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Allometry in carcasses of lambs of the Pantaneiro genetic group slaughtered with different subcutaneous fat thickness

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ABSTRACT. Twenty-four female lambs of the Pantaneiro genetic group, with approximately 100 days of age, average body of 16.24 ± 1.78 kg, were slaughtered with 2.0, 3.0 and 4.0 mm of subcutaneous fat thickness, measured by ultrasound in the *Longissimus*, to evaluate the allometric growth. Lambs fed a complete pelleted diet calculated to ensure a daily weight gain of 0.30 kg. Slaughtering was performed as the female lambs reached the pre-established fat thickness. After 24 hours in a cold chamber at 4ºC, chilled carcasses were cut in half and weighed. The right side was separated into five sections to determine the allometry of carcasses and cuts. Neck and rib showed isogonic growth in all treatments. Loin has remained late growth to 2.0 and 3.0 mm. Shoulder and leg were isogonic growth in the treatments 3.0 and 4.0 mm. The leg in relation to half carcass showed the greatest correlation. The cuts exhibited differentiated development in the growth rates of tissues. It is recommended to slaughter female lambs when they reach 3.0 mm of subcutaneous fat thickness, since the carcass has already reached physiological maturity. Shoulder and leg cuts are best suited for dissection for presenting the highest correlation with the carcass in females of the Pantaneiro group.

Keywords: growth, females, sheep, loin, shoulder, leg.

Alometria em carcaças de cordeiras do grupo genético Pantaneiro abatidas com diferentes espessuras de gordura subcutânea

RESUMO. Foram utilizadas 24 cordeiras do grupo genético Pantaneiro, com aproximadamente 100 dias de idade e peso corporal médio de 16,24 ± 1,78 kg, abatidas com 2,0; 3,0 e 4,0 mm de espessura de gordura subcutânea, avaliadas por ultrassonografia sobre o *Longissimus*, para avaliar o crescimento alométrico. As cordeiras receberam ração completa peletizada para ganho de peso diário de 0,30 kg. Os abates ocorreram à medida que as cordeiras atingiam a espessura de gordura pré-determinada. Após 24 horas refrigeradas a 4ºC, as carcaças frias foram seccionadas ao meio e pesadas. O lado direito foi separado em cinco cortes para determinação da alometria da carcaça e dos cortes. Nos cortes pescoço e costilhar, os tratamentos apresentaram crescimento isogônico. O lombo manteve-se tardio para 2,0 e 3,0 mm. A paleta e perna apresentaram crescimento isogônico nos tratamentos 3,0 e 4,0 mm. A perna em relação à meia carcaça apresentou a maior correlação. Os cortes obtiveram desenvolvimento diferenciado nas taxas de crescimento dos tecidos. Recomenda-se o abate de cordeiras Pantaneiras com 3,0 mm de espessura de gordura pela carcaça já ter atingido a sua maturidade fisiológica. Os cortes paleta e perna são os mais indicados para dissecação por apresentarem a maior correlação com a carcaça, em fêmeas do grupo Pantaneiro.

Palavras-chave: crescimento, fêmeas, ovinos, lombo, paleta, perna.

Introduction

The growing development of agricultural activities in the states of Mato Grosso and Mato Grosso do Sul has propelled researches for improvement of production and growth performance indices. The sheep industry, despite its small representation in the total national herd, 5.5%, has attracted the interest of breeders to improve and provide carcasses with quality (IBGE, 2011).

Sheep of the Pantaneiro genetic group underwent natural selection by climatic conditions of the Pantanal region and have high rusticity, good maternal ability and estrus throughout the year, which increases the value of this group in search of decreasing seasonality in the supply of carcass.

For a preliminary evaluation of lamb carcasses, ultrasound has been used as a tool to select the best time for slaughtering, independent of body weight. Furthermore, previous studies in European sheep breeds suggest the use of ultrasound in fat thickness for predicting carcass composition (RIPOLL et al., 2010).

Analysis of growth and body development parameters are important to an efficient production, since, knowing the rate of growth of tissues and regions comprising the carcass, assist in determining more precisely the best time for slaughtering, promoting standardization and quality to the product (HASHIMOTO et al., 2012).

The use of ultrasound to predict finishing, combined with allometry, through its coefficient, can describe body development, and provide the market with economically important cuts, without waiting to reach weight for standardized slaughtering. According to Wylie et al. (1997), the optimal slaughter weight is determined by the level of fat in the carcass, because with the increase in this tissue also occurs increase in carcass weight.

In this context, this study aimed to determine physiological maturity of carcasses of Pantaneiro lambs, slaughtered with 2.0; 3.0, and 4.0 mm subcutaneous fat thickness, and indicate the commercial cut that best represents the carcass to be used as standard in determining tissue composition by the dissection method.

Material and methods

The experiment was conducted at the Experimental Farm of Iguatemi, State University of Maringá (UEM), Maringá, Paraná State, from October 2012 to January 2013. We used 24 female lambs of the Pantaneiro genetic group, with approximately 100 days of age and average body weight of 16.24 ± 1.78 kg, acquired from extensive system properties in the Southwest region of the Mato Grosso State, area of ecological tension with transition of the Pantanal, Cerrado and the Amazon Rainforest. Initially, animals were weighed and the subcutaneous fat thickness assessed by ultrasound, and subsequently assigned to respective treatments, defined by subcutaneous fat thickness (SFT) in the *Longissimus* muscle, between the 12th and 13th ribs, at 2.0; 3.0, and 4.0 mm. Lambs were dewormed using vermifuge with moxidectin as active ingredient (Cydectin®), and had been adapted to the facilities and diet for 15 days.

The animals were housed in individual pens, with 0.75 m^2 area, with suspended slatted floor. Throughout the experimental period, animals received water ad libitum and fed a complete ration, mixed and pelleted, formulated for daily weight gain of 0.30 kg (NRC, 2007), supplied once daily in the morning, in amounts to allow leftovers of approximately 10%. The chemical composition of the diet (Table 1) was analyzed in the Laboratory of Animal Nutrition and Feeding, Department of Animal Science of UEM, according to AOAC (2000).

Table 1. Composition in g kg^{-1} in the dry matter of ingredients and chemical composition of the experimental diet.

Item	Composition (g kg^{-1})
Oat hay	100.0
Ground corn	448.0
Soybean meal	150.0
Soybean hull	150.0
Rice bran	100.0
Molasses	20.0
Ammonium Chloride	20.0
Mineral mix[1]	10.0
Zinc bacitracin	02.0
Dry matter	912.8
Crude protein	162.4
Ether extract	42.1
Neutral detergent fiber	275.4
Acid detergent fiber	138.6
Ash	45.9
Calcium	02.8
Phosphorus	04.0
In vitro dry matter digestibility	782.5
Total digestible nutrients[2]	766.8

[1]Assurance levels of the mineral mix per kg: Calcium 220 g, Phosphorus 130 g, Magnesium 25.5 g, Sulfur 24 g, Iron 3,000 mg, Manganese 1,500 mg, Zinc 4,000 mg, Copper 1,200 mg, Cobalt 280 mg, Iodine 260 mg, Selenium 30 mg and Fluoride 300 mg. [2]TDN estimated by the equation % TDN = 92.2 – (1.12 x ADF), described by Aldai et al. (2010).

Ultrasound evaluation and weighing were performed every seven days. To measure the thickness of subcutaneous fat, we used an ultrasound equipment (HONDA HS-1500 VET) with multifrequency linear transducer, 50 mm wide, using the frequency of 7.5 MHz. For the measurements, lambs were immobilized manually and with the aid of a comb, we separated the wool in the measurement areas and applied the mucilage to better coupling of the transducer to the skin. The pressure of the transducer head was kept minimal to avoid compression of the fat and all measurements were performed by the same technician, on the left side, between the 12th and 13th ribs, four cm from the midline of the spine. After capturing the image, the thickness of subcutaneous fat was measured using the electronic cursor of the ultrasound.

As lambs reached the predetermined thickness of fat of 2.0; 3.0, and 4.0 mm in the weekly evaluation by ultrasound, they were slaughtered the day after the measurements, regardless of body weight.

Mean body weight at slaughter according to subcutaneous fat thickness and days on feedlot were 20.64 kg and 34 days for lambs slaughtered with 2.0 mm; 26.77 kg and 84 days for lambs slaughtered with 3.0 mm; and 32.12 kg and 111 days for lambs slaughtered with 4.0 mm.

After fasting for solids for 18 hours, animals were stunned by electronarcosis, 220 Volts for 8 seconds, followed by bleeding from jugular veins and carotid arteries, skinning and evisceration.

Carcasses were left to cool for 24 hours at 4°C in cold chamber, and then sectioned in half, where the right half carcasses were divided into five sections and weighed: neck, between the 5th and 6th cervical vertebra; shoulder, by disarticulating the scapula, thus releasing the piece from the carcass; ribs, between 1st and 13th thoracic vertebra; loin, between the 1st and 6th lumbar vertebrae, and leg, between the last lumbar vertebra and the first sacral vertebra. The cuts shoulder, loin and leg were dissected to separate the following tissue groups: total fat; subcutaneous fat; muscles and bones.

To assess the allometric growth of cuts and tissues, we used the allometric equation $Y = aX^b$, linearized by the logarithmic model $\ln Y = \ln a + b \ln X$, described by Huxley (1932), where: Y = weight of the regional cuts or tissue components; X = weight of half carcass corrected or weight of cuts corrected; a = intersection of the linear regression logarithm over Y and b; b = allometric growth coefficient. Analyses to obtain the allometric coefficients were performed using the Reg procedure - Statistical Analysis System (SAS, 2001).

To check the hypothesis (Ho) b = 1, we adopted the procedure described by Furusho-Garcia et al. (2006), using the t-test. When b = 1, the growth is isogonic, i.e., the part grows at the same rate as the body as a whole, and when $b \neq 1$, the growth is heterogonic, i.e., the part grows at a rate different from the body, being early (negative) if $b < 1$ and late (positive) if $b > 1$. The cuts shoulder, leg and loin are used in the literature to predict the tissue composition of the whole carcass. Accordingly, Pearson correlations were performed between these sections and the cold half carcass parametric to evaluate the most appropriate cut to infer the behavior of the carcass.

Results and discussion

The neck cut showed a isogonic behavior, as well as ribs in all treatments (Table 2), that is, these cuts showed a proportional growth to the cold carcass (b = 1), corroborating Rota et al. (2006), analyzing male Criollo sheep and Hashimoto et al. (2012) working with Texel *vs.* Corriedale females.

Shoulder remained in early development in the treatment 2.0 and 3.0 mm thickness of subcutaneous fat ($b < 1$). However, once the lambs were confined for longer time, growth of this cut became isogonic in the treatment 4.0 mm. Roque et al. (1999) studied allometry in wool breed lambs and found that both shoulder and hindquarter were isogonic in relation to cold carcass weight, corroborating the results obtained in this work.

Table 2. Allometric coefficient (b) of the commercial cuts of Pantaneiro female lamb carcass in relation to half carcass.

Item	SFT	A	b	± SE	b ≠ 1	R2
Neck	2.0 mm	1.35	1.11	0.32	ns	66.05
	3.0 mm	- 0.91	0.52	0.63	ns	8.76
	4.0 mm	0.22	0.71	0.66	ns	19.01
Shoulder	2.0 mm	- 0.49	0.65	0.12	*	82.44
	3.0 mm	- 0.33	0.52	0.23	ns	36.60
	4.0 mm	- 0.84	1.10	0.42	ns	57.78
Ribs	2.0 mm	- 0.59	1.06	0.16	ns	87.27
	3.0 mm	- 0.69	1.17	0.27	ns	72.80
	4.0 mm	- 0.80	1.31	0.17	ns	92.09
Loin	2.0 mm	- 1.61	2.03	0.41	*	89.44
	3.0 mm	- 1.87	2.19	0.40	*	89.42
	4.0 mm	- 0.59	0.75	0.51	ns	30.25
Leg	2.0 mm	- 0.32	0.81	0.07	*	95.84
	3.0 mm	- 0.28	0.78	0.16	ns	77.90
	4.0 mm	0.52	1.03	0.19	ns	85.96

SFT = subcutaneous fat thickness; A = intercept b = allometric coefficient; ± SE = standard error of b; *= significant at ($p \leq 0.05$); ns = non-significant at ($p \leq 0.05$); R^2 = Coefficient of determination.

In the loin cut, animals with 2.0 and 3.0 mm of fat thickness showed positive heterogonic development. As lambs were confined for longer, this cut presented isogonic growth as seen in the treatment of 4.0 mm. Souza Júnior et al. (2009) observed in the genetic group Dorper *vs.* Rabo Largo that as well as neck and ribs, the loin also had a growth proportional to the growth of cold carcass (b = 1).

The leg has developed from an early to intermediate stage in treatments 2.0 mm to 3.0 mm and 4.0 mm. According to Pinheiro et al. (2007), in sheep at maturity, the growth is early in the shoulder, intermediate in the leg and late in the loin. However, none of the studied treatments specifically followed this behavior, which can be explained by the lack of breed standardization of this group, since these animals were naturally selected and came from an extensive system. The type of the integrated production system may interfere strongly with the development of tissue and growth rate in sheep (OSÓRIO et al., 1999). These same authors observed isogonic growth in finished animals on native and cultivated pasture. Furusho-Garcia et al. (2006) reported that confined male Texel *vs.* Santa Ines lambs showed isogonic growth in the neck, shoulder and leg. Galvani et al. (2008) evaluate confined male Texel and Ile de France lambs and observed similar rate of growth in the same cuts evaluated (b = 1), except for shoulder in relation to carcass.

Table 3 lists the correlation of these cuts with half carcass. There are several reports indicating that the loin is the best cut expressing the amount of muscle: fat: bone, representing the carcass as a whole (SILVA; PIRES, 2000; CARTAXO; SOUSA, 2008). Nevertheless, in the present study, the cuts leg and shoulder presented the highest correlation with half carcass, corroborating Lombardi et al. (2010) and Landim et al. (2007), followed by the loin. Allometry of leg and shoulder (Table 2) confirms these cuts as the most suitable to represent the carcass, for having the same growth speed as the whole, thus recommending the dissection of one of these cuts to infer the carcass behavior.

Table 3. Pearson correlation of the commercial cuts with the half carcass of Pantaneiro female lambs.

Item	HC[1]	Shoulder	Loin	Leg
HC[1]	1	0.83	0.76	0.83

[1]HC= half carcass.

Evaluating muscle, fat and bone of the whole half carcass (Table 4), we observed that all tissue components of the treatment 3.0 to 4.0 mm had similar growth rate (b = 1) to the development of the half carcass, as observed by Furusho-Garcia et al (2009) and Silva et al. (2000), which may be explained as a tendency for a constant isometric growth. However, the muscle tissue in the treatment 2.0 mm was early, it should be considered the growth phase of these female lambs, which were confined for a shorter time than the others.

Table 4. Allometric coefficient (b) of histological tissues of Pantaneiro female lambs in relation to half carcass.

Item	SFT	A	b	± SE	b ≠ 1	R2
Muscle	2.0 mm	0.26	0.22	0.17	*	21.4
	3.0 mm	- 0.13	0.81	0.34	ns	45.19
	4.0 mm	- 0.42	1.15	0.48	ns	53.08
Fat	2.0 mm	- 2.24	3.39	0.62	*	83.46
	3.0 mm	- 0.87	1.38	0.41	ns	61.6
	4.0 mm	- 0.59	1.08	0.49	ns	49.32
Bone	2.0 mm	0.24	0.34	0.35	ns	13.66
	3.0 mm	0.66	0.97	0.55	ns	30.96
	4.0 mm	- 0.40	0.61	0.65	ns	14.98

SFT = subcutaneous fat thickness; A = intercept; b = allometric coefficient; ± SE = standard error of b; *= significant at ($p \leq 0.05$); ns = non-significant at ($p \leq 0.05$); R^2 = Coefficient of determination.

The fat showed a late growth (b > 1) up to the 2.0 mm, that is, growing faster than the carcass and the growth rate became equal to the carcass when the animals had 3.0 and 4.0 mm of subcutaneous fat. This shows that the finishing of female lambs of the Pantaneiro group with 100 days of age occurs with 2.0 mm of fat cover, indicating a different growth rate of development in Pantaneiro lambs. According to Rosa et al. (2005), fat tissue has the largest variability in the animal, both quantitatively and in distribution, developing different growth rate, influenced by several factors, including: diet, age, sex, body weight and breed (SILVA et al., 2000; NEGUSSIE et al., 2004).

Tissue components of the shoulder cut are shown in Table 5. The muscle and the bone had isogonic growth (b = 1), similar to results obtained by Furusho-Garcia et al. (2009) in female Santa Ines lambs. Both total fat and subcutaneous fat in the treatment 2.0 mm fat thickness had a positive heterogonic growth (b > 1), since it is known that the fat tissue has a late growth. Meantime, as increased the thickness of subcutaneous fat (3.0 and 4.0 mm), fat showed an isogonic behavior. Fat distribution varies among animals, especially in females, between deposits for body reserve, pregnancy and lactation. Perhaps for these reasons and for natural selection of these females, the growth curve of this tissue showed similar speed to the carcass with 3.0 mm subcutaneous fat.

Table 5. Allometric coefficient (b) of histological tissues of Pantaneiro female lambs in relation to the shoulder cut.

Item	SFT	A	b	± SE	b ≠ 1	R2 (%)
Muscle	2.0 mm	- 0.23	0.89	0.29	ns	60.46
	3.0 mm	- 0.24	0.91	0.15	ns	82.98
	4.0 mm	- 0.23	0.64	0.28	ns	51.32
Total fat	2.0 mm	- 0.65	2.16	0.49	*	76.07
	3.0 mm	- 0.66	1.03	0.43	ns	40.62
	4.0 mm	- 0.68	1.96	0.71	ns	60.69
Subcutaneous fat	2.0 mm	- 0.85	6.81	1.09	*	60.46
	3.0 mm	- 1.11	0.86	1.10	ns	82.98
	4.0 mm	- 1.19	2.24	1.05	ns	5132
Bone	2.0 mm	- 0.68	0.47	0.32	ns	22.58
	3.0 mm	- 0.69	1.23	0.53	ns	4378
	4.0 mm	- 0.62	0.22	0.40	ns	5.44

SFT = subcutaneous fat thickness; A = intercept; b = allometric coefficient; ± SE = standard error of b; *= significant at ($p \leq 0.05$); ns = non-significant at ($p \leq 0.05$); R^2 = Coefficient of determination.

Despite the loin cut had late growth (b > 1) in relation to half carcass, its tissue components exhibited different results (Table 6).

Table 6. Allometric coefficient (b) of histological tissues of Pantaneiro female lambs in relation to the loin cut.

Item	SFT	A	b	± SE	b ≠ 1	R2 (%)
Muscle	2.0 mm	- 0.26	0.88	0.15	ns	84.49
	3.0 mm	- 0.34	0.55	0.14	*	69.49
	4.0 mm	- 0.36	0.64	0.15	*	78.64
Total fat	2.0 mm	- 0.55	1.10	0.31	ns	67.60
	3.0 mm	- 0.36	1.61	0.15	*	91.56
	4.0 mm	- 0.39	1.15	0.18	ns	89.23
Subcutaneous fat	2.0 mm	- 0.93	0.989	0.29	ns	66.16
	3.0 mm	- 0.79	1.28	0.35	ns	65.23
	4.0 mm	- 0.74	1.20	0.61	ns	43.78
Bone	2.0 mm	- 0.72	1.40	0.43	ns	60.44
	3.0 mm	- 0.95	1.24	0.27	ns	78.83
	4.0 mm	- 0.85	1.93	0.35	*	85.51

SFT = subcutaneous fat thickness; A = intercept; b = allometric coefficient; ± SE = standard error of b; *= significant at ($p \leq 0.05$); ns = non-significant at ($p \leq 0.05$); R^2 = Coefficient of determination.

Muscles of the treatments 3.0 and 4.0 mm were early relative to the carcass growth, also observed by Furusho-Garcia et al. (2009). Nevertheless, the treatment 2.0 mm followed the growth rate of the whole (b = 1), namely, the muscle showed the same development of the half carcass.

Total fat only had a positive heterogonic growth in the treatment 3.0 mm, and in the other treatments, as well as the subcutaneous fat, it obtained isogonic growth. In evaluating the theoretical curve of growth and maturity of the animal, it can be said that with increasing maturity level there will also be an increasing proportion of fat in the carcass. This growth can be identified and monitored by ultrasonography for slaughter. Thus, the breeder can make interventions by the knowledge of the deposition of subcutaneous fat and compose lots of carcasses with ideal finishing.

The bone showed isogonic growth until slaughtering lambs with 3.0 mm subcutaneous fat thickness. With longer time of confinement, bone tissue had its heterogonic positive growth compared with the growth rate of the carcass. In agreement with Berg and Butterfield (1976), among muscle, bone and fat, bone presents early growth compared with the others. Nevertheless, as the Pantaneiro lambs were still within the growth process and there are no allometric studies for this genetic group, it is likely that these animals have not reached adult body weight, even in the last treatment, causing this late growth.

All tissue components of treatments 3.0 and 4.0 mm showed isogonic behavior (Table 7).

Table 7. Allometric coefficient (b) of histological tissues of Pantaneiro female lambs in relation to the leg cut.

Item	SFT	A	b	± SE	b ≠ 1	R2 (%)
Muscle	2.0 mm	- 0.03	0.19	0.07	*	59.03
	3.0 mm	- 0.199	1.07	0.21	ns	80.69
	4.0 mm	- 0.10	0.67	0.28	ns	52.67
Total fat	2.0 mm	- 1.28	3.15	0.37	*	93.46
	3.0 mm	- 0.92	1.41	0.81	ns	33.51
	4.0 mm	- 1.29	2.35	0.74	ns	67.10
Subcutaneous fat	2.0 mm	- 1.71	3.42	0.79	*	79.01
	3.0 mm	- 1.15	2.45	1.44	ns	32.65
	4.0 mm	- 1.64	2.18	1.27	ns	37.24
Bone	2.0 mm	- 0.58	0.22	0.41	*	32.90
	3.0 mm	- 0.52	0.17	1.36	ns	2.54
	4.0 mm	- 0.78	0.72	1.26	ns	6.11

SFT = subcutaneous fat thickness; A = intercept; b = allometric coefficient; ± SE = standard error of b; *= significant at ($p \leq 0.05$); ns = non-significant at ($p \leq 0.05$); R^2 = Coefficient of determination.

This indicates that within a range of growth rate, body composition is closely related to body size. Hashimoto et al. (2012) also found this behavior in tissue components of the legs of lambs Texel *vs.* Corriedale. Rosa et al. (2005) and Mendonça et al. (2007) observed this behavior for muscle tissue. The bone tissue showed this behavior, isometric growth rather than early, as obtained in the literature (OSÓRIO et al., 1999; SANTOS et al., 2001; MENDONÇA et al., 2007). Once this genetic group has not undergone any genetic improvement (VARGAS JUNIOR et al., 2011), individuals have a larger size due to natural selection in the Pantanal region, where they have broad and thin bones, requirements of the conditions in which they live. Broad and thin bones are the opposite of breeds improved for meat production, which have changes in the bones causing shortening of the limbs and increased thickness of the surrounding muscles (SILVA et al., 2000).

The treatment of 2.0 mm thickness of subcutaneous fat differed as to the muscle and bone, with negative heterogonic growth. In other words, muscle and bone grew early in relation to the growth rate of the half carcass. This result may have a negative aspect, since the development of the muscular tissue of the leg was less than the whole, which accounts for underweight in the marketing of this prime cut. Both total and subcutaneous fat showed late growth. Lambs slaughtered with 3.0 and 4.0 mm thickness of subcutaneous fat showed isogonic behavior for all tissues evaluated.

Conclusion

It is recommended the slaughter of female Pantaneiro lambs with 3.0 mm subcutaneous fat thickness, since their carcasses have already reached physiological maturity (b = 1).. Shoulder and leg cuts are best suited for dissection for presenting the highest correlation with the carcass in females of the Pantaneiro group.

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