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ANIMAL PRODUCTION

Principal components for the *in vivo* and carcass conformations of Anglo-Nubian crossbred goats

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ABSTRACT: *This study aimed to identify the principal components (PC) that explain the highest percentages of total variance and best characterize the in vivo and carcass morphologies of Anglo-Nubian crossbred goats. Nineteen carcass morphometric traits and six in vivo morphometric traits were measured in 28 kids at eight months of age. Principal component analysis indicated that five PC were able to explain 83.57% of the total variance in the 19 original carcass traits. Those components were termed PC_1-Carcass Size, PC_2 - Body Condition, PC_3-Carcass Width, PC_4-Chest Depth, and PC_5 - Hindquarter. For in vivo morphometric traits, the first two principal components explained 78.86% of the total variance. These components were called PC_1-In vivo Size and PC_2-In vivo Conformation.*
Key words: *carcass, correlation, multivariate analysis, variance.*

Componentes principais para conformações *in vivo* e das carcaças em caprinos mestiços da raça Anglo-Nubiana

RESUMO: *Este estudo buscou identificar componentes principais (CP) que explicam os maiores percentuais de variância total e que melhor caracterizam cabritos mestiços da raça Anglo Nubiana, quanto à medidas morfológicas obtidas in vivo, e na carcaça de 28 animais com 8 meses de idade. Foram conduzidas duas análises de componentes principais, sendo uma para 19 características de carcaça e outra para seis características morfométricas in vivo. Os cinco primeiros CP explicaram 82,54% da variância total das 19 características incluídas nessa análise. Estes componentes foram chamados de: CP1 - Tamanho da Carcaça, CP2 - Condição Corporal, CP3 - Largura da Carcaça, CP4 - Profundidade do Tórax e, CP5 - Comprimento do Pernil. Os dois primeiros componentes principais das morfometrias obtidas in vivo explicaram 78,86% da variância total e foram chamados de CP1 - Tamanho in vivo e CP2 - Conformação in vivo.*
Palavras-chave: *análise multivariada, carcaça, correlação, variância.*

INTRODUCTION

Several lines of research in animal science require the measurement of variables of interest to provide a good characterization of animals or experimental groups. Morphometric traits such as body length, chest and rump widths, withers and rump heights, and chest circumference can help to identify which animals have adequate conformation for meat production (JUCÁ et al., 2014). These traits can be measure *in vivo* and do not require expensive equipment for this procedure, which makes them good options for animal breeding strategies. However, obtaining these measurements directly at the carcass of slaughtered animals allows for a more accurate evaluation of the carcass quality (JUCÁ et al., 2016).

Regardless of the time of evaluation - *in vivo* or after slaughter -, the number of morphometric traits in such studies is usually large, which generates excessive work without necessarily improving the characterization of animals or groups. This occurs when high correlations are present among the many studied traits. In this case, a multivariate method is suggested to better understand the complex correlation existing among

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these variables. Principal component analysis (PCA) is a multivariate method that allows for the transformation of a set of correlated original traits into a new set of uncorrelated traits with equivalent dimension, but retaining most of the variance present in the original traits in a few principal components. Therefore, the study of the principal components may reveal aspects not perceived in the separate analysis of the original traits, making it possible to differentiate animals considering a set of variables simultaneously.

In animal science, PCA has been applied in research with several species. PINTO et al. (2005), used PCA to identify redundant morphometric traits in Mangalarga Marchador horses. Similarly, BARBOSA et al. (2005), applied PCA to 33 carcass traits in a swine population and identified 17 redundant traits. YAMAKI et al. (2009), studied 12 chicken traits and reported seven redundant traits. LEITE et al. (2009), evaluated 11 quail carcass traits and noted that only four traits were sufficient for characterization of animals. PINTO et al. (2013), studied 15 performance traits in Angus cattle and had four principal components explaining 80% of total variation. However, no studies have reported PCA applied to reduce the dimensionality of variables in goats. The present research was carried out to identify the principal components that explain the highest percentages of total variance and best characterize the *in vivo* and the carcass morphologies of Anglo Nubian crossbred goats.

MATERIALS AND METHODS

This study was carried out from August to December 2009 (dry season) at the Agronomic Institute of Pernambuco, located in the municipality of Sertânia, Pernambuco State, Brazil (08º04'25"S,37º15'52" W; 600m asl). The ecosystem of the region is the Caatinga biome, and the local climate, according to the Köppen classification, is a hot semiarid BSh type, with two distinct seasons (rainy and dry).The average temperature in the evaluation period was 25.1°C, with an accumulated precipitation of 71.05mm (SILVA et al., 2014). Twenty-eight Anglo-Nubian crossbred withers with an average initial live weight of 18.75 ± 2kg, at eight months of age, were used. Before the start of the experiment, the animals were treated against endo and ectoparasites and vaccinated against clostridiosis and rabies. Goats were kept, in a continuous grazing system, in an experimental 37-ha area covered by a hyperxerophilic Caatinga vegetation of dense trees and shrubs, at a stocking rate of 1.15 head/ha.

The animals remained in the pasture from 7h00 to 14h00, when they were then gathered into the experimental shed and housed in individual stalls to receive feed supplementation. The initial supplement contained 0, 72, 144, and 216g dry matter of the supplement offered daily, which represented 0, 0.5, 1.0, and 1.5% of their live weight, respectively. These amounts were adjusted weekly as a function of live weight. The supplement was isoprotein (average 12% CP), containing 50% small palm (*Nopalea cochenillifera* (L.) SD), 16 to 14% crushed corn, 9.94% wheat bran, 17.22% cottonseed, 5.70% soybean meal, and 1.0% of a mineral mixture formulated according to the nutritional requirements recommended by the NRC (2007) for an average daily gain of 50g by animals receiving the highest level of feed supplementation.

The morphometric traits evaluated *in vivo* on the day of slaughter (after fasting for 16h) were body length, chest width, withers height, rump height, rump width, and chest circumference. Body weight at slaughter, hot carcass weight (obtained immediately after slaughter), cold carcass weight (obtained 24h after slaughter, at 4ºC), and body condition score (1 and 2) (with values ranging from 1 to 5 depending on the muscle development) were also measured.

Traits followed by number 1 are expressed relative to the hot carcass weights, and those followed by number 2 are relative to the cold carcass weights. External carcass length (1 and 2) -distance from the cervico thoracic joint to the first intercoccygeal joint; internal carcass length (1 and 2) -distance between the front border of the pubic bone and the front border of the first rib at its midpoint; rump width (1 and 2) -maximum width between the trochanters of the femurs; rump circumference (1 and 2) -circumference of the rump region, based on the trochanters of the femurs; chest circumference(1 and 2) -circumference measured behind the shoulder; leg length (1 and 2) -distance between the greater trochanter and the border of the tarsal-metatarsal joint; chest depth (1 and 2) -distance from the sternum to the withers; and chest width (1 and 2) -distance between the anterior ends of the sternum. Lengths and circumferences were measured with a tape, and widths with a caliper. Based on these values, the leg compactness index (LCI (cm/cm) = rump width/leg length) and the carcass compactness index (CCI (kg/cm) = cold carcass weight/internal carcass length) were determined, as described by YÁÑEZ et al. (2004).

Hot and cold carcass weights, rump width-2, and leg length-1 were excluded from the PCA because they formed singular or poorly conditioned matrices. All other variables were included in two PCA analyses-one with carcass traits and another with *in vivo* morphometric traits. Minimum, maximum, mean, and standard deviations for measurements used in the PCA can be observed in table 1.

The PCA was carried out on the correlation matrix. The analysis consists of transforming a set of Z1, Z2, ..., Zp variables into a new set of Y1 (PC1), Y2 (PC2), ..., Yp (PCp) variables uncorrelated with each other and arranged in descending order of variance. The principle of this procedure is that the first principal component contains the highest variability of the original data. The principal components were obtained using the following expressions:

$\left| R - \tau I \right| = 0$ →provides the eigenvalues $\tau_1, \tau_2, ..., \tau_p$;

$\left| R - \tau_i I \right| \alpha_i = \emptyset$ →provides the eigenvectors $\alpha_1, \alpha_2, ... \alpha_p$;

Where R = matrix of correlation among the traits; τ_i = eigenvalues of matrix R; α_i = eigenvector associated with eigenvalue τ_i; I = identity matrix of order p(p = number of traits); and $\emptyset$= null vector of dimension p × 1.

Table 1 - Minimum, maximum, mean, and standard deviation for the traits evaluated in Anglo-Nubian crossbred goats.

Trait*	Minimum	Maximum	Mean	Standard deviation
Body weight at slaughter	15.00	28.10	20.28	3.05
Body length	54.00	71.00	61.03	3.81
Chest circumference	59.00	71.00	63.61	2.97
Chest width	12.00	17.00	14.74	1.42
Withers height	53.00	70.00	60.46	3.83
Rump height	51.00	72.00	59.68	4.70
Rump width	9.40	14.40	11.45	1.33
Body condition score 1	2.80	4.30	3.30	0.39
Body condition score 2	2.80	3.80	3.34	0.28
External carcass length 1	47.40	56.70	51.51	2.86
External carcass length 2	47.30	56.50	51.35	2.39
Internal carcass length 1	50.30	62.70	54.78	2.92
Internal carcass length 2	51.00	63.60	55.80	3.28
Leg length 2	33.00	42.00	36.19	2.11
Chest depth 1	20.50	26.80	23.06	1.72
Chest depth 2	19.10	27.00	23.27	1.85
Chest circumference 1	49.40	61.50	48.37	3.00
Chestcircumference 2	50.00	59.60	55.53	2.44
Rump width 1	11.00	20.70	14.76	2.52
Chestwidth 1	11.00	18.90	15.38	1.68
Chestwidth 2	13.70	18.50	16.42	1.40
Rump circumference 1	39.70	53.20	46.24	3.03
Rump circumference 2	38.00	50.80	45.69	2.84
Leg compactness index	0.32	0.56	0.47	0.06
Carcass compactness index	0.12	0.20	0.14	0.02

*Traits followed by number 1 are expressed relative hot carcass weights, and those followed by number 2 are relative to the cold carcass weights.

The α_i eigenvectors were normalized to obtain α_i^*, such that $\alpha_i^{'*}\alpha_i^* = 1$ for $i = 1, 2,..., p$ and $\alpha_i^{'*}\alpha_j^* = 0$ for $i \neq j$.

A minimum percentage of 80% of the explained variance and/or eigenvalues higher than one was assumed as a criterion for evaluation of components. Data were analyzed using the PRINCOMP procedure of SAS software (SAS, 2012).

RESULTS AND DISCUSSION

Carcass traits

The slaughter weight obtained in the present study (20.28kg) corroborates those reported previously for the Anglo-Nubian goat. OLIVEIRA et al. (2007) and OLIVEIRA et al. (2008) slaughtered Anglo-Nubian crossbred goats at 350 days of age and reported body weights ranging from 20 to 30kg. SILVA et al. (2014) evaluated Anglo-Nubian crossbred goats slaughtered at 350 days of age and reported body weights ranging from 18.9 to 22.1kg. Regarding morphometric traits, comparisons with other studies are more difficult due to differences between experiments in terms of animal size, slaughter age, as well as different anatomical points used to measure the traits. However, SOUSA et al. (2009) reported a carcass length of 61.8 ± 2.6cm in Anglo-Nubian crossbred goats, which is close to the values reported here for internal carcass length (Table 1). Therefore, the mean values of the present study are consistent with those of studies on the Anglo-Nubian crossbreed.

Principal components analysis

The objective of principal components analysis (PCA) is to reduce the dimensionality of the variables under study (DUNTEMAN, 1984). Once this has been accomplished by explaining the high percentage of total variance in the original traits with few principal components, it can be concluded that the analysis had a good fit and was successfully applied. The first five principal components were able to explain 83.57% of the total variation existing in the 19 carcass traits evaluated and had eigenvalues very close to one (Table 2). This is a very significant reduction, which can be applied in some areas of animal science. Pinto et al. (2006) used PCA applied to carcass and performance traits in chicken and reported that the first five components accounted for approximately 93.3% of the total variance of 10 traits, and demonstrated that selection for the first

Table 2 - Eigenvalues and proportion of variance of carcass traits explained by each principal component evaluated in Anglo-Nubiancrossbred goats.

Principal component	Eigenvalue	Proportion of variance explained	Accumulated proportion of variance explained
PC_1	9.7231	0.5117	0.5117
PC_2	2.5595	0.1347	0.6465
PC_3	1.5506	0.0816	0.7281
PC_4	1.1326	0.0596	0.7877
PC_5	0.9125	0.0480	0.8357
PC_6	0.7896	0.0416	0.8773
PC_7	0.5957	0.0314	0.9086
PC_8	0.4315	0.0227	0.9313
PC_9	0.3224	0.0170	0.9483
PC_{10}	0.2945	0.0155	0.9638
PC_{11}	0.1787	0.0094	0.9732
PC_{12}	0.1367	0.0072	0.9804
PC_{13}	0.1297	0.0068	0.9872
PC_{14}	0.0925	0.0049	0.9921
PC_{15}	0.0522	0.0027	0.9948
PC_{16}	0.0441	0.0023	0.9988
PC_{17}	0.0306	0.0016	0.9995
PC_{18}	0.0146	0.0008	0.9995
PC_{19}	0.0089	0.0005	1.0000

PC1…PC19 – from first to nineteenth principal components.

principal component already resulted in genetic gain similar to selection for ten individual traits. However, selection for each of the ten traits would be much more complex than for the first principal component only.

This strong dimensional reduction had already been reported in other species, but the present study is the first to indicate this possibility also in goats. In newly born Mangalarga Marchador horses, PINTO et al. (2005) applied PCA for morphometric measurements and observed a reduction from 25 to seven and nine in females and males, respectively, while for angular measurements the reduction was from 11 to six and seven traits in females and males, respectively. BARBOSA et al. (2005) evaluated 33 carcass traits in swine with PC analysis and identified 17 redundant traits. YAMAKI et al. (2009) applied PCA for days at first egg laying, egg production, body weights at different ages, and egg weight, and of the total 12 traits studied, seven were redundant. LEITE et al. (2009) evaluated live body weight; carcass weight; whole leg weight; breast weight; abdominal fat pad weight; weights of liver, gizzard, and heart; and carcass dry matter, fat, and crude protein contents, and of the11 quail carcass traits assessed, only four were sufficient for explaining a large variance percentage. PINTO et al. (2013) studied performance traits in Angus cattle and observed a decrease from 15 to four principal components. All previous studies showed the good fit of PCA in the evaluation of the complex correlation among the many variables of interest in animal production, because many variables are moderated or highly correlated. As shown in table 3, of the171 correlations among carcass traits, only 18 were low (0.20). Besides, some correlation coefficients were very high, such as the 0.91 between body weight at slaughter and internal carcass length.

The first principal component (PC1) of the carcass traits group had positive eigenvectors ranging from 0.1033 to 0.2976 (Table 4) and explained 51.17% of total variation. PC1 was termed Carcass Size, because animals with small values for this

Table 3 - Pearson correlations among carcass traits evaluated in Anglo-Nubiancrossbred goats.

	BW	BCS1	BCS2	ECL1	ECL2	LL2	CD1	CD2	CC1	CC2	ICL1	ICL2	RW1	CW1	CW2	RC1	RC2	LCI	CCI
BW	1.00																		
BCS1	0.22	1.00																	
BCS2	0.43	0.46	1.00																
ECL1	0.74	0.00	0.55	1.00															
ECL2	0.70	-0.17	0.30	0.87	1.00														
LL2	0.75	0.11	0.16	0.62	0.63	1.00													
CD1	0.46	0.00	0.25	0.35	0.32	0.26	1.00												
CD2	0.67	0.08	0.41	0.64	0.55	0.53	0.51	1.00											
CC1	0.67	0.21	0.49	0.73	0.63	0.56	0.42	0.69	1.00										
CC2	0.76	0.32	0.57	0.65	0.59	0.63	0.30	0.57	0.82	1.00									
ICL1	0.91	0.04	0.40	0.79	0.82	0.73	0.48	0.66	0.64	0.72	1.00								
ICL2	0.83	0.03	0.15	0.69	0.78	0.83	0.37	0.59	0.68	0.67	0.82	1.00							
RW1	0.31	0.35	0.37	0.26	0.14	0.32	0.05	0.34	0.01	0.20	0.24	0.02	1.00						
CW1	0.51	0.43	0.61	0.39	0.24	0.30	0.00	0.26	0.45	0.66	0.43	0.31	0.17	1.00					
CW2	0.48	0.48	0.44	0.29	0.20	0.26	0.22	0.26	0.44	0.54	0.45	0.42	-0.20	0.63	1.00				
RC1	0.71	0.45	0.64	0.69	0.54	0.45	0.22	0.42	0.53	0.59	0.53	0.57	0.34	0.54	0.38	1.00			
RC2	0.69	0.45	0.64	0.60	0.48	0.35	0.22	0.28	0.44	0.53	0.52	0.48	0.28	0.50	0.46	0.93	1.00		
LCI	0.28	0.52	0.60	0.36	0.11	0.23	0.36	0.40	0.26	0.28	0.17	0.13	0.42	0.26	0.26	0.56	0.49	1.00	
CCI	0.91	0.24	0.51	0.75	0.66	0.59	0.51	0.60	0.65	0.72	0.79	0.66	0.38	0.50	0.34	0.74	0.70	0.37	1.00

BW - Body weight at slaughter; BCS1and BCS2 - Body condition score 1 and 2; ECL1 and ECL2 - External carcass length 1 and 2; LL2 - Leg length 2; CD1 and CD2 - Chest depth 1 and 2; CC1 and CC2 - Chest circumference 1 and 2; ICL1 and ICL2 - Internal carcass length 1 and 2; RW1 - Rump width 1; CW1 and CW2 - Chestwidth 1 and 2; RP1 and RC2 - Rump circumference1 and 2; LCI - Leg compactness index; CCI - Carcass compactness index.

Table 4 - Eigenvectors for each of the first five principal components in Anglo-Nubiancrossbred goats.

Trait	PC_1	PC_2	PC_3	PC_4	PC_5
Body weight at slaughter	0.2976	-0.0903	-0.0039	-0.0798	0.0855
Body condition score 1	0.1033	0.4831	-0.0705	0.0150	0.3332
Body condition score 2	0.2056	0.3395	0.0438	0.1163	-0.2039
External carcass length 1	0.2751	-0.1293	0.1075	-0.0786	-0.2642
External carcass length 2	0.2436	-0.2906	0.0512	-0.1591	-0.2521
Internal carcass length 1	0.2799	-0.2066	-0.0197	-0.0296	0.0575
Internal carcass length 2	0.2569	-0.2694	-0.1243	-0.0819	0.0868
Leg length 2	0.2325	-0.2038	0.0590	-0.1960	0.4043
Chest depth 1	0.1511	-0.1189	0.1763	0.6742	-0.0858
Chest depth 2	0.2311	-0.1220	0.2008	0.3009	0.2410
Chestcircumference1	0.2569	-0.0934	-0.1579	0.2080	0.0448
Chestcircumference2	0.2723	0.0086	-0.1946	-0.0083	0.2062
Rump width 1	0.1065	0.1973	0.5724	-0.2740	0.3618
Chestwidth 1	0.1936	0.2534	-0.3394	-0.1644	0.1238
Chestwidth 2	0.1732	0.1775	-0.5187	0.2094	0.0885
Rump circumference1	0.2600	0.2031	0.0673	-0.2023	-0.3102
Rump circumference2	0.2405	0.2309	0.0035	-0.1945	-0.4070
Leg compactness index	0.1512	0.3431	0.3122	0.2968	-0.0433
Carcass compactness index	0.2857	-0.0183	0.1071	-0.0342	-0.0678

PC1…PC5 -From first to fifth principal component.

component had small values for the carcass traits studied, while animals with large values for this component had large carcass trait values.

For the second principal component (PC2), body condition scores 1 and 2 and leg compactness index are the most important variables in the second principal component because of their higher eigenvector values (Table 4). Thus, PC2 was termed Body Condition, and animals with higher values for this component were those with better body condition. The PC2 explained 13.47% of total variation, indicating that body condition scores and leg compactness index are important traits for total variation among animals. Animals with positive values for both PC1 and PC2 are also those that simultaneously showed larger carcasses traits and better body condition scores. The ellipse in figure 1 indicates that most of the animals positive for both PC1 and PC2 received supplementation at the level of 1.5%. Conversely animals treated with 0.0% showed negative values for PC1 and PC2 or values near zero for these components. Thus, the treatment used here seems to increase the carcass size and the body condition scores, especially when we compare the treatments with 0.0 and 1.5% supplementation.

According to SANTOS (2011), supplementation at 1.5% of the live weight of the animals in this experiment, reared in a semi-intensive system in the Caatinga biome during the dry season, allowed for greater body weight and body length as well as better carcass fatness and conformation.

Rump width 1 and chest width 2 had higher eigenvectors for the third principal component (PC3) (Table 4). The fact that these eigenvectors had respective positive and negative values reveals an antagonistic relationship between these variables. Thus, animals with a wider rump and a narrower chest showed the highest values for PC3. The opposite was also true: animals with lower values for PC3 were those that had the narrowest rump and the broadest chest. A negative association between these traits was also observed in the correlation analysis (Table 3), but their small value (–0.20) would not have a

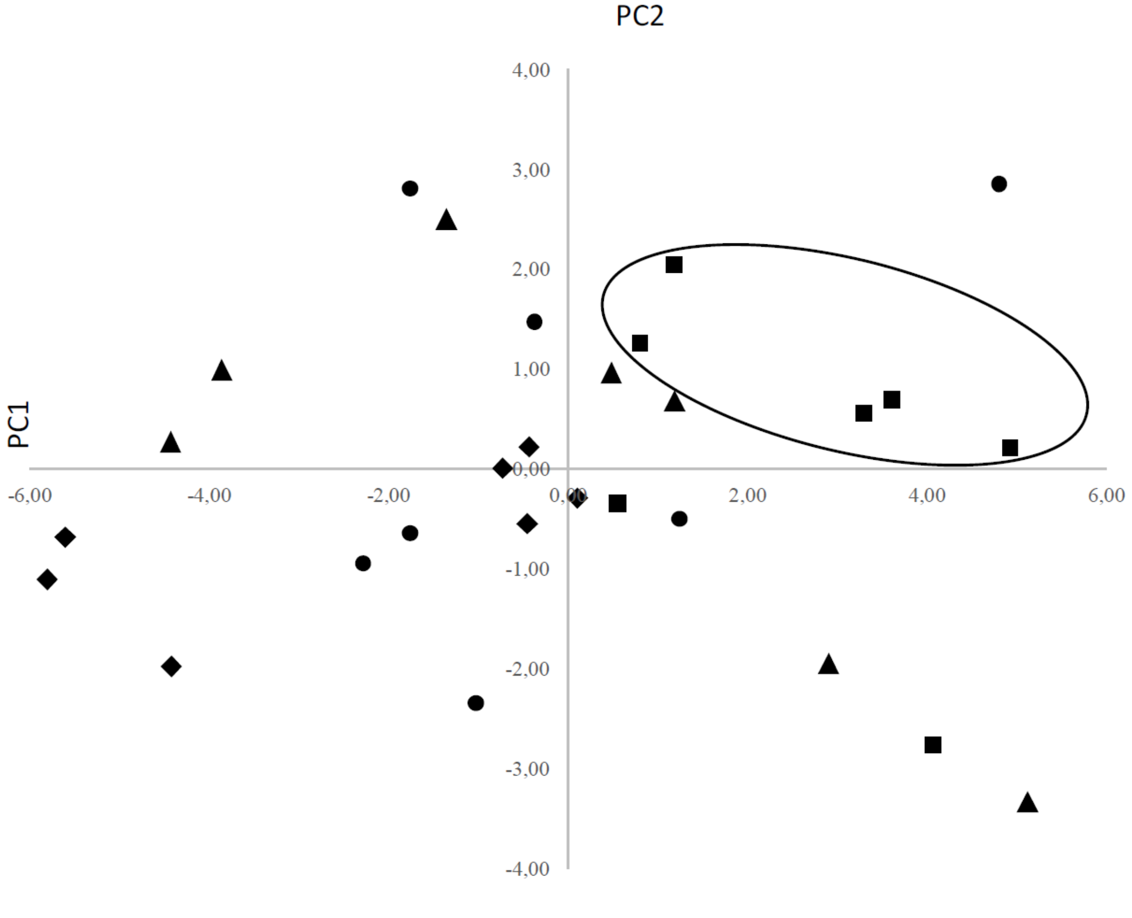

Figure 1 - Scatter diagram of first and second principal components (PC1 × PC2) of carcass traitsin Anglo-Nubiancrossbred goats according to the treatments 0.0% (diamond), 0.5% (circle), 1.0% (triangle),and 1.5% (square).

strong meaning for discussion. Principal component analysis revealed that this correlation is important, because this component explained 8.16% of the total variation of the 19 carcass traits studied here. For goat meat production purposes, animals with high values for this component are desirable, as they will have a more developed carcass hindquarter. Because these two measurements represent the carcass widths in the fore- and hind-quarters, respectively, this component was called Carcass Width.

Chest depth (1) had the highest eigenvector value in the fourth principal component (PC4) (Table 4), and other traits had much lower eigenvectors. PC4 explained 5.96% of the total variation and was termed Chest Depth, as it allowed for the differentiation between animals with greater and smaller values for this trait. Finally, the fifth principal component (PC5) explained 4.80% of total variation and had leg length (2)and rump circumference (2) with the highest eigenvector (Table 4).The eigenvector values were positive for leg length and negative for rump circumference; therefore, these variables showed an inverse relationship; i.e., animals with long legs had a small rump circumference and vice versa. Thus, PC5 was termed Hindquarter, because the two variables are associated with hindquarter development.

In vivo morphometric traits

A PCA was applied to six *in vivo* morphometric traits, and the first two principal components were able to explain almost 80% of the total variation in the six original traits and had

Table 5 - Eigenvalues andproportion of the variance of morphometric traits explained by each principal component evaluated in Anglo-Nubiancrossbred goats.

Principal component	Eigenvalue	Proportion of variance explained	Accumulated proportion of variance explained
PC_1	3.5350	0.5892	0.5892
PC_2	1.1964	0.1994	0.7886
PC_3	0.5594	0.0932	0.8818
PC_4	0.2817	0.0469	0.9287
PC_5	0.2347	0.0391	0.9679
PC_6	0.1928	0.0321	1.0000

PC1…PC6 - From first to sixth principal component.

eigenvalues higher than one (Table 5). Therefore, for this set of variables, PCA also showed good fit, allowing for a reduction of 1/3 the variables of interest. This good fit is also a consequence of correlation between the variables, because of the 15 correlation estimates in table 6, only two were lower than 0.20. Besides, high correlations can be observed such as 0.72 between body length and withers height.

The first principal component explained 58.92% of total variation and is able to differentiate between small and large animals, because all eigenvectors were positive and with very similar magnitudes (0.3157 to 0.4774) (Table 7). Therefore, this component was called *in vivo* size. The second principal component explained 19.94% of total variation and was named *in vivo* conformation, as it showed chest and rump widths, besides rump height, as the traits with the highest eigenvectors (Table 7). In this case, the widths had positive eigenvectors, while withers height had a negative sign. Thus, animals with large values for the second principal component showed high values for chest and rump widths, but a small value for withers height. Therefore, animals with the largest values for the second component are desirable. It is possible to observe, in figure 2, that eight animals showed a PC1value higher than 1.0. Of these, five were treated with supplementation at 1.5% and no animal from treatment 0% appears in this group. Therefore, there is again a clear separation between groups (0% and 1.5%) in this analysis and a strong indication that the supplementation level of 1.5% promotes an increase in size *in vivo* when compared with 0%.

According to SANTOS (2011), the growth and development of animals are influenced by the quality and quantity of feed supplied. As the animal grows, changes in its body measurements occur and the animal begins to develop, and growth and body development decrease gradually when it reaches maturity. In this way, the supplementation level of 1.5% resulted in changes in live weight

Table 6 – Pearson correlation among *in vivo* morphometric traits in Anglo-Nubiancrossbred goats.

	Body length	Chest circumference	Chestwidth	Withers height	Rump height	Rump width
Body length	1.00					
Chest circumference	0.71	1.00				
Chestwidth	0.38	0.60	1.00			
Withers height	0.72	0.67	0.30	1.00		
Rump height	0.67	0.52	0.13	0.70	1.00	
Rump width	0.51	0.58	0.46	0.28	0.14	1.00

Table 7 - Eigenvectors of the first two principal components (PC_i) of morphometrictraits *in vivo*evaluated in Anglo-Nubiancrossbred goats.

	PC_1	PC_2
Body length	0.472960	–0.133121
Chest circumference	0.477428	0.148180
Chestwidth	0.315708	0.545819
Withers height	0.440924	–0.337313
Rump height	0.379145	–0.533397
Rump width	0.332468	0.513917

PC1 and PC2 -First and second principal component.

at slaughter and in body length, confirming the growth of these animals during a period of low forage availability.

Results of this study demonstrate the practical application of PCA in goats to evaluate carcass and *in vivo* body traits. Seven principal components were identified through this analysis: five carcass traits and two *in vivo* morphometric traits. Therefore, the 25 original traits studied can be reduced to seven principal components, which can be useful in experiments in the animal science area. For example, in studies focusing on goat nutrition, instead evaluating the effect of

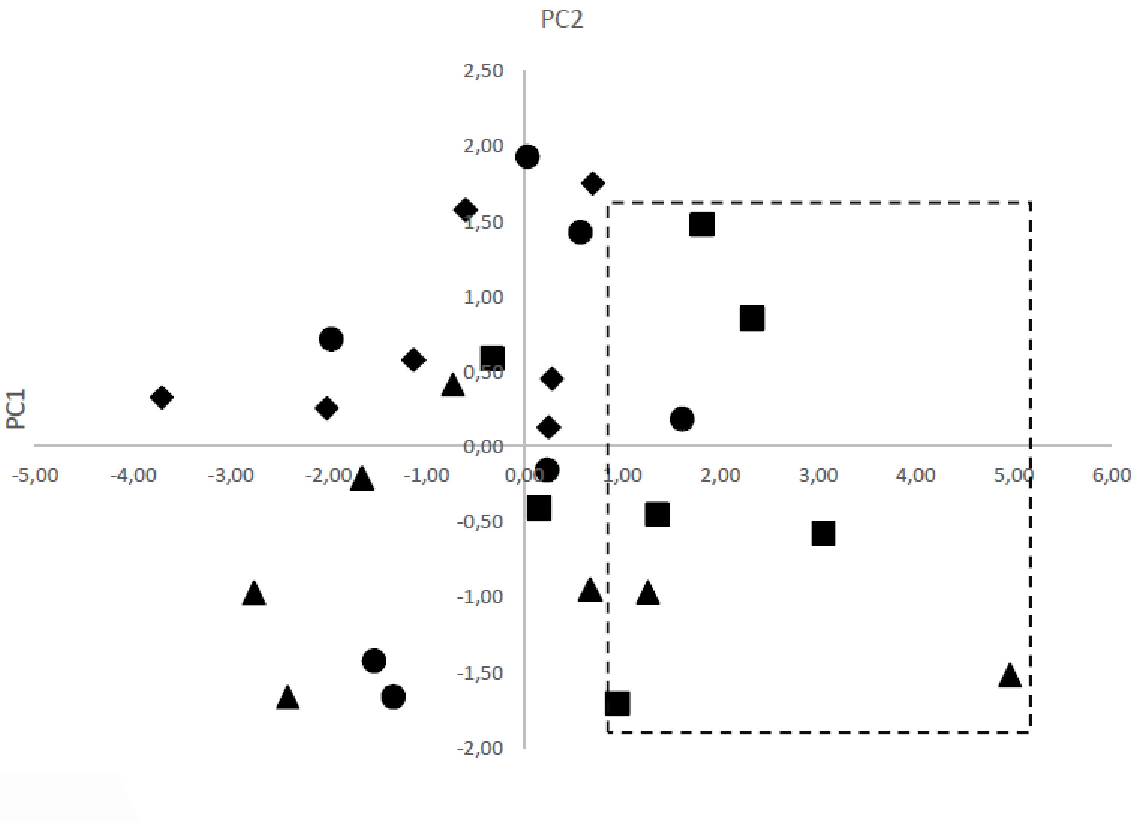

Figure 2 - Scatter diagram of first and second principal components (PC1 × PC2) of *in vivo* morphometric traits in Anglo-Nubian crossbred goats according to the treatments 0.0% (diamond), 0.5% (circle), 1.0% (triangle), and 1.5% (square).

treatments on 25 traits, researchers could solely test the effects for the few principal components analyzed here. This would significantly reduce the occurrence of statistical type-I errors and make the discussion simpler and more objective. Another important aspect of the results obtained in our study was the identification of the original variables that most affected the principal components and thus allowed us to assign names to each component. These variables are also the most important in the differentiation of animals and should be prioritized in future studies aimed univariate statistical analysis.

DECLARATION OF CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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