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Muscularity and adiposity of carcass of Santa Inês lambs: Effects of different levels of replacement of ground corn by forage cactus meal in finishing ration[1]

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ABSTRACT - The objective of this study was to evaluate the effect of the levels of replacement of ground corn by forage cactus meal in the diet on the muscularity and adiposity of carcass of Santa Inês lambs finished at feedlot. This study was carried out at Estação Experimental de Pendência, belonging to Empresa de Pesquisa Agropecuária da Paraíba S.A. (EMEPA-PB). Forty male Santa Inês lambs in feedlot were used in the experiment. Treatments were randomly assigned to the animals according to a completely randomized design, with four treatments, that consisted of growing substitution levels of ground corn for forage cactus meal: 0, 33, 66 and 100% of substitution and ten replications (lambs). Animals were slaughtered and carcasses cooled for 24 hours for later assessment of conformation, morphometry, loin eye-muscle area, fatness, perirenal fat, marbling and subcutaneous fat thickness. Legs were separated for dissection of muscle, bone, subcutaneous fat, inter-muscle fat and total fat, which were weighed for the determination of the muscle:bone and muscle:fat relation and the relative weight of tissue components. Averages were submitted to variance and regression analyses at a 5% level of probability. Diets had no effect on carcass conformation. However, a negative linear effect on weights and yields of fats was observed with the increased levels of forage cactus meal in the diet, and the opposite was observed in the muscle yield behavior. Forage cactus meal is biologically as efficient as ground corn, because it increases the muscularity and reduces the adiposity of the carcass of Santa Inês lambs in feedlot.

Key Words: fat, loin eye area, morphometry, muscle

Introduction

Feedlot is an alternative to improve the reduced weight of lambs bred in the caatinga. However, Santello et al. (2006) affirmed that the cost analysis is not favorable to the finishing of feedlot of lambs, and that one of the factors contributing to the increase in costs is the use of corn as the main source of energy. There is great fluctuation in the price of corn during the year because of its use in human and animal food, which stimulates the search for cheaper food alternatives, particularly inexpensive sources of energy available in the region (Melo et al., 2003).

The largest area of cultivation of forage cactus is in the semi-arid region of the Brazilian Northeast, which has a fundamental strategic importance (Lopes, 2007). The forage cactus is not a bulky food due to the low fiber content in neutral detergent, of about 26% (Mattos et al., 2000), high content of non-fibrous carbohydrates (Wanderley et al., 2002) and high rate of ruminal digestion, which promotes consumption similar to that of concentrates (Bispo et al., 2007). Veras et al. (2005) studied the effect of replacing a ground corn diet with a forage cactus meal diet on the performance traits of Santa Inês lambs. However, the carcasses were not assessed. The evaluation of the final product must include some carcass traits, especially muscularity and adiposity (Cezar & Sousa, 2007), to meet customer demands.

Therefore, the objective of the present study was to assess the effect of the replacement of a ground corn diet by a forage cactus meal diet on the muscularity and adiposity of the carcass of Santa Inês lambs in feedlot.

Material and Methods

The experimental study was conducted at Estação Experimental de Pendência, which belongs to EMEPA (Empresa de Pesquisa Agropecuária da Paraíba S.A), located in the city of Soledade, Paraiba, in the micro-region of the western Curimataú, in the Agreste Meso-Region of Paraíba, in the semi-arid area. The station is located at

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coordinates latitude S 7º 8' 18", longitude W 36º 27' 2" and altitude of 534 meters

Forty 90-day-old Santa Inês lambs, with a 15.52 kg average live weight were distributed in four groups, fed on growing levels of replacement of ground corn by forage cactus meal (0, 33, 66 and100%) in the diet concentrate. The dry matter used in the experiment was tifton hay. The giant cultivar of spineless cactus (*Opuntia fícus indica* Mill.), produced at EMEPA, was chopped and dried in sunlight for three days and ground for preparing the meal.

Animals were identified and randomly distributed in individual cages (1.10 × 0.55 m), with troughs and drinking vessels. They were dewormed, and adaptation was performed in 14 days. Control diet (0% of forage cactus: 100% of corn) was formulated to provide an average gain of 250 g/day, according to NRC recommendations (1985). The diet was offered twice a day (50% in the morning and 50% in the afternoon) and in an amount that ensured a 10% leftover at the end of each meal (Table 1).

The ingredients were analyzed for the dry matter contents (DM), raw protein (RP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ether extract (EE), calcium and phosphorus, according to Silva & Queiroz (2002). The metabolizable energy values of the diet were calculated considering 1 kg of total digestible nutrients (NDT) equal to 4.409 Mcal of digestible energy (DE), to 0.82 Mcal of ME (Coelho da Silva & Leão, 1979).

During the 80 days in feedlot the animals were weighed every 14 days until they reached live weight at slaughter of 35 kg. Prior to slaughter, the animals were subjected to a 24-hour fasting period of solid food and 16-hour fasting period of liquids and then weighed. Slaughter was performed by electrical stunning, followed by incision on the external jugular vein.

Carcasses were kept in cold chamber at 5 ºC, stored in plastic bags where they were kept for 24 hours. At the end of this period, the carcasses were weighed for obtaining the cold carcass weight (CCW).

After weighting, carcasses were suspended and classified according to the methodology described by Cezar & Sousa (2007): 1 (poor), 2 (fair), 3 (good), 4 (very good) or 5 (excellent) for conformation and 1 (very lean), 2 (lean), 3 (medium), 4 (fat) or 5 (very fat) for finishing. Later, the content of perirenal fatness was subjectively assessed in the carcass in a scale of 1 (poor), 2 (medium) and 3 (fat) according to the methodology described by Cezar & Souza (2007) and weighed after the removal of the carcass fat.

Morphometry was used as an objective parameter to determine carcass conformation (Cezar & Sousa 2007) and consisted of the calculation of the morphometric measures: length of carcass external surface (CEC); length of carcass internal surface (CIC); rump width (LG); width of chest (LT); rump circumference (PG); leg length (CP); depth of chest (PT). The measures of length and circumference were obtained with a measuring tape and compass.

Afterwards, carcasses were longitudinally divided into two half-carcasses. A transverse cut between the 12th and 13th ribs was made in the left half-carcasses, with exposure of the *longissimus lumborum* muscle cross-section area, delimitated in transparent film, for subsequent determination of the loin eye-muscle area (AOL), using Autocad® software. Also, subcutaneous fat thickness was measured with a caliper on site C of AOL. The GR

Table 1 - Dietary and chemical composition of the full ration

Ingredient composition	Level of replacement (%)			
	0	33	66	100
Ground corn (%)	45.00	30.15	15.30	0.00
Forage cactus meal (%)	0.00	14.85	29.70	45.00
Soybean meal (%)	20.20	20.20	20.20	21.00
Urea (%)	0.30	0.50	0.70	0.70
Mineral salt (%)	0.50	0.50	0.70	0.00
Limestone (%)	1.00	0.50	0.40	0.00
Tifton hay (%)	33.00	33.30	33.00	33.30
Dietary composition				
Dry matter (%)	89.41	89.50	89.67	89.72
Raw protein (% DM)	18.51	18.56	18.57	18.46
Metabolizable energy (Mcal/kg DM)	2.75	2.58	2.41	2.26
Ether extract (% DM)	2.55	2.28	2.00	1.73
Neutral detergent fiber (% DM)	32.88	35.0	37.24	39.66
Neutral detergent fiber (% DM)	18.12	19.90	21.5	23.47
Calcium (% DM)	5.68	6.90	9.60	11.10
Phosphorus (% DM)	3.03	2.90	2.80	2.70

measure (Grade Rule –depth) of the abdominal wall at the level of the 12th rib and on a point 11 cm way from the average line of the loin was determined in the abdominal wall. The GR measure of the depth of the soft tissue (muscle and fat) deposed on the 12th rib at a point 11 cm away from the average line of the loin was measured with a caliper. The subjective evaluation of intramuscular fat (marbling) was performed in the cross-section of the *longissimus lumborum* muscle, considering the following scores: 1 (absent), 2 (little), 3 (average), 4 (much) or 5 (too much).

The leg of each left half-carcass was removed, kept in plastic bags and frozen at -20 ºC for later dissection into bone, muscle and subcutaneous and intermuscular fat, added for obtaining the total fat value, according Cezar & Sousa (2007). Also, the relations between muscle weight and total fat (RMG) were determined, as well as the muscle:bone relation.

Afterwards, measurement of the femoral bone was performed to determine the index of muscularity of the leg, according to the methodology described by Purchas et al. (1991), using the formula: $IMP = [(PM5/CF)^{0.5}/CF]$, where PM5 is the weight (g) of the five muscles (*biceps femoris*, *semimembranosus*, *semitendinosus*, *quadriceps femoris* and *adductor femoris*) that cover the femur and the LF (femoral length in cm). Also, indexes of leg (weight of leg/length of leg) and carcass (weight of cold carcass/ internal length of carcass) compactness were determined.

The design was completely randomized, with four treatments and ten replicates. Data were submitted to variance and regression analyses at the 5% probability level. Statistical data processing was made using the SAS (1999) software.

Results and Discussion

Visual examination of the profiles of the external surfaces of the carcasses was not influenced (P>0.05) by the diets, with an average score of 3 (Table 2), in a 1-5 scale, suggesting that, regardless of the diet, the carcasses had sub-convex profiles, and, consequently, adequate muscle development.

The levels of replacement of a corn diet by a forage cactus meal diet had no influence (P>0.05) on the morphometric measures (length of carcass external and internal surfaces, length of leg, width of chest and rump, depth of chest and circumference of rump), suggesting that the replacement of a ground corn diet by a forage cactus meal diet did not influence carcass conformation in morphometric assessment.

The similarity between carcass conformation suggests that the replacement of ground corn by forage cactus meal, regardless of the level, did not affect the muscle ratio of the carcasses. Besides, the lack of noticeable differences could be explained by the fact that the experiment involved animals of the same breed (Cañeque et al., 1989) and by the similar weights at slaughter in the four levels of diet replacement: 6.25 kg for 0%; 33.15 kg for 33%; 36.00 kg for 66%; and 34.25 kg for 100%.

The levels of replacement of ground corn by forage cactus meal did not affect (P>0.05) indexes of carcass and leg, AOL, index of muscularity of the leg or muscle:bone relation, whose averages were 0.27; 0.06; 10.91; 0.40 and 3.48, respectively. Objective assessments such as CCI and loin eye muscle area are of great importance due to their direct relationship with greater tissue deposition and

Table 2 - Conformation, morphometry, compactness and muscularity indexes, Loin eye-muscle area (AOL) and muscle:bone relation (RMO) in santa Inês ovines fed on diets containing forage cactus meal in replacement of ground corn

Item	Level of replacement (%)				Equation	r^2	CV (%)
	0	33	66	100			
Conformation	3.17	3.20	3.00	2.95	$\hat{Y} = 3.08^{ns}$	0.07	12.39
Length of carcass external surface (cm)	60.40	62.10	60.30	60.10	$\hat{Y} = 60.72^{ns}$	0.04	4.72
Length of carcass internal surface (cm)	64.50	61.50	63.40	64.40	$\hat{Y} = 63.45^{ns}$	0.10	4.84
Length of leg (cm)	40.80	42.70	41.80	41.90	$\hat{Y} = 41.80^{ns}$	0.10	3.88
Depth of chest (cm)	14.60	14.80	14.60	14.40	$\hat{Y} = 14.60^{ns}$	0.03	5.84
Rump width (cm)	16.60	18.10	18.10	17.60	$\hat{Y} = 17.60^{ns}$	0.16	8.20
Depth of chest (cm)	26.20	25.90	26.50	26.20	$\hat{Y} = 26.20^{ns}$	0.01	4.17
Rump circumference (cm)	59.90	60.00	58.30	58.20	$\hat{Y} = 59.10^{ns}$	0.06	5.15
Index of carcass compactness (g/cm)	0.28	0.30	0.29	0.26	$\hat{Y} = 0.27$	0.40	8.79
Index of leg compactness (g/cm)	0.06	0.06	0.06	0.06	$\hat{Y} = 0.06^{ns}$	0.10	9.79
Leg muscularity index	0.41	0.40	0.39	0.39	$\hat{Y} = 0.40^{ns}$	0.09	4.37
Loin eye-muscle area (cm^2)	11.55	10.82	11.13	10.13	$\hat{Y} = 10.91^{ns}$	0.05	18.99
Muscle:bone relation (g/g)	3.41	3.67	3.48	3.38	$\hat{Y} = 3.48$	0.08	9.40

$\hat{Y}$ = dependent variable; ns = not significant at a 5% probability level.

amount of marketable meat (Gonzaga Neto et al., 2006; Amorim et al., 2008) and, consequently, carcasses of better quality. According to Siqueira et al. (2001), carcass compactness indexes that vary from 0.26 to 0.37 indicate an adequate amount of muscle tissue in the carcass. The values obtained in the present study were similar to those described by the referred authors and indicate that the forage cactus meal promoted tissue deposition similar to that occurred with ground corn, which is a food with potential for use as energy concentrate in diets fed to lambs.

Forage cactus has non-structural carbohydrate content lower than corn (Menezes et al., 2005). However, it contains high pectin contents (Batista et al., 2003; Bispo et al., 2007), its main carbohydrate, unlike corn, whose main carbohydrate is starch. Although forage cactus meal provides less energy than corn, it ensures a better pattern of rumen fermentation due to its higher level of pectin (Van Soest et al., 1994), which, in this case, may justify the absence of variations in the present study.

The subjective measures of finishing, marbling and perirenal fat were not influenced by the replacement levels (P>0.05), and, thus, the average score of all levels of replacement of corn by forage cactus was 2.77 for finishing, 2.10 for marbling and 2.12 for perirenal fat (Table 3), indicating carcasses of average finishing, little marbling and average perirenal fat. Since the amount of fat (adiposity) is inversely related to the amount of muscle (muscularity), it is suggested that muscularity prevailed over adiposity.

The level of replacement of ground corn by forage cactus meal did not influence (P>0.05) the GR measure and the thickness of subcutaneous fat, with averages of 11.45 mm and 3.92 mm, respectively. The finishing is important to reduce the shortening and darkening of muscle fibers caused by cold, and, consequently, to prevent the reduction in tenderness (Ortiz et al., 2005) and the meat to become dark on the carcass (Caparra et al., 2007). The averages obtained in this experiment for thickness of subcutaneous fat showed a minimum of 3 mm, described by Boggs et al. (1998) as the minimum amount required to prevent the shortening of fibers caused by cold. The average of 3.92 mm for thickness of subcutaneous fat was higher than the 1.63 mm obtained by Rodrigues et al. (2008), in a research with Santa Inês lambs slaughtered at a weight of 33 kg, fed on different levels of citrus pulp in feedlot. The GR measure varied from 7 to 12 mm, an interval considered ideal for the finishing of carcasses of woolless sheep, according to Cezar & Sousa (2007).

The high coefficients of variation related to the parameters of carcass fat should be considered normal, according to Cezar & Sousa (2007), once this tissue varies a lot both in its amount and distribution in the carcass of woolless sheep.

The pattern observed in subjective assessment of perirenal fat was similar among the levels of replacement of corn by forage cactus. However, negative linear effect was observed in the quantification of the perirenal fat, and a decrease of 2.87 g of fat in the level of replacement of ground corn by forage cactus meal was estimated as it increased by 1%. Besides having a non-fibrous content lower than corn (Wanderley et al., 2002), forage cactus, according to Menezes et al. (2005), has higher hypolipidemic and hypoglycemic activity, which may explain the decrease in the amount of perirenal fat, the main deposit of fat reserve of woolless sheep (Cezar & Sousa, 2006). The decrease in perirenal fat observed after the increase in the levels of forage cactus in the diet can be favorable, because this fat is not commercialized, which, according to Amorim et al. (2008), generates loss.

In the assessment of the tissue composition of the leg, it was found that the level of replacement of a ground corn diet by a forage cactus meal diet did not have any effect on the weight of muscles, weight and yield of bones, whose averages were 1.623.52 g; 468.43 g; and 20.13 g, respectively (Table 4). However, a positive linear effect (P<0.05) was observed on the muscle yield and muscle:fat relation,

Table 3 - Characteristics of finishing, GR measure, subcutaneous fat thickness, subjective assessment of perirenal fat, marbling and weight of perirenal fat in Santa Inês lambs fed on diets containing forage cactus meal in replacement of ground corn

Item	Level of replacement (%)				Equation	r^2	CV (%)
	0	33	66	100			
Finishing*	2.80	2.92	2.75	2.62	$\hat{Y}$ = 2.77 ns	0.05	12.54
Marbling**	2.20	2.10	1.90	2.20	$\hat{Y}$ = 2.10ns	0.01	42.71
Perirenal fat***	2.30	2.00	2.00	2.20	$\hat{Y}$ = 2.12 ns	0.01	24.54
GR measure (mm)	11.38	12.19	11.91	10.48	$\hat{Y}$ = 11.45	0.16	14.43
EGS (mm)	3.86	3.09	3.86	4.86	$\hat{Y}$ = 3.92ns	0.02	47.77
Perirenal fat (g)	625.05	530.34	435.63	338.05	$\hat{Y}$ = 625.05 − 2.87x	0.26	38.80

$\hat{Y}$ = dependent variable; x = level of replacement; ns = not significant at a 5% probability level.
* Scale for finishing: 1 = very lean; 2 = lean; 3 = average; 4 = fat; or 5 = very fat.
** Scale for marbling: 1 = absent; 2 = little; 3 = average; 4 = much; 5 = too much.
*** Scale for perirenal fat: 1 = poor; 2 = medium; and 3 = fat.

Table 4 - Weights and yield of tissue components of leg, muscle:fat relation of Santa Inês lambs fed on diets containing forage cactus meal in replacement of ground corn

Item	Level of replacement (%)				Equation	r^2	CV (%)
	0	33	66	100			
Leg (g)	2358.70	2390.40	2368.30	2208.00	$\hat{Y}$ = 2331.38^{ns}	0.14	7.87
Muscles (g)	1615.50	1664.70	1659.80	1554.10	$\hat{Y}$ = 1623.52^{ns}	0.10	8.37
Total fat (g)	280.56	253.17	225.78	197.56	$\hat{Y}$ = 280.56 – 0.83x	0.32	19.21
Subcutaneous fat (g)	185.07	168.90	152.73	136.07	$\hat{Y}$ = 185.07 – 0.49x	0.23	20.98
Intermuscular fat (g)	95.49	84.27	73.05	61.49	$\hat{Y}$ = 95.49 – 0.34x*	0.31	24.42
Bones (g)	472.90	459.60	477.70	463.40	$\hat{Y}$ = 468.43 ^{ns}	0.01	10.30
Muscles (%)	68.69	69.35	70.01	70.69	$\hat{Y}$ = 68.69 + 0.02x*	0.15	2.52
Total fat (%)	11.73	10.74	9.75	8.73	$\hat{Y}$ = 11.73 – 0.03x	0.31	16.79
Subcutaneous fat (%)	7.73	7.07	6.41	5.73	$\hat{Y}$ = 7.73 – 0.02x	0.20	19.10
Intermuscular fat (%)	4.00	3.67	3.34	3.00	$\hat{Y}$ = 4.0 – 0.01x	0.30	22.49
Bones (%)	20.09	19.21	20.22	20.99	$\hat{Y}$ = 20.13	0.06	8.18
Muscle:fat relation (g/g)	5.91	6.57	7.23	7.91	$\hat{Y}$ = 5.91 + 0.02x	0.34	17.94

$\hat{Y}$ = dependent variable; x = level of replacement; ^{ns} = not significant at a 5% probability level.

characterizing a growing relative increase in the muscle ratio in relation to fat. A 1.0% increase in the level of replacement of ground corn by forage cactus meal enables the estimation of 0.02% increase in the muscle:fat relation.

The level of replacement of ground corn by forage cactus meal caused a negative linear effect ($P<0.05$) on the weight and yield of the total, subcutaneous and intermuscular fats (Table 4). Cezar & Sousa (2007) affirmed that, the higher the percentage of fat, the lower the percentage of muscle, which explains the increase in muscle yield, once the fats showed an inversely proportional relationship.

The 1% increase in the level of replacement of ground corn by forage cactus meal in the experimental diet of the lambs allowed estimating a decrease of 0.83; 0.49; 0.34 g for the weight of the total, subcutaneous and intermuscular fats, respectively. A decrease of 0.03; 0.02 and 0.01%, in the same order, was observed for the yield of these fats, for every increase of percentage of replacement in the diet.

The lower non-structural carbohydrate content of the forage cactus (55%), compared with the corn (75%), influences the deposition of fat, which may justify the reduction of carcass fat when forage cactus meal is gradually added to the diet (Menezes et al., 2005). Besides, when forage cactus meal was added, the amount of metabolizable energy was reduced, varying from 2.75 Mcal/kg DM for the lowest level or replacement (0%) to 2.26 Mcal/kg DM for the highest level of replacement (100%) (Table 1). Since the fat deposed on the carcass results from lipogenesis (Kosloski, 2002), due to the excess of carbohydrates (Garcia et al., 2003), and since the carcass should have minimum fat content, although sufficient to provide adequate preservation and sensory quality, the forage cactus meal was found to be an optimum energy source in replacement of ground corn.

The lower percentage of the total leg fat mass in the animals fed on the control diet without forage cactus meal (11.73%) compared with those fed on a 100% forage cactus meal diet (8.73%) suggests tht the replacement of ground corn by forage cactus meal may generate carcasses of greater commercial availability by the consumer market, once, according to Cezar & Sousa (2007), the higher the muscularity and the lower the adiposity levels, the greater the value of the edible portion of the carcass. Besides, the production process can be more economic, since the production of fat generates more energy and is more expensive than muscle production. Medeiros et al. (2008) reported that the fat interferes in the commercial value of the carcass and is a highly variable component, which may become a factor of depreciation of carcass. Moreover, obtaining carcasses without excess fat, by replacing a ground corn diet with a forage cactus meal diet, would prevent commercial loss, by reducing waste during carcass cleaning.

Conclusions

The replacement of ground corn by forage cactus meal in the finishing diet of Santa Inês lambs in feedlot increases the value of the edible portion of the carcasses without affecting the yield of fat required for ensuring adequate carcass preservation.

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