

# Carcass and non-carcass components of Santa Ines lambs subjected to food restriction

## Componentes carcaça e não carcaça de cordeiros Santa Inês submetidos à restrição alimentar

Adrielle Albuquerque dos Santos<sup>1</sup>; Patrícia Guimarães Pimentel<sup>2\*</sup>;  
Elzânia Sales Pereira<sup>3</sup>; Guilherme Rocha Moreira<sup>4</sup>;  
José Antônio Delfino Barbosa Filho<sup>5</sup>; Ivone Yurika Mizubuti<sup>6</sup>;  
Edson Luis de Azambuja Ribeiro<sup>7</sup>; Dayanne Lima de Sousa<sup>1</sup>

### Abstract

The objective of this study was to evaluate the effect of sex class (castrated; non-castrated) and level of food restriction (0%, 30% and 60% of *ad libitum* consumption) on the quantitative composition of carcass and non-carcass components of Santa Ines lambs. A completely randomized 3x2 design (restriction level x sex class) was used to evaluate thirty lambs approximately two months of age with an average initial body weight of  $13 \pm 1.49$  kg. When the average body weight of the animals in one of the treatment groups reached 28 kg, all animals were slaughtered. Sex class had effect on body weight at slaughter, empty body weight, hot carcass weight and cold carcass weight. The weight of the leg was greater in non-castrated animals. There was linear decreased effect according to increasing levels of restriction for the carcass cuts, except for leg and rear loin yield. There was statistic difference between sex class for the weights of kidneys, paw and large intestine of non-castrated animals ( $P < 0.05$ ). Blood, head, leather, paw, rumen, reticulum, abomasum, small intestine, large intestine; perirenal, omental, mesenteric and heart fat showed linear decreased effect with the inclusion levels. The quantitative composition of carcass and non-carcass components of Santa Ines lambs is influenced by sex class and food restriction level.

**Key words:** Castration. Commercial cuts. Internal organs. Muscularity index. Sheep.

### Resumo

Objetivou-se com o presente estudo avaliar o efeito de classe sexual (castrado e não castrado) e níveis de restrição alimentar (0%, 30% e 60% do consumo *ad libitum*) sobre as características quantitativas dos componentes carcaça e não carcaça de cordeiros Santa Inês. Foi utilizado delineamento inteiramente casualizado 3x2 (nível de restrição x classe sexual) para avaliar trinta cordeiros, com aproximadamente dois meses de idade e peso corporal inicial médio de  $13 \pm 1,49$  kg. Quando a média de peso corporal

<sup>1</sup> Discentes do Curso de Mestrado, Programa de Pós-graduação em Zootecnia, Universidade Federal do Ceará, UFC, Fortaleza, CE, Brasil. E-mail: albuquerque.zootecnia@gmail.com; dayannels@hotmail.com

<sup>2</sup> Prof<sup>ª</sup> Dr<sup>ª</sup>, Dept<sup>o</sup> de Zootecnia, UFC, Fortaleza, CE, Brasil. E-mail: pgpimentel@hotmail.com

<sup>3</sup> Prof<sup>ª</sup> Dr<sup>ª</sup>, Dept<sup>o</sup> de Zootecnia, UFC, Bolsista de Produtividade do CNPq, Fortaleza, CE, Brasil. E-mail: elzania@hotmail.com

<sup>4</sup> Prof. Dr., Dept<sup>o</sup> de Estatística e Informática, Universidade Federal Rural de Pernambuco, UFRPE, Recife, PE, Brasil. E-mail: guirocham@gmail.com

<sup>5</sup> Prof. Dr., Dept<sup>o</sup> de Eng<sup>ª</sup> Agrícola, UFC, Fortaleza, CE, Brasil. E-mail: zkdelfino@gmail.com

<sup>6</sup> Prof<sup>ª</sup> Dr<sup>ª</sup>, Dept<sup>o</sup> de Zootecnia, Universidade Estadual de Londrina, UEL, Londrina, PR, Brasil. E-mail: mizubuti@uel.br

<sup>7</sup> Prof. Dr., Dept<sup>o</sup> de Zootecnia, UEL, Bolsista de Produtividade do CNPq, Londrina, PR, Brasil. E-mail: elar@uel.br

\*Author for correspondence

dos animais de um dos tratamentos atingiu 28 kg, todos os animais foram abatidos. Houve influência da classe sexual sobre o peso corporal ao abate, peso corporal vazio, peso de carcaça quente e peso de carcaça fria. O peso da perna mostrou-se maior para animais não castrados. Houve efeito linear decrescente de acordo com o aumento dos níveis de restrição para as características e cortes de carcaça, exceto para rendimento de perna e lombo posterior. Houve diferença entre classes sexuais para os pesos dos rins, patas e intestino grosso de animais não castrados. Sangue, cabeça, pele, pata, rúmen-retículo, abomaso, intestino delgado, intestino grosso e gorduras perirrenal, omental, mesentérica e do coração mostraram efeito linear decrescente para os níveis de restrição. As características quantitativas dos componentes carcaça e não carcaça de cordeiros Santa Inês são influenciadas pelas classes sexuais e níveis restrição alimentar.

**Palavras-chave:** Castração. Cortes comerciais. Índice de musculosidade. Órgãos internos. Ovinos.

## Introduction

Most sheep farming in the northeast of Brazil passes through a long drought phases that cause problems such as a decrease in the quantity and quality of food available for animals, resulting in alternating periods of weight gain and weight loss, resulting in low overall productivity and poor quality carcasses. This situation has encouraged producers and food scientists to seek alternative methods of farming that would improve meat production in this region. It has been proposed that food restriction, which is used in goats (YÁÑEZ et al., 2006), bovines (FONTES et al., 2007) and sheep (ALMEIDA et al., 2011) to reduce spending on feed in drought periods and results in compensatory growth, might provide a low-cost alternative to current extensive sheep farming methods. It is important to determine that food restriction would not impair the quality of carcasses, the main link between the producer and the consumer.

During the period of food restriction metabolically active organs related to digestive function decrease in size. Metabolically active tissues such as liver and intestine are the most influenced by restriction which manifests as significant loss in weight (HORNICK et al., 2000). The type of forage and forage-concentrate ratio can also influence the development of non-carcass components, particularly those involved

in digestion, such as the rumen and reticulum (MORENO et al., 2011).

Sexual class is another factor that influences the quality of carcasses. Carvalho et al. (2005) reported faster growth and higher carcass yield in non-castrated than castrated males. Non-castrated males have a more favorable productivity profile. This is more meat and lower fat content in animals of similar body weight (KLEIN JÚNIOR et al., 2008).

The body conformation of the animal depends on the proportion and condition of all components of body weight, thus making more fair trade for producers seeking total quality, benefiting consumers both at the lowest price as the improvement in the sanitary aspect (OSÓRIO et al., 2002). Investigation of non-carcass components is important because they generate extra income for small farmers and may provide an alternative supply of animal protein for under-served populations (MATTOS et al., 2006).

This study aimed to evaluate the effects of sex class and level of food restriction on the quantitative composition of carcass and non-carcass components of Santa Ines lambs.

## Material and Methods

The trial was conducted at the Department of Animal Science, Federal University of Ceara,

Brazil. During the experimental period the average temperature inside the stalls was 25.71 °C and the average relative humidity was 74.67 % (data obtained from sensors connected to dataloggers installed at the experimental shed).

The thirty Santa Ines male lambs (15 castrated; 15 non-castrated) were about two months of age, with an average initial body weight (BW) of 13.00 ± 1.49 kg. The animals were identified, dewormed and placed in individual stalls with feeding troughs to supply the diet and water.

After a 15-day adaptation period, the lambs were randomly allocated to the treatments, with 5 castrated and 5 non-castrated animals in each food restriction group (0%, 30% and 60% of *ad libitum* consumption). The experimental design was a completely randomized 3 (food restriction) x 2 (sex class) factorial design giving six treatment groups.

Food restriction was calculated according to the consumption of animals fed *ad libitum* (0% restriction). Animals were fed on diets as total mixed rations (TMR) twice daily, at 08h00 and 16h00. The animals in the 0% food restriction group received diets formulated to produce a mean daily weight gain of 200 g, with forage: concentrate ratio of 60:40 (NRC, 2007).

Forage and concentrate samples were dried in a forced air oven at 55 °C for 72 h, then ground in a knife mill with a 1 mm screen (Wiley mill, Arthur H. Thomas, Philadelphia, PA, USA). The samples were analyzed for contents of dry matter (DM), ash, crude protein (CP) and ether extract (EE), according to AOAC (1990); neutral detergent fiber (NDF) and acid detergent fiber (ADF), according to Van Soest et al. (1991). The chemical-bromatological composition of Tifton-85 hay, ingredients and diet are shown in Tables 1 and 2.

**Table 1.** Chemical-bromatological composition of the ingredients and concentrate, in g kgMS<sup>-1</sup>.

Nutrient	Tifton-85 hay	Ground corn	Soybean meal	Concentrate
DM	929.58	900.57	901.22	897.51
CP	110.61	77.01	532.05	291.10
Ash	66.95	15.04	70.34	55.10
EE	15.32	66.30	11.84	32.11
NDF <sup>1</sup>	707.70	152.95	193.86	168.22
NDFap	673.52	141.28	128.03	123.37
ADF	352.97	25.96	85.96	57.76
TC <sup>1</sup>	807.12	841.65	385.77	621.68
NFC <sup>2</sup>	133.60	700.37	257.74	520.71

DM: dry matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; NDFap: neutral detergent fiber corrected for ash and protein; ADF: acid detergent fiber; TC: total carbohydrates; NFC: non-fibrous carbohydrates. <sup>1</sup>%TC = 100 - (%CP + %EE + %Ash); Sniffen et al. (1992). <sup>2</sup>NFC = 100 - (%NDFap + %NFC + %EE + %Ash); Weiss (1999).

**Table 2.** Composition of the experimental diet.

Ingredient (%NM)	
Tifton 85 hay	60
Concentrate <sup>1</sup>	40
Ground corn	20,07
Soybean meal	19,23
Limestone	0,19
Dicalcium phosphate	0,41
Sodium chloride	0,07
Mineral premix <sup>2</sup>	0,03
Chemical components (g kgMS <sup>-1</sup> )	
DM	918.10
CP	184.14
Ash	56.53
EE	24.60
NDF	492.60
NDFap	456.49
ADF	233.52
TC	727.37
NFC	270.29
TDN	558.00

<sup>1</sup>Centesimal concentration in relation to the concentrated portion of the diets. <sup>2</sup>Composition: Ca 7.5%; P 3%; Fe 16.500 ppm, Mn 9.750 ppm, Zn 35.000 ppm, I 1.000 ppm, Se 225 ppm, Co 1.000 ppm. DM: dry matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; NDFap: neutral detergent fiber corrected for ash and protein; ADF: acid detergent fiber; TC: total carbohydrates; NFC: non-fibrous carbohydrates; TDN: Total digestible nutrients.

Animals were weighed every 15 days to calculate average daily gain (ADG). The trial lasted 100 days, until the mean body weight (BW) of one of the treatment groups reached 28 kg; which occurred when the animals had an approximate age of 175 days. At this moment all the animals were slaughtered.

Before slaughter, animals were weighed and then subjected to an 18-hour fast (no solid food or water) and then weighed again to obtain body weight at slaughter (BWS). At slaughter, lambs were stunned using a cash knocker and killed by exsanguination from jugular vein. Immediately after bleeding, the digestive tract was completely

removed and weighed full. The individual components: internal organs (liver; heart; lungs, trachea and esophagus; tongue; bladder; kidneys; reproductive tract; spleen), digestive tract (rumen; reticulum; omasum; abomasum; small intestine; large intestine) and fat (omental; mesenteric; perirenal; pericardial) were weighed separately from the body. The contents of the gastrointestinal tract (GIC), bladder (B) and gallbladder (GB) were emptied, washed and drained and then weighed again to obtain the empty body weight (EBW) using the formula  $EBW = BWS - (GIC + B + GB)$ . The legs, head and other internal components were removed and weighed. The carcass was then weighed, and this value, the hot carcass weight (HCW), was used to calculate hot carcass yield (HCY) from the relation between the HCW and BWS. The carcasses were then cooled at 4°C for 24 h.

After the cooling period, the carcasses were weighed, this value was the cold carcass weight (CCW). Loss by cooling (LC) was calculated:  $LC (\%) = [(HCW - CCW) / HCW] \times 100$ . The commercial carcass yield or cold carcass yield (CCY) was calculated as the ratio of CCW to BWS, expressed as a percentage. The biological yield (BY) was calculated using the formula  $BY (\%) = HCW / EBW \times 100$ . After weighing, the yield of non-carcass components (NCC%) was calculated relative to the EBW, using the formula  $NCC (\%) = (NCC \text{ weight in kg} / EBW) \times 100$ .

The left half carcass was divided into eight anatomical regions (shoulder, leg, fore and rear loin, rib, neck, chest and flank), which were individually weighed to determine their percentage in relation of the whole carcass. The cuts were based on the system adopted by Monte et al. (2007).

Carcass musculature was assessed by determining the loin eye area (LEA) according to the method described by Müller (1987) and Cezar and Sousa (2007). The values obtained were inserted into the following formula to determine

the LEA in cm<sup>2</sup>:  $LEA = (A/2 \times B/2) \times \pi$ , where:  $\pi = 3.1416$ .

The normality and homoscedasticity of the distributions of variables were assessed using the Lilliefors and Bartlett tests respectively. All data were then subjected to analysis of variance. When there was no interaction, was applied the F test ( $P < 0.05$ ) for classes and regression analysis to restriction levels.

Statistical analyses were carried out using the SAEG® programs, according to procedures described by Ribeiro Júnior and Melo (2009); considering the effects of sex class, restriction level and the interaction between sex class and restriction level. Significance threshold of 5% was applied to all comparisons.

## Results and Discussion

There were no interactions between restriction level and sex class for carcass traits (Table 3). The non-castrated lambs showed higher BW, BWS, EBW, HCW and CCW than castrated animals. Non-castrated animals have a greater proportion of the hormone testosterone, which promotes muscle growth, thus producing a greater proportion of muscle mass and influencing the quality and carcass composition of lambs, such that the proportion of bone and muscle is higher, and the proportion of fat lower in non-castrated males than castrated males. According to Carvalho et al. (1999), sex class influences the growth rate and deposition of body tissues in various animals, with the highest growth rates in non-castrated males, followed by castrated males, then females.

**Table 3.** Mean initial body weight (IBW), body weight (BW), empty body weight at slaughter (BWS), empty body weight (EBW), hot carcass weight (HCW), hot carcass yield (HCY), cold carcass weight (CCW), cold carcass weight (CCY), biological yield (BY) and losses by cooling (LC) for Santa Ines lambs subjected to food restriction.

Variable	Sex class		Level of restriction			CV <sup>1</sup>	R <sup>2</sup>
	Non-castrated	Castrated	0%	30%	60%		
IBW	13.11	13.10	13.06	13.02	13.23	-	-
BW, kg <sup>2</sup>	24.21 <sup>a</sup>	22.87 <sup>b</sup>	30.20	23.87	17.27	5.25	99.99
BWS, kg <sup>3</sup>	22.19 <sup>a</sup>	21.12 <sup>b</sup>	27.68	22.09	15.84	5.19	99.90
EBW, kg <sup>4</sup>	17.92 <sup>a</sup>	16.94 <sup>b</sup>	23.04	17.70	12.16	5.43	99.99
HCW, kg <sup>5</sup>	10.01 <sup>a</sup>	9.47 <sup>b</sup>	13.02	9.91	6.64	6.34	99.98
HCY, % <sup>6</sup>	44.68	44.40	47.02	44.93	41.93	5.34	98.32
CCW, kg <sup>7</sup>	9.89 <sup>a</sup>	9.40 <sup>a</sup>	12.92	9.83	6.53	6.21	99.96
CCY, % <sup>8</sup>	44.09	44.04	46.47	44.57	41.22	5.14	98.37
BY, % <sup>9</sup>	55.65	55.69	56.50	56.01	54.59	2.92	99.91
LC, % <sup>10</sup>	0.967	0.827	0.753	0.822	1.12	41.64	88.40

<sup>a, b</sup> Means followed by different letters in the row are different by F test ( $P < 0.05$ ). <sup>1</sup>Coefficient of variation (%). <sup>2</sup> $Y = 30.25 - 0.22 X$ ; <sup>3</sup> $Y = 27.79 - 0.20 X$ ; <sup>4</sup> $Y = 23.08 - 0.18 X$ ; <sup>5</sup> $Y = 13.04 - 0.11 X$ ; <sup>6</sup> $Y = 47.17 - 0.08 X$ ; <sup>7</sup> $Y = 12.95 - 0.11 X$ ; <sup>8</sup> $Y = 46.87 - 0.09 X$ ; <sup>9</sup> $Y = 56.66 - 0.03 X$ ; <sup>10</sup> $Y = 0.72 + 0.06 X$ .

Food restriction had a linear decrease effect on BW, BWS, EBW, HCW, HCY, CCW, CCY and BY, indicating that food restriction can reduce the quality of carcass and hence its market value. For each 1% increase in the level of food

restriction, LC increased by 0.06%; this was in line with expectations as the carcasses of the food-restricted animals had less subcutaneous fat which probably facilitated water loss during the cooling period.

Cezar and Sousa (2007) stated that higher weight at slaughter implies a heavier carcass and consequently a higher carcass yield; this may be because the components which make up the commercial carcass grow faster than the other components of the body in terms of live weight. The fastest growing non-carcass regions, such as head and paw, grow slower than the central body region. The trunk composes most of the carcass, so that the increases in body weight associated with the age of the animal results in higher carcasses yields (CEZAR; SOUZA, 2007).

Yñéz et al. (2006) investigated the effect of food restriction on carcass characteristics in Saanen goats, reporting that BWS, EBW, HCW and CCW were negatively associated with food restriction. Almeida et al. (2011), evaluating compensatory growth in Santa Ines lambs fed three different diets (*ad libitum* intake; intake to maintain body weight; a period of food restriction followed by *ad libitum* intake), observed that animals subjected to food restriction had lower final live weights (51.5 kg) when compared to *ad libitum* intake (58.3 kg) and

compensatory growth (62.8 kg).

In this study, HCY, CCY, BY and LC did not show differences between the sex classes. Osório et al. (2005), evaluating carcass morphology *in vivo*, production and commercial characteristics of Corriedale lambs, and Carvalho et al. (2005), studying hot carcass yield in Sussex lambs, in consonance with this research, did not find differences for sex classes.

The fore loin, weighted in kg, was the only commercial cut that showed interaction ( $P < 0.05$ ) between sex class and level of food restriction (Table 4). Non-castrated animals, in the 0% restriction group, presented higher values of fore loin weight than castrated animals. The fore loin weight of non-castrated animals decreased 0.008 kg for every 1% increase in the level of restriction. Probably the animals subjected to 0% restriction consumed more food than the other groups and the amount of nutrients ingested was sufficient to supply the requirements of maintenance and production, thus revealing differences between the sex classes.

**Table 4.** Average fore loin weight (kg) for Santa Ines lambs subjected to food restriction.

Category	Level of restriction		
	0%	30%	60%
	Fore loin (kg)		
Non-castrated <sup>1</sup>	0.888 <sup>A</sup>	0.602	0.406
Castrated <sup>2</sup>	0.593 <sup>B</sup>	0.690	0.404

<sup>A,B</sup> Means followed by different letters in the column are different by F test ( $P < 0.05$ ). Coefficient of variation = 20.07. <sup>1</sup>Y = 0.873 - 0.008 X; R<sup>2</sup> (%) = 98.85. <sup>2</sup>Y = not significant.

The weight and yield of the commercial cuts leg, shoulder, chest, ribs, flank, rear loin and neck, as for the fore loin yield did not show significant interaction between sex class and restriction level (Table 5). The mean weight (in kg) of the leg cut was higher in non-castrated males ( $P < 0.05$ ), but its yield was not influenced by sex class. The leg is a noble cut that concentrates a large number of

muscles; BWS and EBW were also higher in non-castrated animals than in castrated animals in this study, which may account for the difference in leg cut weights.

According to Cezar and Souza (2010), the proportions of the different cuts in the carcass are an important factor in market value. In this way, the

higher proportion of cuts containing more muscle and the lower proportion containing a large amount of bones makes the carcass more commercially valuable. The shoulder, chest, ribs, flank and neck cuts was negatively influenced by food restriction; the greater the level of food restriction the less

these cuts weighed. Nóbrega et al. (2013) studied compensatory growth in sheep subjected to different levels of food restriction (0, 20, 40 and 60%) and reported that the weight of various cuts decreased linearly as the level of restriction increased, even if restriction was followed by refeeding.

**Table 5.** Average weights (kg) and yields (%) for the leg, shoulder, chest, ribs, flank, neck, fore end rear loin of Santa Ines lambs subjected to food restriction.

Variable	Sex Class		Level of restriction			CV <sup>1</sup>	R <sup>2</sup>
	Non-castrated	Castrated	0%	30%	60%		
Leg, kg <sup>2</sup>	1.727 <sup>a</sup>	1.637 <sup>b</sup>	2.192	1.734	1.176	5.90	99.25
Leg, % <sup>3</sup>	34.782	35.028	33.906	34.983	35.839	3.32	99.54
Shoulder, kg <sup>4</sup>	0.955	0.915	1.212	0.951	0.672	6.81	99.97
Shoulder, % <sup>5</sup>	19.748	19.671	18.787	19.396	20.858	7.15	94.62
Chest, kg <sup>6</sup>	0.415	0.380	0.556	0.409	0.246	14.38	99.91
Chest, % <sup>7</sup>	8.377	7.956	8.597	8.349	7.617	14.36	-
Rib, kg <sup>8</sup>	0.263	0.247	0.382	0.250	0.147	20.63	99.49
Rib, % <sup>9</sup>	5.220	5.059	5.889	5.063	4.550	16.03	98.19
Flank, kg <sup>10</sup>	0.291	0.276	0.391	0.294	0.177	11.60	99.68
Flank, % <sup>11</sup>	5.841	5.813	6.040	5.991	5.472	8.91	81.56
Neck, kg <sup>12</sup>	0.376	0.343	0.493	0.355	0.245	20.91	99.62
Neck, % <sup>13</sup>	7.590	7.328	7.606	7.204	7.601	17.93	-
Fore loin, % <sup>14</sup>	12.750	13.411	13.557	13.154	12.559	11.49	-
Rear loin, kg <sup>15</sup>	0.232	0.216	0.277	0.241	0.166	18.28	96.18
Rear loin, % <sup>16</sup>	4.773	4.871	4.258	4.925	5.160	16.19	92.95

<sup>a, b</sup> Means followed by different letters in the row are different by F test ( $P < 0.05$ ). <sup>1</sup> Coefficient of variation (%). <sup>2</sup>  $Y = 2.208 - 0.117 X$ ; <sup>3</sup>  $Y = 33.943 + 0.032 X$ ; <sup>4</sup>  $Y = 1.214 - 0.009 X$ ; <sup>5</sup>  $Y = 18.644 - 0.035 X$ ; <sup>6</sup>  $Y = 0.559 - 0.005 X$ ; <sup>8</sup>  $Y = 0.377 - 0.004 X$ ; <sup>9</sup>  $Y = 5.835 - 0.022 X$ ; <sup>10</sup>  $Y = 0.394 - 0.004 X$ ; <sup>11</sup>  $Y = 6.120 - 0.009 X$ ; <sup>12</sup>  $Y = 0.488 - 0.004 X$ ; <sup>15</sup>  $Y = 0.248 - 0.002 X$ ; <sup>16</sup>  $Y = 4.329 + 0.015 X$ ; <sup>7, 13, 14</sup> not significant.

In this study, chest, neck and fore loin yields were unaffected by food restriction. These results are consistent with the law of anatomical harmony, which states that the proportions of the various cuts will be similar across carcasses even with different weights, possibly due to the differences in the development of tissues, such as muscle and fat.

Food restriction increased leg and rear loin cuts yields this is greater food restriction resulted in an increase in the proportion of half carcass weight made up by those cuts. Immediately after birth many of the muscle groups of the lower

limb, such as semi-membranous muscles, grow much faster than the muscle mass as a whole and this group of muscles quickly comes to make up a greater proportion of total muscle mass than at birth (BUTTERFIELD, 1988). In lambs subjected to 60% food restriction, this muscle group is proportionally the largest component of muscle mass when the animal weighs around 20% of its adult mass. As the animals continue to grow, the relative weight of lower limb muscle decreases gradually as the relatively high growth rate in this muscle group is gradually overtaken by the growth of the muscles

as a whole. Other muscle groups increase rapidly in mass to fulfill the functional requirements of the developing animals. The muscles located around the spine presents the same behavior, because the *longissimus* and *psaos major* comprise about 60% of the weight of the muscle group and their growth patterns have a profound influence on the growth and maturation of the group as a whole.

There was no interaction between restriction level and sex class for the LEA although food

restriction had a negative effect on LEA (Table 6). This finding was unsurprising as most of the carcass variables studied for instance BWS, EBW, HCY, CCY, cuts and carcass measurements were also sensitive to feed decrease. These results indicate that very high levels of food restriction can compromise carcass quality in lambs. Urano et al. (2006) reported a mean LEA of 14.8 cm<sup>2</sup> in Santa Ines lambs fed with increasing levels of whole soybean, higher than the obtained in this study.

**Table 6.** Mean loin eye area (LEA) in Santa Ines lambs subjected to food restriction.

Variable	Sex class		Level of restriction			CV <sup>1</sup>	R <sup>2</sup>
	Non-castrated	Castrated	0%	30%	60%		
LEA <sup>2</sup>	8.934	9.082	11.692	9.041	6.616	20.12	99.97

<sup>1</sup>Coefficient of variation (%). <sup>2</sup>Y = 11.602 - 0.084 X.

There was a linear negative association between restriction level and heart weight and yield and respiratory system weight (Table 7). These results conflict with those of Moreno et al. (2011) who stated that the yields of vital organs such as the

respiratory tract, brain and heart were, unlike organs related to digestion and metabolism of food, not influenced by diet as they had priority in the use of nutrients and thus their integrity was robust against changes in the nutritional status of the animals.

**Table 7.** Average weights (kg) and yields (%) of the heart, respiratory system (Resp. Syst.), liver, kidneys and spleen in Santa Ines lambs subjected to food restriction.

Variable	Sex class		Level of restriction			CV <sup>1</sup>	R <sup>2</sup>
	Non-castrated	Castrated	0%	30%	60%		
Heart, kg <sup>2</sup>	0.109	0.105	0.136	0.105	0.083	10.00	98.43
Heart, % <sup>3</sup>	0.619	0.630	0.592	0.596	0.683	11.78	77.34
Resp. Syst., kg <sup>4</sup>	0.591	0.556	0.731	0.598	0.409	11.53	98.91
Resp. Syst., % <sup>5</sup>	3.282	3.325	3.171	3.375	3.351	8.51	-
Liver, kg <sup>6</sup>	0.315	0.297	0.447	0.287	0.200	9.06	-
Liver, % <sup>7</sup>	1.731	1.725	1.941	1.623	1.644	7.27	-
Kidneys, kg <sup>8</sup>	0.072 <sup>a</sup>	0.066 <sup>b</sup>	0.090	0.069	0.050	7.34	99.99
Kidneys, % <sup>9</sup>	0.405	0.392	0.392	0.388	0.415	8.95	-
Spleen, kg <sup>10</sup>	0.039	0.038	0.053	0.038	0.027	16.34	98.59
Spleen, % <sup>11</sup>	0.219	0.223	0.229	0.212	0.222	16.67	-

<sup>a, b</sup> Means followed by different letters in the row are different by F test (P < 0.05). <sup>1</sup>Coefficient of variation (%). <sup>2</sup>Y = 0.136 - 0.009 X; <sup>3</sup>Y = 0.578 - 0.01 X; <sup>4</sup>Y = 0.739 - 0.005 X; <sup>8</sup>Y = 0.090 - 0.007 X; <sup>10</sup>Y = 0.051 - 0.0004 X; <sup>5, 6, 7, 9, 11</sup> not significant.

There were no interactions between restriction level and sex class for the heart, respiratory system, liver, kidneys and spleen (Table 7), however there were sex class differences in the weight of the kidneys.

We observed no significant changes in liver weight or yield, indicating that increasing the level of food restriction produced no reduction in the weight or performance of that organ, in contrast to Ferrell and Jenkins (1998) who observed that the liver exhibits a high metabolic rate because it participates actively in nutrient metabolism and therefore responds to reductions in food intake.

Non-castrated animals had heavier kidneys than castrated animals. Luchiari Filho (2000) noted

that the carcasses of non-castrated animals have approximately 8% less fat and 38% more muscular portion than those of castrated animals due to the action of the hormone testosterone. Kidneys participate actively in the excretion of substances and the carcasses of non-castrated animals are heavier than those of castrated animals, so this may account for the observed difference in kidney weight.

Spleen weight was negatively affected by food restriction (Table 7), as observed by Seebeck's (1967) in a study with bovines subjected to food restriction. The cited authors noted that one of the functions of the spleen is to store blood for release under stressful conditions. In this research, lower spleen weights may have been thus related to the concomitant reduction blood weight (Table 8).

**Table 8.** Average weights (kg) and yields (%) for blood, head, leather, paw, omasum (OMA), abomasum, rumen-reticulum (RURE), small intestine (SI) and large intestine (LI) in Santa Ines lambs subjected to food restriction.

Variable	Sex class		Level of restriction			CV <sup>1</sup>	R <sup>2</sup>
	Non-castrated	Castrated	0%	30%	60%		
Blood, kg <sup>2</sup>	1.020	0.965	1.326	0.994	0.693	7.57	99.92
Blood, % <sup>3</sup>	5.681	5.706	5.767	5.614	5.704	7.73	-
Head, kg <sup>4</sup>	1.024	1.003	1.154	1.021	0.881	5.50	99.96
Head, % <sup>5</sup>	5.982	6.124	5.027	5.775	7.248	5.85	-
Leather, kg <sup>6</sup>	1.672	1.550	2.119	1.675	1.097	13.06	99.42
Leather, % <sup>7</sup>	9.284	9.157	9.194	9.449	9.024	10.25	-
Paw, kg <sup>8</sup>	0.564 <sup>a</sup>	0.539 <sup>b</sup>	0.682	0.561	0.426	5.68	99.78
Paw, % <sup>9</sup>	3.194	3.261	2.964	3.177	3.512	7.40	98.43
OMA, kg <sup>10</sup>	0.063	0.057	0.069	0.065	0.046	14.08	-
OMA, % <sup>11</sup>	0.361	0.340	0.300	0.367	0.380	11.02	88.18
Abomasum, kg <sup>12</sup>	0.085	0.079	0.010	0.078	0.070	22.62	94.18
Abomasum, % <sup>13</sup>	0.495	0.485	0.434	0.446	0.582	19.62	81.80
RURE, kg <sup>14</sup>	0.500	0.496	0.619	0.526	0.362	12.06	97.78
RURE, % <sup>15</sup>	2.827	2.958	2.683	2.979	2.988	10.44	76.72
SI, kg <sup>16</sup>	0.427	0.412	0.522	0.420	0.300	13.31	99.92
SI, % <sup>17</sup>	2.398	2.448	2.404	2.380	2.477	15.33	-
LI, kg <sup>18</sup>	0.308 <sup>a</sup>	0.269 <sup>b</sup>	0.370	0.272	0.233	13.23	94.80
LI, % <sup>19</sup>	1.748	1.624	1.606	1.536	1.913	12.56	-

<sup>a, b</sup> Means followed by different letters in the row are different by F test ( $P < 0.05$ ). <sup>1</sup>Coefficient of variation (%). <sup>2</sup> $Y = 1.322 - 0.011 X$ ; <sup>4</sup> $Y = 1.155 - 0.004 X$ ; <sup>6</sup> $Y = 2.141 - 0.017 X$ ; <sup>8</sup> $Y = 0.658 - 0.004 X$ ; <sup>9</sup> $Y = 2.944 - 0.009 X$ ; <sup>11</sup> $Y = 0.309 - 0.001 X$ ; <sup>12</sup> $Y = 0.098 - 0.0005 X$ ; <sup>13</sup> $Y = 0.412 - 0.002 X$ ; <sup>14</sup> $Y = 0.630 - 0.004 X$ ; <sup>15</sup> $Y = 2.731 - 0.005 X$ ; <sup>16</sup> $Y = 0.361 - 0.002 X$ ; <sup>18</sup> $Y = 0.550 - 0.004 X$ ; <sup>3, 5, 7, 10, 17, 19</sup> not significant.

There were no interactions between sex class and restriction level for weights of blood, head, leather and paw. These variables were negatively affected by food restriction, an unsurprising result which was similar to the pattern of effects on carcass traits. The weight of the paw differed between sex classes (Table 8); non-castrated animals had a higher mean paw weight than castrated animals. The omasum, although participates actively in food digestion, was not influenced by food restriction, considering its weight in kg.

There was no interaction between sex class and food restriction level in terms of the weights or yields of abomasum, rumen-reticulum or small or large intestine although food restriction was negatively associated with the weight and performance of these organs, possibly because they are directly involved in food digestion. Furlan et al. (2006) stated that the function of the small intestine is to absorb nutrients and that its size is proportional to the organism's body size and related to the type of food consumed. These authors suggested that experience of a vast dietary nutrient intake

stimulates further development of the intestines, as nutrients that escape ruminal fermentation induce mitotic processes of intestinal villi. Hornick et al. (2000) also reported that highly metabolically active tissues such as the intestines were more affected by food restriction which manifested as large weight losses in these tissues, as observed in this study.

The data presented in Tables 7 and 8 show that feeding restrictions imposed on the lambs reduced the size of their internal organs and that this decrease may have been associated with lower basal metabolism.

There was no interaction between food restriction level and sex class influencing fats (Table 9). Fat deposits were negatively affected by food restriction, probably because nutrients taken in during feeding are converted into energy and excess energy is then transformed into muscle and adipose tissue (LISBOA et al., 2010). When food intake is lower the body produces less adipose tissue as the energy from food is used to meet the needs of the animal.

**Table 9.** Average values weights (kg) and yields (%) for perirenal fat (PF), omental fat (OF), mesenteric fat (MF) and heart fat (HF) in Santa Ines lambs subjected to food restriction.

Variable	Sex class		Level of restriction			CV <sup>1</sup>	R <sup>2</sup>
	Non-castrated	Castrated	0%	30%	60%		
PF, kg <sup>2</sup>	0.117	0.121	0.184	0.107	0.081	30.02	92.38
PF, % <sup>3</sup>	0.655	0.714	0.806	0.606	0.661	28.38	-
OF, kg <sup>4</sup>	0.188	0.207	0.318	0.191	0.081	43.95	99.83
OF, % <sup>5</sup>	0.970	1.260	1.379	1.086	0.663	38.94	98.91
MF, kg <sup>6</sup>	0.153	1.182	0.263	0.153	0.086	27.19	98.07
MF, % <sup>7</sup>	0.827	0.984	1.141	0.866	0.698	22.89	98.16
HF, kg <sup>8</sup>	0.035	0.039	0.060	0.031	0.019	38.72	94.58
HF, % <sup>9</sup>	0.179	0.201	0.247	0.171	0.158	30.19	86.25

<sup>1</sup>Coefficient of variation (%). <sup>2</sup>Y = 0.175 - 0.002 X; <sup>4</sup>Y = 0.315 - 0.004 X; <sup>5</sup>Y = 1.4 - 0.12 X; <sup>6</sup>Y = 0.255 - 0.003 X; <sup>7</sup>Y = 1.123 - 0.007 X; <sup>8</sup>Y = 0.057 - 0.0007 X; <sup>9</sup>Y = 0.236 - 0.001 X; <sup>3</sup> not significant.

## Conclusion

Food restriction negatively influences the quality of carcasses. Sex class affects quantitative carcass traits, with higher carcass and cut weights in non-castrated males. The weight and yield of the non-carcass components of growing Santa Ines lambs are influenced by sex class and food restriction level.

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