Evaluation of principal component analysis in animal breeding and selection in the breed improvement program of male Katjang-Boer crossbred

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Abstract

The evaluation of body composition and growth performance is important to assess the animals' potential. Body measurements of animals have been widely used to assess skeletal growth and changes in animal conformation against age. Principal component analysis could be used to determine the factors that explain the highest variation in the dataset over the dependent variable. The objective of this study was to evaluate the principal component of the body measurements namely body length (BL), chest depth (CD), chest girth (CG), withers height (WH), width at withers, (WW), hip height (HH) and rump width (RW) and body indices namely length index (LI), depth index (DI), body index (BI), conformation index (CI), Proportionality (Pr), Relative depth of thorax (RDT), thoracic development (TD) and area index (AI) as selection criteria of 56 male Katjang-Boer goat. Two factors were extracted with a total variance was 86.87% where the first and second factor contributed to 48.05% and 38.82% after varimax rotation. The BL, CD, CG, HH and HW contributed the most for the first factor while the second factor mainly influenced by RW and WW. Three factors were extracted from body indices that accounted for 96.41% of total variance where the first, second third factor contributed to 42.70%, 27.55% and 26.16% of total variance, respectively. The LI, BI, Pr and AI contributed the most for the first factor while the second and third factor was influenced by CI, TD and DI, RDT, respectively. It is concluded that principal component analysis could be employed in animal breeding and selection as it can reduce the number of parameters to be considered in the breed improvement program.

Keywords: body measurements, principal component analysis, Katjang-Boer goats

Introduction

Characterization of livestock breed is the first approach for sustainable use of genetic resources. Food and Agricultural Organization (FAO) underline a global strategy that involves identifying and understanding a unique genetic resource in a particular region and developing the proper use of the associated diversity. Growth plays a significant role to ensure the sustainability of a livestock operation alongside reproductive efficiency, thus it is an important criterion to emphasize in animal selection. Growth is defined as the net accretion of protein and fat in respective tissues controlled by nutrition, environment and the genetic capacity to grow (Breever et al., 1992). It is important to understand the animals' growth in order to decide the optimum age and body weight for breeding or slaughtering purposes. Body measurements have been used widely in large animals to describe the variation in sizes and shape (Gilbert et al., 1993; Shahin et al., 1995). Body measurements might act as another additional trait for animal selection apart from body weight itself. Linear body measurements can be used as selection criteria in the goat breeding and selection program (Putra and Ilham, 2019). Desirable body conformation for meat production is a complex selection process, thus little progress has been made to reduce it to a single measurement that can be taken on live animals. The use of body indices from different body measurements to assess body conformation may be relatively easier (Mwacharo et al., 2006). Analysis of variance and correlations are widely used to characterise the phenotypic and genetic relationship among body measurements, however, the use of principal component analysis (PCA) proved to be a refinement to the analysis (Yakubu et al., 2009). PCA is a multivariate statistical tool that could be a more reliable assessment of morphometric relationship in livestock (Yakubu, 2013). PCA is an interdependence technique primarily used to define the underlying structure among variables under study and has been used as a tool in evaluating the body conformation to understand the complex process in the body dimensions of animals during the growth period (Putra and Ilham, 2019). This analysis transforms an original group of variables into another group, principal component which are linear combinations of the original variables (Yakubu et al., 2009). Principal components simultaneously considered as a group of attributes which may be used in animal selection purpose.

Kambing Katjang goats are indigenous to Malaysia, Southern Thailand and Indonesia. They possess good natural characteristics of tick tolerance and high fecundity under harsh circumstances, however, the growth performance is relatively low (Tsukahara et al., 2008) and considered as non-economical in commercial production (Johari and Jasmi, 2009). Crossbreeding of animals provides an opportunity to increase productivity (Hirooka et al., 1997; Johari and Jasmi, 2009), thus a crossbreeding program between Katjang bucks and Boer does was conducted to develop a synthetic goat breed by combining the hardiness of KK goats and well-muscled Boer goats. Following a structured breeding and selection program, a flock of Katjang-Boer crossbred was established in MARDI Kluang that will meet farmers' preferences towards low maintenance goat breed yet still produce higher meat yield compared to local indigenous KK goat breed. The objective of this study was to analyze the morphological structure of male Katjang-Boer crossbred goats using PCA analysis.

Materials and Methods

Data of body measurements namely body length (BL), chest depth (CD), chest girth (CG), withers height (WH), width at withers, (WW), hip height (HH) and rump width (RW) were collected from 66 male Katjang-Boer goats from birth to 48 months old in MARDI Kluang. Body weight was measured using a weighing scale while BL is the distance from the point of shoulder to the pin bone; WH is the vertical distance from the ground to the withers measured vertically from the ridge between the shoulder bone to the forehoof; CW is the measured as the distance from left to the right side of the shoulder; CD is the distance from the backbone at the shoulder to the brisket between the front legs, CG is the circumference of the chest behind the front legs, RH is the vertical distance from the ground to the pelvic girdle and RW is the width between the hip bones (Yakubu, 2013). The age of the animals was determined from farm records where the date of birth and date of weighing were available.

The body indices were calculated as described by Khargaria et al. (2015) as follows:

Length index (LI)	= BL/WH
Depth index (DI)	= CD/WH
Body index (BI)	= (BL/CG) x 100
Conformation index (CI)	= CG^2/WH
Proportionality (Pr)	= (WH/BL) x 100
Relative depth of thorax (RDT)	= (CD/CG) x 100
Thoracic development (TD)	= CG/WH
Area index (AI)	= WH x BL

Principal component analysis was conducted by using SAS 9.3 for body measurements and body indices and tested for sampling adequacy (Kaiser-Meyer-Olkin test) and sphericity (Bartlett's test). The Kaiser-Meyer-Olkin should be greater than 0.5 for satisfactory factor analysis to proceed. The rotation of principal components was through the transformation of the components to approximate a simple structure (Putra and Ilham, 2019).

Results and Discussion

The Kaiser-Meyer-Olkin measure of sampling adequacy for body measurements and body indices were 0.877 and 0.648, respectively. Bartlett's test of sphericity for body measurements and body indices were 357.39 ($p<0.01$) and 1206.34 ($p<0.01$), respectively indicating that it provides enough support to validate the factor analysis of the data. The results of Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity are comparable to the study conducted by Salako (2006) on Uda sheep, Okpeku et al. (2011) on West African Dwarf and Red Sokoto goats, Mavule et al. (2013) on Zulu sheep and Putra and Ilham (2019) on Indonesian Katjang does.

The communality values that represent the proportion of the variance in the original variables that is accounted for by the factor solution (Okpeku et al., 2011) are presented in Table 1. Communality values The communality for body measurements values ranged from 0.720 to 0.947, where the CD showed the lowest communality value while WW showed the highest value of communality. In contrast, Putra and Ilham (2019), Mavule et al. (2013) and Okpeku et al. (2011) reported that the chest girth showed the highest communality values in Indonesian Katjang does, Zulu sheep and West African Dwarf goats, respectively. Putra et al. (2020) and Markovic et al. (2019) found that height at withers showed the highest communality in Pasundan cows and Pramenka sheep breeds, respectively. Table 1 also showed the communality values for body indices that ranged from 0.818 to 0.999. DI and RDT showed the highest communality values at 0.999 while CI showed the lowest at 0.818. The result showed a contradictory finding to Indonesian Katjang does where body index showed the highest communality (Putra and Ilham, 2019), while thoracic development showed the highest value in Pasundan cows (Putra et al., 2020) and Pramenka sheep breeds (Markovic et al., 2019).

The result of PCA for body measurements and body indices are presented in Table 2. Only factors that have eigenvalue greater than one were retained (Mavule et al., 2013), therefore two components were retained from body measurements that accounted for 86.87 % of the total variance. The first factor explained 62.2% of total variance while the second factor explained 24.27% of total variance. After varimax rotation, the first and second factors explained 48.05% and 38.83% from total variance, respectively.

Table 1. Communality values of body measurements and body indices in male Katjang-Boer crossbred

Parameter	Extraction
Body measurements	
Body length (BL)	0.824
Chest depth (CD)	0.720
Chest girth (CG)	0.840
Hip height (HH)	0.806
Rump width (RW)	0.917
Withers height (WH)	0.892
Width at withers (WW)	0.947
Body indices	
Length index (LI)	0.989
Depth index (DI)	0.999
Body index (BI)	0.980
Conformation index (CI)	0.818
Proportionality (Pr)	0.993
Relative depth of thorax (RDT)	0.999
Thoracic development (TD)	0.942
Area index (AI)	0.994

Yakubu (2013) reported four components were extracted from body measurements in Yankasa sheep aged below 15.5 months and three components for sheep aged 15.5-28.3 months old with total variance for below 15.5 months and 15.5-28.3 months old Yankasa sheep were 89.27% and 75.21%, respectively. The total variance is comparable to the study done by Putra et al. (2020) in Pasundan cows, Markovic et al. (2019) in Pramenka sheep breeds, Okpeku et al. (2011) in West African Dwarf and Red Sokoto goats, and Khargaria et al. (2015) on the morphological traits of Assam Hill Goat.

Three factors were retained as the eigenvalues greater than one with total variance of 96.41% for body indices. The first factor explained 54.66% of total variance, while second and third factor explained 28.32% and 13.43% of total variance respectively. From varimax rotation, the first factor, second and third factor explained 42.70%, 27.55% and 26.16% form total variance, respectively for body indices. Total variance in this study was higher than the Pasundan cows (Putra et al., 2020), Indonesian Katjang does (Putra and Ilham, 2019), but lower than the Pramenka sheep breeds (Markovic et al., 2019).

Table 2. Total variance explained by different components of body measurements and body indices in male Katjang-Boer goats.

Group/ Component				Extraction sums of squared loadings			Rotation sums of squared loadings		
	Initial Eigenvalues	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
Body measurements									
1	4.38	62.60	62.60	4.38	62.60	62.60	3.36	48.05	48.05
2	1.70	24.27	86.87	1.70	24.27	86.87	2.72	38.82	86.87
3	0.35	4.99	91.86						
4	0.22	3.17	95.03						
5	0.14	2.05	97.08						
6	0.11	1.62	98.70						
7	0.09	1.30	100.00						
Body indices									
1	4.37	54.66	54.66	4.37	54.66	54.66	3.42	42.70	42.70
2	2.27	28.32	82.98	2.27	28.32	82.98	2.20	27.55	70.25
3	1.07	13.43	96.41	1.07	13.43	96.41	2.09	26.16	96.41
4	0.28	3.45	99.86						
5	0.01	0.09	99.95						
6	0.00	0.03	99.98						
7	0.00	0.02	100.00						
8	0.00	0.00	100.00						

The rotated component matrix of body measurements and body indices are presented in Table 3. The factor patter coefficients were used to evaluate the relative contributions of the various body measurements in determining the numerical value of the corresponding factor (Okpeku et al., 2011). Two factors were extracted that contributed to 48.05% and 38.82% for first and second factor, respectively. The first factor mainly influenced by BL, CD, CG, HH and HW and could be termed as "body size factor" as suggested by Okpeku et al. (2011) and Salako (2006). Mavule et al. (2013) also suggested that chest girth, body length and height at wither as good descriptors of general body size. The second factor is mainly influenced by RW and WW. This two measurements could be associated with body shape. Similar study by Mavule et al. (2013) also found that RW associated with the body shape. For body indices, LI, BI, Proportionality and AI showed the main influence to the first factor, while CI and TD contributed the most for the second factor. This is a similar finding to the study in Pasundan cows where CI and TD contributed the most in the second factor (Putra et al., 2020) but differs from the study on Katjang does where CI and TD contributed the most in the first factor (Putra and Ilham, 2019).

Table 3. Rotated component matrix of different factors for body measurements and body indices in male Katjang-Boer goats

Parameter	Principal component		
	1	2	3
Body measurements			
Body length	<u>0.821</u>	0.387	-
Chest depth	<u>0.639</u>	<u>0.559</u>	-
Chest girth	<u>0.726</u>	<u>0.559</u>	-
Hip height	<u>0.856</u>	0.271	-
Rump width	0.374	<u>0.882</u>	-
Height at withers	<u>0.878</u>	0.348	-
Width at withers	0.333	<u>0.915</u>	-
% of total variance	48.05	38.82	
Body indices			
Length index (LI)	<u>0.929</u>	0.334	0.120
Depth index (DI)	-0.075	0.194	<u>0.978</u>
Body index (BI)	<u>0.847</u>	-0.492	-0.144
Conformation index (CI)	-0.303	<u>0.831</u>	0.189
Proportionality (Pr)	<u>0.925</u>	-0.343	-0.140
Relative depth of thorax (RDT)	-0.075	0.211	<u>0.974</u>
Thoracic development (TD)	-0.176	<u>0.912</u>	0.282
Area index (AI)	<u>0.920</u>	-0.358	-0.139
% of total variance	42.70	27.55	26.16

Underlined values are ≥0.5

Conclusion

The principal component analysis can be used to consolidate and describe the interdependence among body measurements and body indices in male Katjang-Boer goat. The results shows that two and three components were extracted for body measurements and body indices, respectively. Body length, chest depth, chest girth, hip height and height at withers contributed the most for the first component that described the general body size while the second component mainly influenced by rump width and width at withers that described the body shape. As the first component represent the highest percentage of variance, the body measurements that included in the first factor can be used as the selection criteria for male Katjang-Boer crossbred goats. Three components were extracted for body indices where the first component mainly influenced by length index, body index, proportionality and area index. Conformation index and thoracic development were the highly associated to the second factor while depth index and relative depth of thorax influenced the third factor the most. The use of principal component analysis can be used effectively in animal selection based on a group of variables that are related.

Acknowledgement

The author would like to thank the staff of MARDI Kluang for their assistance on recording, compilation and management of the animal information and data for this study.

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