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ANIMAL PRODUCTION

Canonical discriminant analysis on the characterization of the goat carcass

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ABSTRACT. The objective of this work is to identify which carcass and cut characteristics have the best discriminatory power, between sexes and slaughter weights, through discriminant analysis. Were used 32 goats, with initial average weights of 3.11 kg for males and 3.06 kg, for females, for animals slaughtered at 70 days; 3.65 kg for males and 3.25 kg for females for animals slaughtered at 100 days of weight. Objective assessments consisted of morphometric measurements: external carcass length (ECL); internal carcass length (ICL); leg length (LEL); chest width (CHW); croup width (CRW); thigh perimeter (THP); croup perimeter (CRP); chest perimeter (CHP); chest depth (CHD); internal chest depth (ICD) using the hypsometer and flexible tape (Truper®). In the total of 18 primary variables evaluated, the following variables were included in the discriminant model, using the stepwise method: empty body weight, chest depth, chest width, thigh circumference, neck, loin, leg length, and rump width. The discriminant analysis was efficient to discriminate and identify the carcass and cut characteristics with better discriminatory power between the sex and slaughter weight of the animals.

Keywords: canonical variable; cuts; yields; *Mahalanobis*; mestizos.

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Introduction

In the meat production system, the qualitative and quantitative characteristics of carcasses are essential, as they are directly related to the final product. Some authors call attention to the influence of factors such as breed, genotype, slaughter weight, sex, and age of the animal on these characteristics (Costa et al., 2010). There is a need to offer the market a product with an excellent conformation carcass, a high proportion of muscles, and an adequate amount of intramuscular fat (Sousa et al., 2009).

Carcass measurements are essential because they allow comparisons between races, weights, and ages of the slaughtered body, feeding systems, and correlations with other measurements or tissues that make up the carcass, allowing one to estimate its characteristics (Silva & Pires, 2000). Carcass evaluation studies are generally done considering a large number of characteristics, and some are redundant (Barbosa, Lopes, Regazzi, Guimarães, & Torres, 2005), making it difficult to interpret through univariate analysis. Thus, multivariate analysis techniques are shown as extremely efficient alternatives when the situation requires a combination of multiple information from an experimental plot (that is, from an observational vector), to associate or predict biological phenomena based on a complex of essential variables for the development of the experimental plan (Dillon & Goldstein, 1984).

Thus, a better interpretation of the data set can be obtained through multivariate analysis techniques, as they are more appropriate for the study of a set of correlated variables that will be analyzed simultaneously.

Canonical discriminant analysis is a multivariate technique for reducing the dimensionality of data similar to the principal component technique and canonical correlation analysis. However, this technique is a specialty of discriminant analysis and is used to represent several populations in a small subspace (Guedes, Ribeiro, & Carvalho, 2018). Some studies have already been carried out using the discriminant analysis with carcass characteristics of other species (Almeida et al., 2015), and sheep carcass characteristics (Paim et al., 2013; Notter et al., 2014; Camacho, 2015) however, work with goats is still scarce (Macena et al., 2022) mainly to identify the essential variables that discriminate groups according to the sex and age of the animals. Therefore, the objective of this work is to identify which carcass and cut characteristics have the best discriminatory power, between sexes and slaughter weights, through discriminant analysis.

Material and methods

Local of the experiment

The experiment was carried out at the Pendência Experimental Station, belonging to the Paraíba State Agricultural Research Corporation, located in the municipality of Soledade, micro-region of Cariri Paraibano, located between the geographical coordinates of 7° 8 '18 ” South and 36° 27 '2 ” latitude west of Greenwich, with an altitude of 534 m, the average temperature of 30°C and average relative humidity of 70.13%.

Animals

The Animal Ethics Committee of the Federal University of Paraiba (UFPB) approved this study, in Brazil. It used 32 goats (16 males: 8 slaughtered at 70 days and eight slaughtered at 100 days + 16 females: 8 slaughtered at 70 days and eight at 100 days), crossbred Boer breed with local goats. The animals had average weights at birth of 3.11 kg ± 0.64 (males) and 3.00 kg ± 0.76 (females) for those slaughtered at 70 days and weights of 3.65 kg ± 0.71 (males) and 3.25 kg ± 0.38 (females), for those slaughtered at 100 days of age.

The animals were initially identified, weighed, and treated against ecto and endoparasites and vaccinated against clostridia, then they were distributed in individual stalls with free access to drinking fountains and feeders. The adaptation of the animals was made for 14 days, and the weight gain was carried out weekly. All experimental animals were selected one week before the first weaning (70 days), taking into account the type of birth (single, double, and triple) and live weight to prevent these effects from influencing the evaluated characteristics.

Diet

The diet was formulated according to the National Research Council (NRC, 2007), aiming at a weight gain of 200 g day^{-1}, with a forage: concentrate ratio of 12:84, composed of Tifton grass hay (*Cynodon dactylon*), and the concentrates were composed of ground corn, soybean meal, finely ground, mineral supplement and calcitic limestone. The adaptation of the animals was made for 14 days, and the weight gain was carried out weekly. All experimental animals were selected one week before the first weaning (70 days) (Table 1). From 10 days of age, the pups received a complete diet ad libitum in their troughs.

Table 1. Percentual and bromatological composition of experimental diets.

Ingredient (g kg^{-1} DM)	Diet
Tifton hay	480
Ground corn	360
Soybean meal	120
Finely ground	20
Mineral supplement	10
Calcitic limestone	10
Chemical composition	
Dry matter, DM (g kg^{-1} as fed)	889
Crude protein, CP (g kg^{-1} DM)	180
Mineral matter, MM (g kg^{-1} DM)	61
Ethereal extract, EE (g kg^{-1} DM)	48
Neutral detergent fiber, NDF (g kg^{-1} DM)	210
Calcium (g kg^{-1} DM)	8,0
Phosphorus (g kg^{-1} DM)	4,2
Metabolizable energy, ME (Mcal kg^{-1} DM)	2,5

After 70 days, the other half of the offspring that remained in the system started different management, and were released with their respective mothers having access to the pickets and multi-nutritional blocks in the morning and the afternoon, when they returned to the facilities, they received hay of Tifton grass (Cynodon dactylon) and concentrate in a 48% roughage ratio: 52%: concentrate (Table 2), until 100 days are complete, at the time of slaughter. The concentrate consisted of corn bran (36%), soybean meal (12%), soybean oil (2%), mineral salt, and limestone (2%).

Table 2. Chemical composition of the experimental diet ingredients based on the dry matter for offspring up to 100 days old.

Ingredient (g kg^{-1} DM)	Diet
Tifton hay	200
Ground corn	550
Soybean meal	210
Soybean oil	20
Mineral supplement	10
Calcitic limestone	10
Chemical composition	
Dry matter, DM (g kg^{-1} as fed)	890
Crude protein, CP (g kg^{-1} DM)	233
Mineral matter, MM (g kg^{-1} DM)	61
Ethereal extract, EE (g kg^{-1} DM)	50
Neutral detergent fiber, NDF (g kg^{-1} DM)	258
Calcium (g kg^{-1} DM)	8,4
Phosphorus (g kg^{-1} DM)	3,8
Metabolizable energy, ME (Mcal kg^{-1} DM)	2,5

Carcass slaughter and evaluation

When the animals reached the established period, they were weighed to obtain the final live weight. Subsequently, they were subjected to a solid fast of 16 hours and weighed to obtain body weight at slaughter (BWS).

The slaughter was carried out under the current rules of RIISPOA (Brasil, 2000): the animals were stunned by a captive dart pistol, by stunning in the atlantooccipital region followed by bleeding, for four minutes, by the carotid and jugular sections. The blood sample was collected in a previously tared container for later weighing.

After skinning and evisceration, the head (section in the atlantooccipital joint) and legs (section in the metacarpal and metatarsal joints) were removed, and the hot carcass weight (HCW) was recorded. After obtaining the hot carcass (HC), the carcasses were taken to the cold chamber, with an average temperature of 4°C, where they remained for 24 hours suspended on hooks by the tendon of the gastrocnemius muscle, and subsequently, the cold carcass weight (CCW) was obtained, according to methodology Cezar and Sousa (2007). With these weighings, it was possible to calculate hot carcass yield [$\text{HCY} = \frac{\text{HCW}}{BWS}$ x 100], cold carcass yield [$\text{RCF} = \frac{\text{CCW}}{\text{BWS}}$ X 100], and cooling loss [$CL\ (\%) = \frac{(\text{HCW}-\text{CCW})}{\text{HCW}}$ x 100].

The gastrointestinal tract (GIT) was weighed full (GITF) and empty (GITE) to determine the weight of the empty body (EBW), using the following formula: EBW = BWS-[(GITF-GITE) + urine + bile juice], whose variable is the basis for the calculation of actual or biological yield [BY(%) =HCW/EBW x 100].

Objective assessments consisted of morphometric measurements: external carcass length (ECL); internal carcass length (ICL); leg length (LEL); chest width (CHW); croup width (CRW); thigh perimeter (THP); croup perimeter (CRP); chest perimeter (CHP); chest depth (CHD); internal chest depth (ICD) using the hypsometer and flexible tape (Truper®).

Subsequently, the carcasses were sectioned at the ischio-pubic symphysis, following the body and spinous apophysis of the sacrum, lumbar and dorsal vertebrae. Then, the carcass was submitted to a longitudinal cut. The left half-carcass was weighed. The half carcasses were sectioned into six anatomical regions that made up the commercial cuts: neck, palette, rib, handsaw, loin, and ham, according to the methodology of Cezar and Sousa (2007). Then the individual weight of each cut was recorded to calculate its proportion concerning the sum of the reconstituted half carcass, thus obtaining the yield of the carcass cuts.

The data were subjected to canonical discriminant analysis to verify possible differences between the treatments evaluated (sexes and slaughter weights), identify the variables that best discriminate, and use these variables to create a discriminating function that represents the differences between treatments.

For the selection of variables with higher discriminatory power, the stepwise method was used. The selection of variables by this method starts without any variable in the model, and, at each stage, the addition of variables with higher discriminatory power is combined and eliminating those with less contribution, that is, based on the F statistic or lambda value. Wilks. The main objective of this procedure is to find the best set of variables to compose the discriminant function. Statistical analyses were performed using the Statistica 8.0 software.

Results and discussion

In the total of 18 primary variables evaluated, the variables empty body weight, chest depth, chest width, thigh perimeter, neck, loin, leg length, and rump width were included in the discriminant model by stepwise method (Table 3). This set of selected variables is those that best compose the discriminatory model for the evaluated treatments.

Table 3. Variables selected and excluded by the method *stepwise*.

Variables selected	Wilks' (Lambda)	Partial (Lambda)	p-value
Empty body weight	0.053691	0.712653	0.063622
Chest depth	0.046638	0.820427	0.235511
Chest width	0.050651	0.755436	0.110453
Thigh perimeter	0.054925	0.696646	0.051176
Neck	0.044699	0.856030	0.342161
Loin	0.058262	0.656748	0.028916
Leg length	0.051220	0.747047	0.099465
Croup width	0.045746	0.836434	0.279611

Among the selected variables, the most important for the discriminant function, that is, the one with the highest significance ($p < 0.05$) or the most significant discrimination power between treatments was the loin trait ($P = 0.028916$) (Table 4). The other variables in the model were not significant at the 5% probability level and, therefore, do not have a considerable influence on treatment discrimination. According to Hashimoto et al. (2012) the area of the longissimus dorsi muscle or rib eye area is considered a representative measure of the quantity and distribution of muscle masses, as well as the quality of the carcass. Late maturing muscles are indicated to represent the most reliable index of muscle tissue development and size; therefore, the longissimus dorsi is the most recommended, as, in addition to late ripening, it is easy to measure.

Table 4. Functions and percentage of classification by treatment obtained by the stepwise method.

Sorting function	%
$Y_{(F70)} = -544.39-11.19_{(EBW)}+0.37_{(CHD)}+25.53_{(CHW)}+18.40_{(THP)}-118.44_{(Neck)}-10.62_{(Loin)}+12.05_{(LEL)}+15.26_{(CRW)}$	100
$Y_{(F100)} = -620.99-11.10_{(EBW)}+0.32_{(CHD)}+21.38_{(CHW)}+21.81_{(THP)}-108.00_{(Neck)}+66.27_{(Loin)}+10.43_{(LEL)}+18.60_{(CRW)}$	75
$Y_{(M70)} = -540.73-9.68_{(EBW)}+0.36_{(CHD)}+24.58_{(CHW)}+17.43_{(THP)}-95.40_{(Neck)}-73.00_{(Loin)}+13.28_{(LEL)}+14.19_{(CRW)}$	75
$Y_{(M100)} = -595.70-8.28_{(EBW)}+0.66_{(CHD)}+19.33_{(CHW)}+21.03_{(THP)}-114.186_{(Neck)}-15.86_{(Loin)}+11.10_{(LEL)}+16.22_{(CRW)}$	100

EBW = empty body weight, CHD = chest depth, CHW=chest width, THP= thigh perimete, neck, loin, LEL= Leg length and CRW = croup width

Naturally, factors such as sex and age influence the carcass measurements, several studies have already been developed to verify the morphology and the carcass quality of goats slaughtered according to age and sex. These studies involve multiple measures that take time and manpower to measure. The loin variable is essential for discriminating goats based on the sex and age of the animals for future studies of this nature (Gomes et al., 2011).

The functions and percentage of classification generated from the discriminant analysis are shown in Table 4. The animals subject to F70 and M100 were all classified in their groups of origin, indicating the homogeneity of these treatments. Concerning treatments F100) and M70, only 75% of the animals were classified in their origin group.

Table 5 contains the quadratic Mahalanobis distances between treatments, based on the variables selected by the stepwise method. The shortest distance was observed between treatments M70 and F70, but not significant ($p > 0.05$). The treatments M100 and F100 also showed a small but significant distance ($p < 0.001$). These results indicate that males and females with the same slaughter time (70 and 100 days) showed similar growth for biometric measurements and carcass profiles. The most considerable and most significant distances were observed between M70 and F100; M70 and M100; F70 and M10 and F70 and F100, showing the age influences on biometric measurements and carcass cuts since we can observe that the distances are due to the age of slaughter and not to the sex of the animals (Table 5).

The standardized canonical coefficients, the canonical correlation, and the variation explained by each canonical variable (eigenvalues) for the new data set obtained by the stepwise method are shown in Table 6. The first three canonical variables explained 100% of the total variation. These results allow us to study the behavior of the variables through three canonical variables with safety in the information, since the three linear combinations explain the entire variation (100%), with no loss of explanation of the phenomenon studied (Table 6). The higher proportion of variation explained by the first canonical variables, the more efficient the analysis and the better the explanation of the multivariate phenomenon.

Table 5. Quadratic *Mahalanobis* distance between evaluated treatments.

Treatments	M70	F70	M100	F100
M70	0.000000	4.835809	23.826280*	32.247250*
F70		0.000000	22.389280*	24.351800*
M100			0.000000	9.011556*
F100				0.000000

* significance by the F test ($p < 0.05$)

Table 6. Stan Standardized canonical (CAN) coefficients, eigenvalues, total variation, canonical correlation, Lambda Wilks test, and *p-value*.

Variáveis	CAN 1	CAN 2	CAN 3
Empty body weight	0.148376	-1.36648	-0.069766
Chest depth	0.102325	-0.54405	-0.473394
Chest width	-0.591717	0.62851	-0.034310
Thigh perimeter	0.750881	0.13954	-0.205810
Neck	-0.071521	-0.08767	0.879210
Loin	0.856096	0.80569	-0.741171
Leg length	-0.644938	-0.37975	0.606172
Croup width	0.402375	0.42565	0.100874
Eigenvalues	6.454946	1.44315	0.434900
Cumulative ratio	0.774625	0.94781	1.000000
Canonical correlation	0.930516	0.768565	0.550534
Lambda de *Wilks*	0.038263	0.285251	0.696913
p-value	0.000001	0.004935	0.172044

Based on standardized canonical coefficients and considering that the canonical variable 1 (CAN 1) has greater discriminating power than the others, in addition to being considered as Fisher's linear discriminant function, being arranged as CAN 1 = 0.148376 (BWS) + 0.102325 (CHD) - 0.591717 (CHP) + 0.750881 (CRP) - 0.071521 (Neck) + 0.856096 (Loin) -0.644938 (LEL) + 0.402375 (CRW). The canonical correlation associated with the first function (CAN 1) was 0.930516, this analysis aims to verify the multiple associations between discriminant scores and groups, its square value (87%) measures, and indicates the high explanatory power of the first discriminating function. Also, another model validation test is Wilks' Lambda, which aims to test the significance of the discriminant function. We can infer that CAN 1 is highly significant and, thus, better discriminates groups (Wilks lambda = 0.038263) (P= 0.000001) (Table 6). The lower the value of Wilks' Lambda statistic, the greater the degree of differentiation between groups or treatments (Hair Júnior, Tatham, Anderson & Black, 2009). The variable with the highest weight in the first canonical variable was the loin, an expected result since this was the most significant ($p < 0001$) to discriminate the treatments (Table 3). The variables with the highest weight in the second and third canonical variables were empty body weight and Neck, respectively.

Figure 1 illustrates the canonical representation of treatments F70, M70, F100, and M100, using canonical variables 1 and 2. The first two canonical variables (CAN1 and CAN2) were sufficient to explain 77.46 and 17.32% of the total variation of the data, respectively.

It is possible to observe that the groups F70 and M70 are close, as has already been described, they are the shortest treatments (Table 4), as well as an approximation of groups M100 and F100, the most extended treatments. Some females with 100 days of treatment behaved similarly to males at 100 days, and some male animals at 70 days behaved similarly to females at 70 days. Although sex is a factor that can influence carcass characteristics, it is possible that in some cases the behavior of animals of the opposite sex may be the same, as already reported by Gomes et al. (2011) when studying Carcass traits of characteristics of kids goats from five breed groups raised in a feedlot system.

When considering the use of canonical discriminant analysis, it is essential to measure, in the sample elements, variables that can distinguish populations. Otherwise, the quality of adjustment of the discrimination rule will be compromised. A common misconception is to think that increasing the number of response variables increases the capacity for discrimination (Mingoti, 2005). In general, the treatments are visually well separated, showing good discrimination.

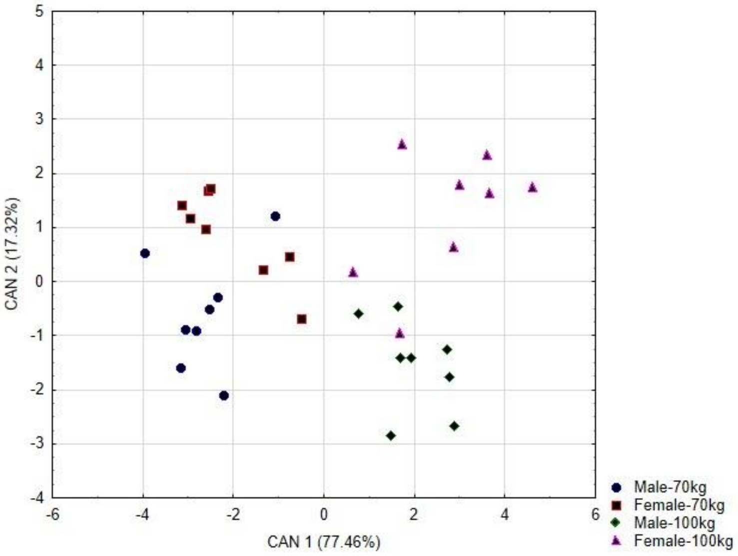

Figure 1. Two-dimensional graph of the canonical discriminant analysis of F70, F100, M70, and M100 for biometric measurements and cuts of the goat carcass.

Conclusion

The discriminant analysis was efficient to discriminate and identify the carcass and cut characteristics with better discriminatory power between the sex and slaughter weight of the animals.

The variable with the most significant discriminatory power between treatments, selected using standardized canonical coefficients in increasing order of importance was the loin, which was also selected for presenting the highest discriminatory power by the stepwise method

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