 ±48,25	*
Oleic (C18:1n - 9)	443,87 ±71,05	713,40 ±108,13	*
Linoleic (C18:2n - 6)	40,30 ±7,65	43,90 ±6,50	NS

NS=not significant (P>0.05); *P value <0.05; **P value <0.01

Table 7. Means and standard errors for sensory attributes evaluated by consumers of lamb meat in two feeding systems

Characteristics	Unweaned lambs	Supplemented weaned lambs	P *value*
Color	6.53 ±0.70	6.53 ±0.73	NS
Tenderness	7.80 ±0.56	7.71 ±0.55	NS
Flavor	7.32 ±0.63	7.32 ±0.65	NS
Overall liking	7.41 ±1.19	7.38 ±0.55	NS

NS= not significant (P>0.05); *P value <0.05; **P value <0.01

Evaluation with structured scale of nine points according to Dutcosky (2014): (1= ‘strongly disliked’; 2 = ‘disliked’; 3 = ‘moderately disliked’; 4 = ‘slightly disliked’; 5 = indifferent; 6 = ‘slightly liked’; 7 = ’moderately liked’; 8 = ‘liked’; 9 = ‘strongly liked’)

The myristic (C14:0) and palmitic acids (C16:0) are responsible for increasing plasma cholesterol (Santos *et al*., 2013), causing concern to consumers. In this study, myristic (C14:0) and palmitic acids (C16:0) had no significant difference in meat from both systems. Likewise, Panea *et al*. (2011) also found no significant effect on myristic acid (C14:0) content in the meat of lambs raised under different feeding systems (pasture, grazing + supplement, and confinement).

In this study, the oleic acid (C18:1) content was affected ($p < 0.05$) by the feeding system and it was found as the highest values among the identified FA. Similarly, Velasco *et al* (2004) observed higher oleic acid in the meat of lambs fed with grains and cereals than in grazing animals. Bas & Morand-Fehr (2000) found higher percentage of myristic acid (C14:0), palmitic acid (C16:0) and oleic acid (C18:1) and lower proportion of stearic acid (C18:0), linoleic (C18:2) and linolenic acid (C18:3) in the meat of suckling lambs than of weaned lambs. The ewe´s milk is rich in myristic (C14:0) and palmitic acid (C16:0). We highlight that the weaned lambs were fed with concentrate diet after weaning that altered this result. According to Bas and Morand-Fehr (2000), after weaning, the percentage of myristic acid (C14:0) gradually decreases and the percentage of long chain saturated FA increases, probably due to the lower percentage of short and medium chain FA and the high percentage of long chain acids in the post-wean diet. In fact, meat from supplemented weaned lambs showed higher long chain FA content (stearic acid-C18:0, oleic acid-C18:1 and linolenic acid-C18:3) than suckling lambs.

The linoleic acid (C18:2n - 6) content also did not differ ($p > 0.05$) in lamb meat, even with the concentrate supplementation. Similarly, Fernandes *et al.* (2010) studying four feeding systems (weaned in pasture, suckling lambs in pasture, creep feeding, and weaned in feedlot) did not find differences in linoleic acid (C18:2n - 6) content in lamb meat.

The scores for sensory attributes in lamb meat were similar among the feeding systems ($p > 0.05$; Table 6). Despite the presence of concentrate in the diet of weaned lambs, there was no difference in sensory characteristics. Similarly, Tonetto *et al*. (2004) found no differences in the juiciness and tenderness of meat from lambs reared in three different feeding systems (pasture with supplement, ryegrass, and confinement). Otherwise, Sañudo *et al.* (1998a) reported improved sensorial quality of the meat flavor in milk-fed, suckling animals. Cañeque *et al*. (1989) stated that the presence of concentrate can modify the meat taste and flavor due to the change in the fat lipid composition. However, in the present study, the proportion of FA type was similar, causing no influence on the meat flavor.

Scores for overall liking of lamb meat were above 7.0 for both treatments, indicating a 'moderately liked' to 'liked' perception of meat by the consumers (Dutcosky, 2014). Overall liking is a mixture of flavor and tenderness scores, as well as other sensations that consumers perceive when they taste the meat lamb samples (Guerrero *et al*., 2013).

As discussed by Guerrero *et al.* (2013), the effect of the production system on the meat quality has been dealt with from different points of view, as it may be considered an effect from multi-causal factors, including feeding, for instance, the breed, the previous management to finishing time, and mainly feeding and duration of the finishing period. It is, therefore, highly important to consider differences among consumers. A market study has to be carried out, because consumers from different countries and different regions within the same country may have differences in lamb meat preferences.

4. Conclusions

Lamb meat from both feeding systems showed good meat quality and high sensory acceptance. Early weaning and supplementation seem to be a better choice for producing lambs in the winter–spring pasture and for integrated livestock crop areas in subtropical conditions, if the cost of the concentrate is favorable. It made better carcass and meat traits which could improve the payment to the farmers, as also improve the market value of lambs. This feeding system still favors the body condition of the ewes in the next breeding season.

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