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ANIMAL SCIENCE

Effects of maternal nutrition regimen of ewes on performance, carcass, and meat traits of their feedlot-finished lambs

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Abstract: The objective of this study was to evaluate the effects of diets with two energy levels fed to Ile de France ewes during the last third of gestation on the performance, carcass, and meat traits of their offspring. Treatments were: D0: maternal diet meeting the requirements for the last third of gestation, and D20: maternal diet containing an additional 20% energy requirements. Twenty single-born male lambs, ten from each group of ewes, were weaned at 60 d (18.3 ± 1.4 kg initial BW) and fed a common finishing diet. Animals were slaughtered when they reached 32 kg BW. Dry matter intake, average daily gain, feed conversion, and days on feed were unaffected by treatments (P≥0.09). No effects were observed on hot and cold carcass weights, dressing percentage, chilling loss, commercial cuts yields, and loin-eye area (P≥0.17). Meat pH, thawing loss, cooking loss, shear force, and water holding capacity were also not affected by treatments (P≥0.09). Temperature and meat color, as well as centesimal composition were similar between treatments (P≥0.27). Adding 20% energy on top of the requirements of Ile de France ewes during the last third of gestation does not influence the performance, carcass traits, nor meat traits of their offspring.

Key words: energy, fetal programming, lamb, sheep, tissue composition.

INTRODUCTION

The maternal nutrition during gestation affects fetal development and may influence the performance, carcass, and meat traits of the offspring (Sartori et al. 2020). Some disturbances involving feed restriction or overfeeding during gestation can affect the offspring's skeletal muscle composition and, consequently, influence meat quality (Costa et al. 2021). This maternal stimulus at a critical period was defined as fetal or developmental programming (Barker et al. 1993). According to Kenyon & Blair (2014), there is enough evidence suggesting fetal programming could be used to increase sheep productivity, but this must be economically advantageous for the producers.

Vonnahme (2012) found that feed restriction to mothers during gestation reduced the vascularization of their placenta, limiting nutrient supply to the fetus and the expression of its genetic growth potential. Specifically, regarding energy restriction during late gestation, there are reports of downregulation of genes involved in oxidative metabolism, which affects glycolytic metabolism in the skeletal muscle (Sanglard et al. 2018). On the other hand, Swanson et al. (2008) observed that overfeeding ewes in the middle and last thirds of gestation, by providing diets containing up to 140% of their energy requirements, reduced the birth weight of lambs.

Therefore, it is crucial to validate the impact of maternal nutrition on lamb production, since the consumer market values carcasses with greater uniformity and quality, with maximum muscle deposition and sufficient fat to provide satisfactory organoleptic characteristics of meat (Osório et al. 2005). It is clear that there are stimuli during the gestational stage that induce changes in the supply of substrates and oxygen in the fetus-placental environment that have repercussions on fetal growth and birth weight. However, the limit necessary for this induction to be effective in modifying the proximate composition of the meat and the synthesis of fatty acids, in a safe way for the ewe, the offspring, and the consumer, is still under discussion and controversial.

The hypothesis is that changes in the formation of the muscle fiber during fetal development, in response to additional energy in ewe's diets, result in different lamb performance, carcass, and meat characteristics. Thus, this study was designed to evaluate the influence of diets with two energy levels (one meeting the energy requirements [NRC 2007], and the other exceeding 20% of energy requirements) fed to Ile de France ewes during the last third of gestation on performance, carcass quantitative traits, and meat qualitative traits of their offspring.

MATERIALS AND METHODS

All experimental procedures followed the principles of animal experimentation from the National Council for the Control of Animal Experimentation (CONCEA) and were approved by the Committee of Ethics in Animal Use (CEUA) from São Paulo State University (approval #018943/14).

Local, experimental treatments and management

The experiment was conducted at the Sheep Laboratory from the Animal Science Department, São Paulo State University "Julio de Mesquita Filho" (FCAV/Unesp), Jaboticabal, São Paulo, Brazil (21°15'22" S latitude and 48°18'58" W latitude, 595 m altitude).

Fifty Ile de France ewes, averaging 20 months old and 60 ± 4.1 kg body weight (BW), were mated with the same Ile de France ram by natural service during the breeding season. Upon reaching 100 days of gestation, the 50 ewes underwent an ultrasound examination of the gravid uterus, after which 40 animals in a single pregnancy were selected. This new lot was divided into two groups of 20 pregnant ewes, which were allocated to two 0.5-ha paddocks cultivated with Tifton-85 bermudagrass (*Cynodon* spp.), which were kept with forage sward at 4 cm, to not affect feed intake. Paddocks were equipped with feedbunks and waterers.

The experimental diets fed to the ewes (Table I) had two levels of energy: one was formulated to meet the nutritional requirements of the last third of gestation (D0), and the other had an additional 20% of the energy requirements (D20), following NRC (2007) recommendations. Diets were delivered twice daily at 0700 and 1700 h (50:50), to allow *ad libitum* access to feed, observing approximately 10% orts. Samples of diets (delivered and refused) were sampled weekly for later chemical analyses, and the amount of feed delivered was adjusted daily.

After lambing, the ewes were allocated to the maternity paddock (approximately 1 ha), which was also cultivated with Tifton-85 bermudagrass and equipped with feedbunks and waterers, where they were fed a common diet, formulated according to NRC (2007) for lactation phase, and a creep-feeding diet was provided to the lambs

Table I. Ingredient and chemical composition of diets fed to experimental ewes at the last third of gestation.

Item	Diet	
	D0	D20
Ingredient (% DM)		
Corn silage	70.00	30.00
Soybean meal	19.88	20.90
Ground corn	8.16	43.10
Mineral-vitamin premix[1]	1.00	1.00
Calcitic limestone	0.54	0.80
Dicalcium phosphate	0.22	0.00
Soybean oil	0.00	4.00
NaCl	0.20	0.20
Analyzed nutrient composition		
Dry matter, %	48.79	72.41
Organic matter, % DM	93.14	94.35
Crude protein, % DM	15.47	15.59
Ether extract, % DM	2.85	6.99
Minerals, % DM	6.86	5.65
Neutral detergent fiber, % DM	42.74	25.62
Acid detergent fiber, % DM	25.88	13.94
Total carbohydrates, % DM[2]	74.82	71.77
Non-fibrous carbohydrates, % DM[3]	32.08	46.15
Metabolizable energy, Mcal kg^{-1} DM[4]	2.39	2.87

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation.
[1]Composition per kilogram: calcium - 120 g; chlorine - 90 g; sodium - 62 g; magnesium - 54 g; phosphorus - 50 g; sulfur - 34 g; zinc - 1.600 mg; manganese - 1.500 mg; iron - 1.064 mg; fluorine (max) - 730 mg; copper - 50 mg; iodine - 25 mg; selenium 20 mg; cobalt - 10 mg; Vit. A - 100.000 IU; Vit. D3 - 40.000 IU; Vit. E - 600 IU.
[2]Calculated according to Sniffen et al. (1992).
[3]Calculated according to Weiss (1999).
[4]Estimated based on NRC (2007).

Performance evaluations

The survival rate from birth to weaning was 80%, resulting in 32 lambs. From those, 20 single-born male lambs (18.3 ± 1.4 kg initial BW), 10 from each treatment were used. Lambs were weaned 60 days after lambing, with 18.3 ± 1.4 kg BW, identified according to the mothers' prenatal dietary treatment, dewormed, vaccinated against clostridial diseases, and housed in individual 1-m^2 suspended slatted-floor pens. The animals' entry interval into the feedlot facility was 20 days.

The lambs' diets had a roughage:concentrate ratio of 40:60 and were composed of 16% crude protein (CP) and 3.00 Mcal ME^{-1} kg DM, following the recommendations of the NRC (2007), to meet the requirements of growing lambs with an expected average daily weight gain of 300 g (Table II). The animals were fed the total mixed ration twice daily, at 0700 and 1700 h (50:50), to allow *ad libitum* access to feed, allowing approximately 10% orts. Feed and orts were weighed daily and adjusted. Feed samples were collected weekly and 10% orts were collected

Table II. Ingredient and chemical composition of diets fed to experimental feedlot lambs.

Item	Diet
Ingredient (% DM)	
Corn silage	40.00
Soybean meal	21.00
Ground corn	36.25
Mineral-vitamin premix[1]	1.00
Limestone	0.30
Dicalcium phosphate	1.45
Analyzed nutrient composition	
Dry matter, %	66.28
Crude protein, % DM	15.88
Ether extract, % DM	3.07
Minerals, % DM	6.77
Neutral detergent fiber, % DM	30.21
Acid detergent fiber, % DM	17.04
Metabolizable energy, Mcal kg^{-1} DM[2]	2.64

[1]Composition per kilogram: calcium - 120 g; chlorine - 90 g; sodium - 62 g; magnesium - 54 g; phosphorus - 50 g; sulfur - 34 g; zinc - 1.600 mg; manganese - 1.500 mg; iron - 1.064 mg; fluorine (max) - 730 mg; copper - 50 mg; iodine - 25 mg; selenium 20 mg; cobalt - 10 mg; Vit. A - 100.000 IU; Vit. D3 - 40.000 IU; Vit. E - 600 IU.
[2]Estimated based on NRC (2007).

daily for dry matter (DM) determination and DM intake (DMI) calculation.

Every 14 days, the lambs were weighed and the incidence of *Haemonchus contortus* was monitored by the Famacha® method (Van Wyk & Bath 2002). Using the initial BW (IBW), final BW (FBW), and days on feed (DOF), we calculated the average daily gain (ADG = [FBW-IBW]/DOF). The feed conversion (FC) was calculated as FC = DMI/ADG.

Carcass and meat traits

When lambs reached approximately 32 kg BW, they were harvested at the FCAV/Unesp experimental abattoir, after a 16-h solid fast, following a humane slaughter, according to MAPA (2000), and slaughter weight (SW) was recorded. The carcass pH and temperature were measured 45 min after the slaughter (pH_{45min}, T_{45min}), in triplicate, by inserting a penetration electrode, equipped with a pH meter and thermometer (Testo 205, Testo AG, Lenzkirch, Germany), into the *Longissimus lumborum* muscle between the 12th and 13th ribs. After measurements, the carcasses were weighed to access the hot carcass weight (HCW) and transferred to a cold room at approximately 6 °C, where they remained for 24 h, hung by the gastrocnemius tendons. After chilling, meat pH values (pH_{24h}), temperature (T_{24h}), and the color attributes by the coordinates L* (lightness), a* (redness), and b* (yellowness), were measured according to Miltenburg et al. (1992), using a colorimeter (CR-400, Konica Minolta Sensing Inc., Osaka, Japan). The carcasses were reweighed to determine the cold carcass weight (CCW). Hot carcass yield (HCY % = (HCW/SW) × 100), cold carcass yield (CCY % = (CCW/SW) × 100), carcass dressing percentage (CD % = (HCW/SW) × 100), and chilling loss (CL % = [(HCW – CCW)/HCW] × 100) were also calculated.

Carcasses were sectioned into two half-carcasses, and the left half was divided into five anatomical regions: neck, shoulder, ribs, loin, and leg (Silva Sobrinho et al. 2008). Using a digital caliper and a graduated tape at the 13th rib over the *Longissimus dorsi* muscle, we measured the maximum length (measure A), maximum depth (measure B), minimum fat thickness on the muscle (measure C), and maximum fat thickness on the surface of the 13th rib, at 11 cm from the midline (measure F), and the loin-eye area (LEA) was calculated using the following formula: $(A/2 \times B/2)\pi$, following methodology described by Silva Sobrinho et al. (2003).

Meat quantitative analyses, including water holding capacity (WHC), thawing (TL) and cooking (CKL) losses, shear force (SF), and centesimal composition, were performed on the *Longissimus lumborum* muscle. The water holding capacity (WHC), was determined by adapting the filter-paper press method, proposed by Hamm (1986), using 500-mg samples and 10-kg load pressing for 5 min. Results were expressed as a percentage of water lost relative to the initial sample weight. The TL was determined following the methodology described by Koohmaraie et al. (1996). Fresh meat samples were weighed, frozen, and kept in a BOD incubator at 5 °C for 16 h, to reach an internal temperature between 2 and 5°C. After incubation time, samples were reweighed and TL was calculated. To determine CKL, samples were weighed in grill pans and heated in a gas oven at 170 °C until reaching an internal temperature of 71 °C. Afterward, they were removed from the oven, cooled to room temperature, and reweighed. Subsequently, to determine the shear force, six sub-samples were collected with a 1.27-cm diameter cylinder punch (Wheeler & Koohmaraie 2002), evaluated with a texture analyzer (CT3, Brookfield Engineering Laboratories Inc., USA) coupled to a 1.016-mm-thick Warner-Bratzler blade, and values were expressed in kgf. Analyses of the centesimal composition of the *Longissimus lumborum* muscle for moisture, protein, fat, and minerals followed the recommendations described by Silva & Queiroz (2002).

For dissection, the legs were thawed at 10 °C in a refrigerator for 8 h and cleaned for removal of any extra tissue, adjunct fat, and other soft tissues medial to the pelvic bone and coccygeal vertebrae. Thus, they were weighed and dissected following the methodology described by Brown & Williams (1979), separating the groups of tissues: fat (external, subcutaneous, and intermuscular), bones, muscles (*Biceps femoris*, *Semitendinosus*, *Adductor*, *Semimembranosus*, and *Quadriceps femoris*) and others (tendons, glands, and blood vessels). The leg muscularity index (LMI) was calculated according to Purchas et al. (1991): LMI = √(W5M/FL)/FL, where WM5 = weight (g) of the five muscles surrounding the femur (*Biceps femoris*, *Semitendinosus*, *Adductor*, *Semimembranosus*, and *Quadriceps femoris*) and FL = femur length (cm).

Statistical analyses

The experiment was carried out in a completely randomized design with two treatments, ten replications, and lambs were considered the experimental units. The following statistical model was used: $Y_{ij} = \mu + T_i + e_{ij}$, where Y_{ij} = observed value of the dependent variable i; μ = overall mean; T_i = effect of treatment i (i = 1–2); and e_{ij} = random error. Data were submitted to normality (Kolmogorov-Smirnov) and variance homoscedasticity (Levene) tests and analyzed using the GLM procedure of SAS statistical software (version 9.2). The significance was defined as P<0.05.

RESULTS

Performance traits

The average days on feed were similar between the lambs born from ewes fed diets with or without the additional 20% energy (average = 54 d; P=0.67), with no effect on initial body weight (average = 18.3 kg; P=0.09) and final body weight (average = 32.4 kg; P=0.32). No treatment differences were also observed on lamb's DMI (average = 1.06 kg; P=0.09), ADG (average = 0.254 kg; P=0.32) nor for FC (average = 4.15; P=0.09; Table III).

Carcass and meat traits

Carcass quantitative traits, such as HCW (average = 15.0 kg; P=0.19) and CCW (average = 14.5 kg; P=0.17), their respective yields (average HCY = 47.5%; P=0.56, and average CCY = 46.1%; P=0.57), and dressing percentage (average = 56.8%; P=0.56) did not differ (Table IV) between treatments tested. The same was true for the commercial cuts, which average values were 1.70 kg shoulder (P=0.37), 0.470 kg neck (P=0.77), 1.67 kg ribs (P=0.31), 0.85 kg loin (P=0.47, and 2.50 kg leg (P=0.51; Table V).

Regarding carcasses' tissue composition, similar percentage values were observed for bone (average = 17.4%; P=0.90), muscle (average = 65.8%; P=0.55), and fat (average = 14.3%; P=0.73; Table VI). The LMI values of both treatments were similar (average = 0.53; P=0.36). The same trend was observed for femur weight and length

Table III. Effects of maternal nutrition on dry matter intake and feedlot performance of lambs.

Item	Diet		P-value	SEM
	D0	D20		
Days on feed, n	55.00	53.00	0.67	0.11
Initial body weight, kg	18.00	18.63	0.85	0.14
Final body weight, kg	32.50	32.30	0.32	0.15
Average daily gain, kg	0.27	0.24	0.32	0.05
Dry matter intake, kg	1.10	1.02	0.09	0.10
Feed conversion, kg kg^{-1}	4.04	4.30	0.09	0.12

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation; SEM - standard error of the mean.

(averages = 139.20 g [P=0.60], and 16.2 cm [P=0.49], respectively).

The characteristics of *Longissimus dorsi* muscle of lamb born from ewes fed diets with or without 20% additional energy were similar for maximum length (average = 5.33 cm; P=0.93), maximum depth (average = 3.26 cm; P=0.58), minimum fat thickness (average = 2.67 mm; P=0.55), maximum fat thickness (average = 5.33 mm; P=0.74), and LEA (average = 13.97 cm^2; P=0.17; Table VII).

Meat qualitative traits, evaluated at 45 min: pH_{45min} (average = 6.63; P=0.64), T_{45min} (average = 37.4 °C; P=0.85), L^*_{45min} (average = 31.8; P=0.38), a^*_{45min} (average = 12.4; P=0.38), b^*_{45min} (average = 2.3; P=0.74), and at 24h postmortem: pH_{24h} (average = 5.67; P=0.63), T_{24h} (average = 6.88 °C; P=0.58), L^*_{24h} (average = 37.6; P=0.83), a^*_{24h} (average = 14.6; P=0.26), b^*_{24h} (average = 2.05; P=0.71), as well as TL (average = 2.61%; P=0.21), WHC (average = 61.35%; P=0.89), SF (average = 2.83 kgf cm^{-2}; P=0.33) and CKL (average = 27.8%; P=0.09) did not differ between treatments (Table VIII).

The centesimal composition of the *Longissimus lumborum* muscle was unaffected by treatments, with average minerals (average = 1.07%; P=0.42), protein (average = 19.6%; P=0.48), fat (average = 2.08%; P=0.48), and moisture (average = 77.8%; P=0.66; Table IX).

Table IV. Effects of maternal nutrition on carcass traits of feedlot lambs.

Item	Diet		P-value	SEM
	D0	D20		
HCW, kg	14.82	15.18	0.19	0.22
CCW, kg	14.37	14.73	0.17	0.30
FCW, kg	25.89	27.00	0.12	0.22
HCY, %	47.33	47.76	0.56	0.41
CCY, %	45.89	46.37	0.57	0.52
CD, %	57.34	56.22	0.56	0.57
CL, %	3.04	2.92	0.77	0.39

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation; SEM - standard error of the mean. HCW - hot carcass weight; CCW - cold carcass weight; FCW - full-carcass weight; HCY - hot carcass yield; CCY - cold carcass yield; CD - carcass dressing percentage; CL - chilling loss.

Table V. Effects of maternal nutrition on commercial cuts yield of feedlot lambs.

Item	Diet		P-value	SEM
	D0	D20		
Left half-carcass, kg	7.15	7.39	0.29	0.15
Shoulder, kg	1.69	1.71	0.37	0.11
Neck, kg	0.47	0.48	0.77	0.01
Ribs, kg	1.69	1.63	0.31	0.14
Loin, kg	0.87	0.84	0.47	0.07
Leg, kg	2.48	2.52	0.51	0.06

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation; SEM - standard error of the mean.

DISCUSSION

Performance traits

The results found in recent studies in which fetal programming was evaluated, especially when testing the overnutrition of ewes and the effects on the offspring, are highly heterogeneous (Sartori et al. 2020).

It is known that the development of skeletal muscle is dependent on the availability of nutrients during the fetal stage and malnutrition limits post-natal muscle growth, increasing the time and costs necessary to achieve the market weight of these animals (Du et al. 2013, Bell & Greenwood 2016). On the other hand, some research indicates that overnourishing ewes during gestation could negatively impact the performance of the offspring, impairing organ development (Wallace et al. 2002; using Border Leicester × Scottish Blackface), myogenesis in fetal skeletal muscle (Tong et al. 2009; using

Rambouillet × Columbia ewes) and causing light birth weights (Da Silva et al. 2001; using Border Leicester × Scottish Blackface ewes). Reed et al. (2014), working with Dorset, Shropshire, and Southdown ewes reported that both over (140%) or restricted (60% requirement) maternal nutrition of ewes during gestation affect muscle fiber cross-sectional area, lipid accumulation, muscle fiber type, and gene and protein expression in the muscle of lambs, impairing post-natal muscle growth.

In the present study, lambs from the two different treatments reached similar weights at 60 days of age (feedlot initial BW), maintained the same DMI and ADG during the finishing phase, and were slaughtered at the same final body weight, resulting in a similar number of days on feed. Similar results were observed by Peel et al. (2012), who overfed ewes 22% above the recommended nutritional requirements and observed no effect on the post-natal performance of lambs. The same was reported by Wilson et al. (2016), who fed beef cows in late gestation 100 or 125% energy requirements and observed no effects on the performance or carcass traits of the offspring. In contrast, Oliveira (2020), studying fetal programming using Dorper × Santa Inês ewes fed up to 110% energy requirements, observed that the surplus energy resulted in lambs with the best performance at 60 days of age.

Research has shown prepartum diets cause notable changes in gene expression in fetal *Longissimus dorsi* muscle, subcutaneous, and perirenal adipose tissues. Peñagaricano et al. (2014) evaluating the effects of ewe's maternal nutrition on the structure, physiology, and metabolism of the offspring, reported that the diet with high fiber, protein, and fat concentrations impacted fetal subcutaneous and perirenal adipose tissues, and many of the most significantly altered genes are associated with skeletal muscle development (i.e., MYOD1, ANKRD1, HIRA). Sousa et al. (2023) overfed Morada Nova ewes (21% more ME than the requirements or 26% more ME and CP), and reported significantly improved production rates, hormonal profile, placental characteristics, neonatal behavior, and lambs' performance. However, the diets used in the current study

Table VI. Effects of maternal nutrition on tissue composition and leg muscularity index of feedlot lambs.

Item	Diet		P-value	SEM
	D0	D20		
Muscle:bone ratio	3.74	3.85	0.94	0.01
Leg muscularity index (LMI)	0.54	0.52	0.36	0.11
Femur weight, g	138.39	140.02	0.60	0.10
Leg weight, kg	2.36	2.37	0.88	0.03
Femur length, cm	16.00	16.35	0.49	0.16
Bone, %	17.43	17.25	0.90	0.02
Muscle, %	65.16	66.47	0.55	0.05
Fat, %	14.60	13.98	0.73	0.02
Others, %	2.81	2.31	0.22	0.20

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation; SEM - standard error of the mean.

Table VII. Effects of maternal nutrition on length (A), maximum depth (B), minimum thickness (C), and maximum thickness (F) of fat and loin-eye area (LEA) of the *Longissimus* muscle of feedlot lambs.

Item	Diet		P-value	SEM
	D0	D20		
A, cm	5.38	5.40	0.93	0.06
B, cm	3.15	3.38	0.58	0.07
C, mm	2.72	2.63	0.55	0.08
F, mm	5.28	5.39	0.74	0.55
LEA, cm^2	13.52	14.43	0.17	0.40

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation; SEM - standard error of the mean.

were not different enough to translate those effects in lamb's feedlot performance.

Carcass and meat traits

Despite the similarity between treatments, the average HCW (15.0 kg), CCW (14.5 kg), and CD (56.8%) were greater than those found by Zundt et al. (2006), who studied feedlot-finished lambs born from ewes supplemented in the initial, middle, and last thirds of gestation, and found average HCW, CCW, and CD of 13.96 kg, 13.61 kg, and 55.63%, respectively. Those differences are probably due to differences in the breed and nutritional regimen adopted in both trials. However, the CD values of the present research (56.8%) agree with those proposed by Sañudo & Sierra (1986), as adequate for sheep commercial carcasses.

The lack of effects of treatments on commercial cuts yield (left half-carcass, shoulder, neck, ribs, loin, leg) follows the same trend of performance traits. It indicates no changes occurred in body composition, which was confirmed with the centesimal analysis of the *Longissimus*. There are no reported results in the literature, so far, of commercial cuts of animals from fetal programming with the use of overfeeding, especially with the sheep species, showing the relevance of the present study. What is well-established is that lamb cut yields are reduced when ewes undergo nutrient restrictions of 40 or 30% during pregnancy (Piaggio et al. 2018).

According to Du et al. (2015), the skeletal muscle matures at late gestation in sheep (approximately day 105 of gestation) and nutrient restriction after this stage has no major impact on muscle fiber number, only in the size of the muscular fibers. It should be noted that diet D0 was sufficient to meet the nutritional requirements of ewes in the last third of pregnancy without compromising the post-natal growth of their lambs. On top of that, the surplus of 20% dietary energy did not influence either the carcass characteristics, or affect

Table VIII. Effect of maternal nutrition on meat qualitative traits of *Longissimus* muscle of feedlot lambs.

Item	Diet		P-value	SEM
	D0	D20		
$pH_{45\ min}$	6.64	6.61	0.64	0.06
$pH_{24\ h}$	5.69	5.66	0.63	0.04
$Temperature_{45\ min}$, °C	37.35	37.53	0.85	0.005
$Temperature_{24\ h}$, °C	7.00	6.77	0.58	0.05
$Color_{45\ min}$				
L*	32.04	31.54	0.38	0.11
a*	12.16	12.66	0.38	0.11
b*	2.22	2.35	0.74	0.02
$Color_{24\ h}$				
L*	37.72	37.40	0.83	0.007
a*	14.39	14.80	0.27	0.17
b*	1.91	2.19	0.71	0.02
Thawing loss, % (TL)	2.61	2.32	0.21	0.21
Cooking loss, % (CKL)	27.80	22.60	0.09	0.35
Water holding capacity, % (WHC)	61.20	61.50	0.89	0.003
Shear force, kgf (SF)	2.98	2.69	0.33	0.13

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation; SEM - standard error of the mean.
L* - lightness; a* - redness; b* - yellowness.

Table IX. Effects of maternal nutrition on the centesimal composition of the *Longissimus* muscle of feedlot lambs.

Item	Diet		P-value	SEM
	D0	D20		
Minerals, %	1.10	1.04	0.42	0.09
Protein, %	20.10	19.07	0.48	0.07
Fat, %	1.89	2.27	0.48	0.07
Moisture, %	77.46	78.21	0.66	0.02

D0 - diet meeting the nutritional energy requirements (NRC 2007); D20 - diet containing 20% more than the energy requirement of a pregnant ewe in the last third of gestation; SEM - standard error of the mean.

the qualitative traits of the *Longissimus dorsi* muscle, such as maximum length and depth, minimum and maximum fat thickness, and LEA.

Despite not differing between both groups of lambs, mean values for leg muscularity index (0.52) were higher than the 0.47 reported by Endo et al. (2015), who evaluated the leg muscularity index of Ile de France lambs fed fresh or hydrolyzed sugarcane. The nutritional uptake from diet D0 met the nutritional needs of the fetuses, not limiting their post-natal growth. Therefore, the 20% surplus energy in the ewes' diet was not necessary to stimulate hyperplasia of the muscle cells during the fetal development of their lambs.

The greater nutrient supply during fetal development provides an increase in the number of adipocytes formed and the size of muscle fibers, whereas restriction leads to a reduction in the number of fibers and an increase in the concentration of collagen, which are factors that reduce meat tenderness in young animals (Mohrhauser et al. 2015). However, the 20% surplus energy in the ewes' diet did not affect the qualitative traits of the *Longissimus* muscle of the lamb's carcasses. The pH values are within the normal range for sheep meat proposed by Sañudo (1992), which should range between 6.56 and 6.69 for pH_{45min} and between 5.66 and 5.78 for pH_{24h}, providing stability to the meat-quality parameters such as color, water holding capacity, and tenderness, since these are closely related to the pH value (Leão et al. 2012). Results obtained herein confirm the assumptions of those authors since the association of lower thawing and cooking losses with an increased water-holding capacity of meat resulted in greater nutrient retention, juiciness, and meat tenderness, which are characteristics desired by the consumer.

Color variables L*, a*, and b* represent the lightness, redness, and yellowness of the meat, respectively. Meats presenting high L* and b* values are considered pale and yellowish, whereas higher a* values indicate redder meat, which is more attractive to the consumer (Miltenburg et al. 1992). According to Sañudo et al. (2000), for sheep meat, the ideal range of values is between 30.03 and 49.47 for L*, 8.24 to 23.53 for a*, and 3.38 to 11.10 for b*. The ewe diets with or without the surplus of 20% energy on top of the requirements during the last third of gestation did not influence the color of the lamb meat, and the L* and a* values agree with the values proposed by the aforementioned authors, despite a slight variation in b*. Leão et al. (2012) reported similar b* values in the meat of lambs fed diets containing sugarcane or corn silage and two levels of concentrate, averaging 2.12 and 4.93 at 45 min and 24 h postmortem, respectively.

Data from previous studies show that improving the nutritional status of cows during mid to late gestation can improve meat tenderness and increase adipose tissue deposition and growth in steers, as well as decrease the moisture content of the *Longissimus* muscle (Underwood et al. 2010). The lack of effect on quality traits of the *Longissimus* muscle shows that both treatments were considered adequate in providing nutrients to the fetus and that 20% surplus energy is not enough to cause either improvements or detrimental effects in the post-natal development of the muscle.

The meat centesimal analysis reflects the variation in carcass composition stemming from several factors, such as genetics and nutrition. However, we observed that providing only the nutritional requirements of ewes in the last third of gestation (D0), was sufficient to meet the nutritional demands for the development of the lambs, which resulted in meat with similar centesimal composition, with values close to those recommended by Tornberg (2005) for sheep meat, as follows: 75% moisture, 20% protein, 3% fat, and 2% non-protein substances (minerals, vitamins, and carbohydrates), approximately.

The lack of effects of the energetic overfeeding of ewes on the performance of lambs makes this strategy economically unfeasible and unnecessary. However, further studies are needed to elucidate the metabolic mechanisms involved in fetal programming, which still leads to controversial results.

In conclusion, adding 20% energy on top of the NRC (2007) requirements of Ile de France ewes, during the last third of gestation, considering the experimental conditions, does not significantly influence the performance, carcass quantitative traits, nor meat qualitative traits of their offspring.

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