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RUMINANT NUTRITION

Weaning and concentrate supplementation on the characteristics of carcass cuts and *longissimus* muscle of Suffolk lambs finished on pasture

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ABSTRACT. The aim of this study was to evaluate the influence of weaning and concentrate supplementation on the characteristics of carcass cuts and *longissimus* muscle of Suffolk lambs finished on a Tifton 85 (*Cynodon* spp.) pasture. Weaning and concentrate supplementation strategies were evaluated in four finishing systems: i) non-weaned and non-supplemented lambs; ii) non-weaned lambs supplemented with concentrate in creep feeding; iii) weaned and non-supplemented lambs; and iv) weaned lambs supplemented with concentrate. In the systems with weaning, lambs were weaned at 46 ± 6 days of age. In the systems with supplementation, the concentrate was offered daily at 2% of lambs' body weight. Weaning led to a decrease, whereas supplementation led to an increase in carcass cut weights. Supplemented lambs had lower yields of neck and uncovered ribs, and higher yields of breast + flank and loin. The characteristics of loin eye and fat thickness over the *longissimus* muscle presented lower values in weaned lambs and higher values in supplemented lambs. Keeping lambs with their dams and offering concentrate supplementation until slaughter are strategies recommended to obtain heavier cuts with increased muscularity and fat content.

Keywords: creep feeding; fat thickness; leg; loin eye area; muscularity.

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Introduction

In lamb production systems, weaning is used to improve productivity and accelerate the recovery of ewes' body condition score (Fernandes et al., 2011). Therefore, this strategy allows an early return of ewes to cyclicity, reducing the interval between parturitions, and increasing the rate of lambs produced per ewe year^{-1} (Oliveira et al., 2014). When weaning is associated with concentrate supplementation offered after weaning, the main results obtained are increased individual performance (Souza et al., 2010; Geron, Mexia, Garcia, Silva, & Zeoula, 2012) and lamb stocking rate on pasture (Carvalho et al., 2006; Silva et al., 2014). Use of forage grasses such as Tifton 85 (*Cynodon* spp.) in grazing production systems has also provided good animal performance due to its high nutritional quality, high dry matter (DM) production, and proper structural characteristics for grazing lambs (Souza et al., 2010; Silva et al., 2019).

Supplementation in grazing systems is a strategy to mitigate the variations in forage allowance and forage quality of pasture, improving sheep performance, and increasing the number of animals to slaughter (Geron et al., 2012; Alves et al., 2013; Silva et al., 2019). In addition, concentrate supplementation may be necessary to meet the nutritional requirements of breeds specialized for meat production, such as Suffolk, allowing these animals to express their growth potential under grazing conditions. Studies performed in the Brazilian subtropical region showed that Suffolk lambs finished at 32–37 kg of body weight (BW) on Tifton 85 pasture presented an average daily gain of 135 – 280 g day^{-1} in systems without weaning; 50 – 110 g day^{-1} in systems with weaning and without supplementation; and around 150 g day^{-1} when they received concentrate supplementation post-weaning (Silva et al., 2014; Poli et al., 2020). In systems without weaning, the protein–energy supplementation offered in creep feeding has been widely used to improve lambs' growth, resulting in batches of lambs more homogeneous (body size and BW), reducing their dependence on the dams' milk, and the mortality rate (Zundt et al., 2014).

When compared to adult sheep, lambs produce a better quality carcass, presenting meat cuts with more attractive qualitative traits (color and tenderness) to consumers (Hopkins, Stanley, Martin, Toohey, & Gilmour, 2007; Esteves et al., 2018). The carcass is the most important product obtained from the animals, and its quantitative and qualitative traits can be influenced by several factors such as age, breed, production system, and nutritional and feeding management (Silva Sobrinho, Purchas, Kadim, & Yamamoto, 2005; Cartaxo et al., 2017; Gallo, Arrigoni, Lemos, Haguiwara, & Bezerra, 2019). Furthermore, the cuts derived from the carcass have distinct commercial values and hence, the proportions of each cut are important variables to evaluate the commercial value of the carcass (Hashimoto et al., 2012; Piola Junior et al., 2020).

The evaluation of loin characteristics is important in the study of carcass tissue composition. In this cut, the fat thickness indicates the adipose tissue deposition whereas the measurements taken in the *longissimus* muscle are associated with the muscle mass accretion in the carcass (Siqueira & Fernandes, 2000). The *longissimus* is evaluated because it is a muscle of later maturation, easy to access, and simple to measure. The loin eye area is considered a good indicator of body composition, since it represents the muscle content of the carcass, which has a significant influence on carcass classification and price definition of lamb meat (Costa, Lima, Oliveira, Azevedo, & Medeiros, 2012; Prado et al., 2013).

Changes in lamb performance due to the use of different nutritional or feeding strategies in production systems (as aforementioned) may affect body composition and carcass traits. In this context, the aim of this study was to evaluate the influence of weaning and concentrate supplementation strategies, which are commonly used in Brazilian lamb finishing systems, on the characteristics of carcass commercial cuts and *longissimus* muscle of Suffolk lambs finished on pasture.

Material and methods

All procedures described in this research followed the guidelines of the National Council of Animal Experimentation Control (*Conselho Nacional de Controle de Experimentação Animal – CONCEA*), and were approved by the Animal Care and Use Committee (*Comitê de Ética no Uso de Animais – CEUA*) of the Federal University of Paraná (*Universidade Federal do Paraná – UFPR*), Agricultural Sciences Campus, under protocol number 025/2009-CEUA/AG. The trial was carried out at the Sheep and Goat Production and Research Center (*Laboratório de Produção e Pesquisa em Ovinos e Caprinos – LAPOC*) of UFPR, located in Pinhais, Paraná State, Brazil, between November 2008 and March 2009.

To evaluate the weaning and concentrate supplementation strategies, four finishing systems were established on a Tifton 85 pasture: i) non-weaned and non-supplemented lambs; ii) non-weaned lambs supplemented with concentrate in creep feeding; iii) weaned and non-supplemented lambs; and iv) weaned lambs supplemented with concentrate. All systems were evaluated during the period of Tifton 85 production, totaling 98 days of trial.

The trial was set out in a randomized block design with four treatments (systems) and three replicates (paddocks), with two tester lambs per replicate. Three blocks were defined based on the ewes' age at lambing, which differed ($p < 0.05$) by six months between blocks and presented an overall mean of 4.4 ± 1.1 years (mean ± standard deviation [SD]). Twenty-four non-castrated male Suffolk lambs were uniformly distributed into the systems based on birth weight and type of birth (single or twin).

The pre-trial period comprised the breeding and lambing periods. The breeding period lasted 21 days, starting in the second half of May until the first days of June 2008. During this period, ewes were submitted to estrus synchronization and controlled natural mating. The lambing period lasted one week, starting at the end of October until the first days of November 2008. During this period, the animals were kept in an elevated shelter with a slatted floor. At the end of the lambing period, lambs were introduced with their dams to a Tifton 85 paddock (with the same characteristics to that of the experimental area), where they were kept until the start of the trial.

Animals were monitored for endoparasite infection every 21 days, from the pre-trial period until the end of the trial. Control was performed by observation of clinical signs such as diarrhea, submandibular edema, and determination of the anemia degree according to the Famacha® method (Van Wyk & Bath, 2002). Anthelmintic treatment was administered to animals that presented clinical signs and a Famacha score ⩾ 3.

Lambs started the trial at 46 ± 6 days of age and 16.7 ± 4.4 kg BW. In the systems with weaning, lambs were weaned at 46 days of age and immediately allocated to the paddocks. In the systems with supplementation, lambs received a protein–energy concentrate (Table 1) at 2% BW day^{-1}, on a DM basis. The supplement was offered once a day in the afternoon (16:30) and adjustments to the amount of concentrate supplied were performed every 21 days based on the lambs' BW.

The continuous grazing method with variable stocking rate was used, where the tester animals stayed in the paddocks and extra animals were used to adjust the stocking rate following the "put and take" technique (Mott & Lucas, 1952). The adjustments were performed every 21 days maintaining a 12% forage allowance (12 kg green DM per 100 kg BW day^{-1}) to maximize the lambs' performance (Hodgson, 1990).

Table 1. Ingredients and chemical composition of the concentrate supplemented, and chemical composition of the forage samples collected by simulated grazing during the trial period in the finishing systems on Tifton 85 pasture.

Component[I]	Protein-energy concentrate	Forage
Ingredients		
Soybean meal (g kg^{-1} DM)	399.0	
Ground corn (g kg^{-1} DM)	396.0	
Wheat bran (g kg^{-1} DM)	148.0	
Limestone (g kg^{-1} DM)	28.0	
Sodium chloride (g kg^{-1} DM)	6.0	
Mineral supplement (g kg^{-1} DM)[II]	23.0	
Chemical composition[III]		
DM (g kg^{-1} NM)	881.5	274.3
CP (g kg^{-1} DM)	254.7	218.6
EE (g kg^{-1} DM)	31.7	40.3
NDF (g kg^{-1} DM)	201.2	704.2
ADF (g kg^{-1} DM)	76.7	290.6
Lignin (g kg^{-1} DM)	10.9	33.9
Ash (g kg^{-1} DM)	76.6	62.0
Ca (g kg^{-1} DM)	13.2	5.8
P (g kg^{-1} DM)	6.2	5.6
TDN (g kg^{-1} DM)	783.1	626.8
ME (Mcal kg^{-1} DM)	3.04	2.34

[I]NM: natural matter; DM: dry matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; ADF: acid detergent fiber; Ca: calcium; P: phosphorus; TDN: total digestible nutrients; ME: metabolizable energy. [II]Guaranteed analysis – macrominerals: 110-135 g kg^{-1} calcium, 87 g kg^{-1} phosphorus, 147 g kg^{-1} sodium and 18 g kg^{-1} sulphur; Trace minerals: 15 mg kg^{-1} cobalt, 590 mg kg^{-1} copper, 20 mg kg^{-1} chromium, 870 mg kg^{-1} fluorine, 50 mg kg^{-1} iodine, 2,000 mg kg^{-1} manganese, 300 mg kg^{-1} molybdenum, 20 mg kg^{-1} selenium, and 3,800 mg kg^{-1} zinc. [III]The contents of DM, CP, EE, lignin, ash, Ca and P were determined according to the procedures of the Association of Official Analytical Chemists (AOAC, 1990); the contents of NDF and ADF were determined according to the procedures described by Van Soest, Robertson, and Lewis (1991); and the contents of TDN and EM were calculated as proposed by Weiss, Conrad, and St. Pierre (1992).

Lambs were slaughtered at the end of the trial at 136 ± 20 days of age. The slaughter was conducted in accordance with good animal welfare practices, in which the animals were stunned by electronarcosis (electric discharge of 220 V for 8 seconds), followed by bleeding (performed by severing the jugular veins and carotid arteries), skinning, and evisceration. After slaughter, the carcasses were identified, suspended by the metatarsal joints on appropriate hooks (spaced apart by approximately 17 cm), and transferred to a cold room at 5°C, where they remained for 24 hours. The time spent in the slaughter procedure and the carcass cooling time were standardized, and the temperature of the cold room was carefully monitored. After cooling, the carcasses were cut into halves in the caudal–cranial direction, with the left half sectioned into seven commercial cuts as proposed by Colomer-Rocher and Espejo (1972): shoulder, neck, uncovered ribs, true ribs, breast + flank, leg, and loin. These cuts were individually weighed and, then, their relative yields to the left half carcass were calculated.

In the dorsal portion of the *longissimus* muscle of the loin, at the cutoff point between the 13th thoracic vertebra and the first lumbar vertebra, the minimum and maximum backfat thickness on the loin eye (BFT, mm), the maximum width (LEW, cm), and maximum depth (LED, cm) of the loin eye, and the loin eye area (LEA, cm^2) were measured, as described by Siqueira and Fernandes (2000). The minimum and maximum BFT were obtained using a digital caliper, and both measures were used to calculate the mean BFT. The contour of the transverse section of the *longissimus* muscle was traced on tracing paper and scanned into a computer for LEA measurement using a WinRHIZO® LA 1600 scanner (Regent Instruments Inc., Quebec, Canada). The LEW and LED were obtained from the contour of the loin eye tracing, using a ruler with a scale in millimeters. The ratio between both measures (W:D ratio) was also calculated.

Data were submitted to analysis of variance (ANOVA) following a randomized block design in a 2 × 2 factorial arrangement model (PROC GLM), where both strategies of weaning (with and without) and concentrate supplementation (with and without) used in the finishing systems were the analyzed factors. The statistical model used in the data analysis was:

$$\hat{Y}_{ijkl} = \mu + B_i + W_j + S_k + W_j S_k + \varepsilon_{ijkl},$$

where: $\hat{Y}_{ijkl}$ = value of dependent variable from the *l*th lamb in the *i*th block of *j*th weaning strategy and *k*th supplementation strategy; μ = mean value of the dependent variable; B_i = effect of *i*th block; W_j = effect of *j*th weaning strategy; S_k = effect of *k*th supplementation strategy; W_jS_k = effect of interaction between weaning and supplementation strategies; and ε_{ijkl} = random error. The means were fitted to the statistical model and compared by the F test when the independent effects (weaning and supplementation) or the interaction effect was significant (LSMEANS Statement). A significance level of 0.05 was adopted in all statistical analyses, which were carried out using the Statistical Analysis System software, version 9.0 (SAS, 2002).

Results and discussion

There were independent effects of weaning and concentrate supplementation on the weight of all commercial cuts of lamb carcasses (Table 2). Weaning led to a decrease, whereas concentrate supplementation led to an increase of cut weights (Table 3). Despite these effects being associated with the lower carcass weight of weaned lambs compared to non-weaned ones (10.65 *vs.* 14.77 kg), and to the higher carcass weight of supplemented lambs compared to non-supplemented ones (15.11 *vs.* 10.31 kg) (Fernandes et al., 2011), these results show that keeping lambs with their dams or supplying them with concentrate until slaughter are important strategies to increase the weight of commercial cuts of carcasses. This is explained by the higher digestibility and higher efficiency of metabolizable energy utilization from milk (Geenty, 2010; Ribeiro et al., 2013) and concentrate feed (Clementino et al., 2007; Cartaxo et al., 2011; Jacques, Berthiaume, & Cinq-Mars, 2011; Piola Junior et al., 2020) compared to the forage available on pasture. Additionally, the absence of a stress condition caused by weaning (Napolitano, Rosa, & Sevi, 2008), the learning of grazing activity with the dams, and the social interaction with other individuals from the herd (Provenza, Gregorini, & Carvalho, 2015) are very important aspects contributing to good lamb performance in systems without weaning, resulting in better quality carcasses.

In addition, the ruminal physiology should also be accounted for, where the lambs may have a disproportional development of the forestomach in relation to their body size until 90 days old, as described by Cavalcanti et al. (2014). These authors also reported that a fast growth of the forestomach occurs after weaning, where its mass increase follows the body development in a proportional way (isogonic growth). However, due to lambs being immature ruminants, there is a low efficiency of fibrous component fermentation (forage) in the rumen, and a better utilization of more digestible feedstuffs such as milk and concentrate feed; with the higher intake of these feedstuffs, the lambs' nutritional requirements are easily and efficiently met, resulting in better carcass development and heavier commercial cuts.

When evaluating the carcass traits of Texel × Corriedale lambs in three finishing systems on natural pasture, Hashimoto et al. (2012) observed that weaning and concentrate supplementation did not influence the weight of commercial cuts; probably, the lack of these effects was related to the higher weaning age (70 days), the lower amount and lower quality of concentrate supplement (soybean hulls at 1% BW day^{-1}), and the better quality of pasture available to the lambs (predominance of *Cynodon dactylon*, *Pennisetum clandestinum*, and *Lolium multiflorum* on the natural pasture) compared to the current study. On the other hand, Santos et al. (2010) reported an increase in weight of shoulder, neck, and ribs with the increase in amount of concentrate supplement (0 to 1.5% BW day^{-1}) offered to Santa Ines lambs on natural pasture improved with Buffel grass (*Cenchrus ciliaris* L.); in this case, the positive effect of supplementation was not only related to the amount of concentrate supplied, but also to the low lambs' BW when the supplementation was started (around 16 kg), which had a strong influence on the slaughter weight (around 20 and 27 kg for 0 and 1.5% BW day^{-1} of supplementation, respectively) and commercial cut weights. Gallo et al. (2019) also verified a higher weight of shoulder and ribs in Texel × Santa Ines lambs supplemented with concentrate (2% BW day^{-1}) compared to non-supplemented ones on Aruana grass (*Panicum maximum* syn. *Megathyrsus maximus*) pasture. Corroborating Santos et al. (2010) and Gallo et al. (2019), a positive response to concentrate supplementation on the commercial cuts was also observed in the current study (Table 3).

Table 2. Result of analysis of variance (ANOVA) for weight and yield of commercial cuts, and characteristics of loin of Suffolk lambs (n = 24) in response to the weaning and concentrate supplementation strategies used in the finishing systems on Tifton 85 pasture.

Variable[I]	Source[II]				Mean	SEM[III]	r^2 [III]
	Block	W	S	W × S			
Cuts weight							
Neck (kg)	0.3112	0.0088	0.0007	0.2064	0.555	0.034	0.61
Shoulder (kg)	0.0474	0.0021	<0.0001	0.4726	1.301	0.087	0.74
Uncovered ribs (kg)	0.4857	0.0395	0.0116	0.2971	0.338	0.022	0.45
True ribs (kg)	0.3965	0.0174	<0.0001	0.6049	0.557	0.039	0.67
Breast + flank (kg)	0.0574	0.0017	<0.0001	0.6855	0.693	0.055	0.75
Loin (kg)	0.1511	0.0025	<0.0001	0.5814	0.714	0.055	0.79
Leg (kg)	0.1174	0.0096	<0.0001	0.4999	2.059	0.133	0.74
Cuts yield							
Neck (%)	0.6121	0.9769	0.0280	0.5945	9.03	0.21	0.30
Shoulder (%)	0.0852	0.5311	0.1053	0.7545	21.02	0.30	0.35
Uncovered ribs (%)	0.1516	0.5147	0.0061	0.9362	5.54	0.18	0.46
True ribs (%)	0.3400	0.4124	0.3544	0.0613	8.98	0.20	0.33
Breast + flank (%)	0.2523	0.0612	0.0426	0.6885	10.92	0.23	0.39
Loin (%)	0.8160	0.6390	0.0035	0.6866	11.27	0.25	0.42
Leg (%)	0.6956	0.1777	0.5809	0.4358	33.24	0.32	0.18
Characteristics of loin							
LEW (cm)	0.3417	0.0160	<0.0001	0.5032	5.44	0.18	0.66
LED (cm)	0.1649	0.1958	<0.0001	0.0195	2.37	0.13	0.77
W:D ratio	0.8738	0.3082	0.0008	0.0598	2.37	0.08	0.55
BFT_{MIN} (mm)	0.0421	0.1427	0.0382	0.8159	0.98	0.14	0.45
BFT_{MAX} (mm)	0.0279	0.0007	0.0002	0.9068	2.39	0.28	0.72
BFT_{MEAN} (mm)	0.0178	0.0029	0.0007	0.9745	1.68	0.19	0.68
LEA (cm^2)	0.6229	0.0043	<0.0001	0.1758	11.76	0.85	0.83

[I]LEW: maximum width of loin eye; LED: maximum depth of loin eye; W:D ratio: ratio between LEW and LED; BFT: backfat thickness (MIN: minimum; MAX: maximum); LEA: loin eye area. [II]W: weaning; S: supplementation; W × S: interaction between weaning and supplementation. [III]SEM: standard error of the mean; r^2: coefficient of determination of the statistical model.

Table 3. Weight of commercial cuts from the carcasses of Suffolk lambs (n = 24) in response to the weaning and concentrate supplementation strategies used in the finishing systems on Tifton 85 pasture.

Variable[I]	Weaning[II]	Supplementation[II]		Mean
		S_0	S_1	
Neck (kg)	W_0	0.548 ± 0.088	0.685 ± 0.022	0.617 ± 0.048^A
	W_1	0.338 ± 0.053	0.605 ± 0.017	0.471 ± 0.036^B
	Mean	0.443 ± 0.036^b	0.645 ± 0.018^a	
Shoulder (kg)	W_0	1.208 ± 0.177	1.707 ± 0.115	1.458 ± 0.126^A
	W_1	0.767 ± 0.109	1.415 ± 0.035	1.091 ± 0.074^B
	Mean	0.987 ± 0.074^b	1.561 ± 0.072^a	
Uncovered ribs (kg)	W_0	0.341 ± 0.056	0.405 ± 0.032	0.373 ± 0.032^A
	W_1	0.219 ± 0.039	0.363 ± 0.021	0.291 ± 0.027^B
	Mean	0.280 ± 0.027^b	0.384 ± 0.019^a	
True ribs (kg)	W_0	0.491 ± 0.069	0.734 ± 0.063	0.612 ± 0.058^A
	W_1	0.329 ± 0.055	0.626 ± 0.020	0.478 ± 0.037^B
	Mean	0.410 ± 0.037^b	0.680 ± 0.035^a	
Breast + flank (kg)	W_0	0.622 ± 0.112	0.964 ± 0.060	0.793 ± 0.079^A
	W_1	0.360 ± 0.068	0.754 ± 0.034	0.557 ± 0.046^B
	Mean	0.491 ± 0.046^b	0.859 ± 0.046^a	
Loin (kg)	W_0	0.607 ± 0.103	0.988 ± 0.041	0.798 ± 0.078^A
	W_1	0.374 ± 0.061	0.819 ± 0.021	0.597 ± 0.041^B
	Mean	0.490 ± 0.041^b	0.904 ± 0.034^a	
Leg (kg)	W_0	1.828 ± 0.235	2.668 ± 0.129	2.248 ± 0.180^A
	W_1	1.188 ± 0.137	2.379 ± 0.055	1.783 ± 0.092^B
	Mean	1.508 ± 0.092^b	2.524 ± 0.080^a	

[I]Values expressed as mean ± standard error. [II]W_0: non-weaned; W_1: weaned; S_0: non-supplemented; S_1: supplemented. Lowercase letters in the row and uppercase letters in the column compare the means by F test ($p < 0.05$).

Regarding the systems without weaning, the neck weight was higher, the shoulder weight was similar, and the weight of other cuts obtained in the current study (Table 3) were lower than those observed by Pellegrin et al. (2018) in non-weaned Texel × Ile de France lambs finished on annual ryegrass (*Lolium multiflorum* Lam.) pasture, supplemented or not with concentrate at 1.15% BW day^{-1} in creep feeding, and slaughtered at 31 kg BW. The authors verified no effect of supplementation on the weight of commercial cuts, and the better results obtained by them for most of the cut weights was probably related with the better quality of the pasture.

Keeping lambs with their dams and concentrate supplementation, both until slaughter, are important strategies to increase the weight of the prime cuts of lambs carcasses (Table 3). The weight of shoulder, loin, and leg were, respectively, 33.6, 33.7, and 26.1% higher in the systems without weaning compared to the systems with weaning; the weight of the same cuts in the systems with supplementation were, respectively, 58.2, 84.5, and 67.4% higher than in the systems without supplementation. Obtaining heavier prime cuts is necessary to increase the yield of the edible portion (muscle), and to offer meat cuts of better quality to consumers, which contributes to ensuring the maintenance of the lamb meat market. As the weight and yield of carcass are the main traits used to define commercial value, farmers can get a better remuneration by producing lamb carcasses with increased weight and yield of commercial cuts. This is a way to increase the revenue from lamb meat commercialization and hence, improve the economic result of sheep production (Prado et al., 2013; Raineri, Santos, & Gameiro, 2015). It is highlighted that the concentrate supplementation had a greater impact on the prime cuts than the non-weaning of lambs. This indicates an advantage for the supplementation offered on grazing after weaning, since this strategy promotes an increase in the productivity and the production of better quality carcasses (Carvalho et al., 2006; Silva et al., 2014).

Regarding the yield of commercial cuts, there was an independent effect of concentrate supplementation on the yield of neck, uncovered ribs, breast + flank, and loin (Table 2). Supplemented lambs had lower yields of neck and uncovered ribs, and higher yields of breast + flank, and loin (Table 4).

Table 4. Yield of commercial cuts from the carcasses of Suffolk lambs (n = 24) in response to the weaning and concentrate supplementation strategies used in the finishing systems on Tifton 85 pasture.

Variable[I]	Weaning[II]	Supplementation[II]		Mean
		S_0	S_1	
Neck (%)	W_0	9.62 ± 0.56	8.47 ± 0.39	9.04 ± 0.37
	W_1	9.42 ± 0.42	8.69 ± 0.21	9.06 ± 0.29
	Mean	9.52 ± 0.29^a	8.58 ± 0.21^b	
Shoulder (%)	W_0	21.61 ± 0.82	20.85 ± 0.72	21.23 ± 0.53
	W_1	21.44 ± 0.59	20.33 ± 0.26	20.88 ± 0.40
	Mean	21.53 ± 0.40	20.59 ± 0.37	
Uncovered ribs (%)	W_0	5.94 ± 0.30	4.99 ± 0.39	5.46 ± 0.27
	W_1	6.11 ± 0.32	5.21 ± 0.29	5.66 ± 0.21
	Mean	6.02 ± 0.21^a	5.10 ± 0.24^b	
True ribs (%)	W_0	8.72 ± 0.11	9.03 ± 0.74	8.87 ± 0.36
	W_1	9.20 ± 0.46	9.01 ± 0.28	9.10 ± 0.31
	Mean	8.96 ± 0.31	9.02 ± 0.38	
Breast + flank (%)	W_0	10.75 ± 0.41	11.81 ± 0.46	11.28 ± 0.33
	W_1	10.09 ± 0.44	10.82 ± 0.38	10.46 ± 0.30
	Mean	10.42 ± 0.30^b	11.32 ± 0.32^a	
Loin (%)	W_0	10.50 ± 0.64	12.16 ± 0.38	11.33 ± 0.43
	W_1	10.47 ± 0.47	11.77 ± 0.21	11.12 ± 0.32
	Mean	10.49 ± 0.32^b	11.96 ± 0.22^a	
Leg (%)	W_0	32.86 ± 0.99	32.70 ± 0.58	32.78 ± 0.55
	W_1	33.27 ± 0.72	34.17 ± 0.25	33.72 ± 0.48
	Mean	33.06 ± 0.48	33.44 ± 0.38	

[I]Values expressed as mean ± standard error. [II]W_0: non-weaned; W_1: weaned; S_0: non-supplemented; S_1: supplemented. Lowercase letters in the row and uppercase letters in the column compare the means by F test ($p < 0.05$).

With the increased carcass weight of supplemented lambs (Fernandes et al., 2011), there was a higher deposition of muscle and fat in the breast + flank, and loin, which are cuts that present late development compared to the neck and uncovered ribs (Galvani, Pires, Oliveira, Wommer, & Jochims, 2008; Carvalho et al., 2016). As both these cuts cease their growth early, the other cuts continue developing and hence, present a higher yield with the increase of carcass weight. In fact, Hashimoto et al. (2012) observed that the loin presented late growth, and the muscle: fat ratio decreased whereas the intermuscular fat deposition increased in leg of lambs supplemented with concentrate on a natural pasture. The same responses may have occurred in the lambs that were supplemented in the current study, even though the yield of leg was not been affected by the concentrate supplementation.

There were independent effects of weaning and concentrate supplementation on the LEW, BFT_{MAX}, BFT_{MEAN}, and LEA, and the supplementation also affected the W:D ratio and BFT_{MIN} (Table 2). Except for the W:D ratio, these traits presented lower values in weaned lambs compared to non-weaned ones, and higher values in supplemented lambs compared to non-supplemented ones; the W:D ratio was lower in supplemented lambs in relation to non-supplemented ones (Table 5). An interaction between weaning and supplementation was also detected for LED (Table 2), which was lower in weaned and non-supplemented lambs (Table 5). These results demonstrate that keeping lambs with their dams and supplying concentrate supplement until slaughter affected body composition, resulting in greater muscle development and higher fat deposition on the lambs' carcasses.

Table 5. Characteristics of loin of Suffolk lambs (n = 24) in response to the weaning and concentrate supplementation strategies used in the finishing systems on Tifton 85 pasture.

Variable[I]	Weaning[II]	Supplementation[II]		Mean
		S_0	S_1	
LEW (cm)	W_0	5.22 ± 0.34	6.17 ± 0.13	5.69 ± 0.22^{A}
	W_1	4.24 ± 0.21	5.88 ± 0.14	5.06 ± 0.14^{B}
	Mean	4.73 ± 0.14^{b}	6.03 ± 0.10^{a}	
LED (cm)	W_0	2.17 ± 0.18^{Ab}	2.83 ± 0.14^{Aa}	2.50 ± 0.15
	W_1	1.51 ± 0.13^{Bb}	2.82 ± 0.03^{Aa}	2.16 ± 0.09
	Mean	1.84 ± 0.09	2.83 ± 0.07	
W:D ratio	W_0	2.45 ± 0.08	2.20 ± 0.12	2.33 ± 0.08
	W_1	2.82 ± 0.13	2.08 ± 0.06	2.45 ± 0.09
	Mean	2.64 ± 0.09^{a}	2.14 ± 0.07^{b}	
BFT_{MIN} (mm)	W_0	0.83 ± 0.31	1.42 ± 0.33	1.13 ± 0.23
	W_1	0.53 ± 0.25	1.00 ± 0.22	0.76 ± 0.17
	Mean	0.68 ± 0.17^{b}	1.21 ± 0.20^{a}	
BFT_{MAX} (mm)	W_0	2.25 ± 0.53	3.75 ± 0.44	3.00 ± 0.40^{A}
	W_1	0.84 ± 0.36	2.42 ± 0.20	1.63 ± 0.24^{B}
	Mean	1.54 ± 0.24^{b}	3.08 ± 0.31^{a}	
BFT_{MEAN} (mm)	W_0	1.54 ± 0.41	2.58 ± 0.32	2.06 ± 0.29^{A}
	W_1	0.68 ± 0.27	1.71 ± 0.20	1.20 ± 0.18^{B}
	Mean	1.11 ± 0.18^{b}	2.15 ± 0.22^{a}	
LEA (cm²)	W_0	9.96 ± 1.14	15.70 ± 0.53	12.83 ± 1.05^{A}
	W_1	6.22 ± 0.86	14.21 ± 0.63	10.22 ± 0.58^{B}
	Mean	8.09 ± 0.58^{b}	14.96 ± 0.45^{a}	

[I]Values expressed as mean ± standard error; LEW: maximum width of loin eye; LED: maximum depth of loin eye; W:D ratio: ratio between LEW and LED; BFT: backfat thickness (MIN: minimum; MAX: maximum); LEA: loin eye area. [II]W_0: non-weaned; W_1: weaned; S_0: non-supplemented; S_1: supplemented. Lowercase letters in the row and uppercase letters in the column compare the means by F test ($p < 0.05$).

Following the results of weight and yield of commercial cuts (Tables 3 and 4), the concentrate supplementation had a greater influence on the characteristics of loin than the non-weaning of lambs, which is confirmed by the lower W:D ratio and higher LEA of supplemented lambs compared to non-weaned lambs (W:D ratio = 2.14 *vs.* 2.33; LEA = 14.96 *vs.* 12.83 cm^2, respectively; Table 5) – this is not a statistical comparison, but only a numerical comparison. These measurements reflect the morphology of the loin eye, which was more rounded (low W:D ratio) and larger (high LEA) in supplemented lambs, indicating a higher muscle tissue deposition in the carcasses. The increase of carcass muscularity with the increase of concentrate intake was verified in other studies with lambs finished in feedlot (Clementino et al., 2007; Cartaxo et al., 2011) and in grazing with concentrate supplementation (Hashimoto et al., 2012; Gallo et al., 2019). The carcass fatness was also slightly higher in supplemented lambs, since they presented higher BFT_{MIN} than non-supplemented ones (1.21 *vs.* 0.68 mm, respectively), whereas this characteristic did not differ between weaned and non-weaned lambs (mean of 0.95 mm). The increase of covering fat thickness in the carcass occurs with a great increase in dietary energy content (Clementino et al., 2007; Jacques et al., 2011; Piola Junior et al., 2020), which was observed between the systems with and without concentrate supplementation.

In the systems without weaning, free access to milk intake allows lambs to meet their nutritional requirements more efficiently than using only pasture. However, the concentrate supplementation offered in creep feeding may reduce the dependence of lambs on the dams' milk and improve their performance (Zundt et al., 2014; Peruzzi, Monreal, Caramalac, & Caramalac, 2015; Santos et al., 2018), which would result in carcasses with higher muscularity, and higher thickness and uniformity of covering fat. This was observed in the current study, since the LEA and the fat thickness measurements over the *longissimus* muscle had the highest values in the carcasses of lambs supplemented in creep feeding (Table 5). This response was not reported in other studies with purebred or crossbred lambs from late maturing breeds, such as Ile de France and Suffolk, probably due to the lower amount of concentrate supplement offered in creep feeding (around 1% BW day^{-1}) (Prado et al., 2013; Pellegrin et al., 2018), or the low quality of the pasture in which this strategy was used (Ribeiro et al., 2013).

Another aspect that should be highlighted is the variation of the means for weight and yield of cuts (Tables 3 and 4), and for the characteristics of *longissimus* muscle of lambs (Table 5) in response to non-weaning and to concentrate supplementation. The standard error of most traits was lower for supplemented lambs compared to non-weaned lambs. This indicates a greater uniformity of the commercial cuts (based on size, weight, muscularity, and fat deposition) obtained with the use of concentrate supplementation strategy compared to those obtained with the non-weaning strategy. Therefore, the concentrate supplementation offered in creep feeding or after weaning to grazing lambs can be used to produce standardized commercial cuts to meet the lamb meat market. It is worth mentioning that the positive results for the characteristics of commercial cuts and *longissimus* muscle occurred in response to the concentrate supplementation at 2% BW day^{-1}, since lower supplementation levels (below 1.5% BW day^{-1}) do not provide the same results in non-weaned or weaned lambs finished on pasture (Santos et al., 2010; Prado et al., 2013; Pellegrin et al., 2018).

Conclusion

Keeping lambs with their dams and offering concentrate supplementation, both until slaughter, are strategies recommended for the finishing systems of Suffolk lambs on Tifton 85 pasture to obtain heavier carcass cuts, with high muscularity and fat content. The magnitude of these responses is greater with the concentrate supplementation offered to lambs before (creep feeding) or after weaning.

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