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Factor and Discriminant Analyses in the Morphostructure of Batur and Wonosobo Sheep Breeds

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ABSTRACT

Background: Batur and Wonosobo sheep are two Indonesian indigenous sheep breeds from Central Java Province, Indonesia. This study aimed to describe and discriminate the morphostructure of Batur sheep and Wonosobo sheep with body measurements and body indices.

Methods: Fourteen body measurements and nine body indices were measured from 37 Batur and 83 Wonosobo sheep. Two statistical methods of factor and discriminant analyses were computed with SPSS 25.0 program to describe the sheep's morphostructure and characterization.

Result: The factor analysis in body measurements was obtained three principal components (PCs) that explain about 76.58% (Wonosobo sheep) and 73.51% (Batur sheep) of the total variance in animals' morphostructure. Meanwhile, the factor analysis in body indices was obtained on three PCs that explain about 79.16% (Batur sheep) and 95.57% (Wonosobo sheep) of the total variance in animals' morphostructure. About 95.2% of Wonosobo sheep and 92.7% of Batur sheep can be classified with body measurements (RW, SW, EL, EW, RH and TL). Meanwhile, about 75.7% of Batur sheep and 80.7% of Wonosobo sheep can be classified with body indices (TI and CI). In conclusion, Batur and Wonosobo sheep can be accurately characterized by their body measurements.

Key words: Body indices, Body measurements, Discriminant analysis, Factor analysis, Indonesian sheep.

INTRODUCTION

Batur sheep and Wonosobo sheep are two Indonesian indigenous sheep breeds from Central Java Province, Indonesia. Batur sheep resulted from a crossbreed between Merino sheep and Thin-Tailed sheep that originated and spread widely in Batur District, Banjarnegara Regency. Wonosobo sheep is a new breed developed from crossing the local sheep and Texel sheep and spread widely in the Wonosobo Regency. Batur and Wonosobo sheep have been cultivated, maintained and raised by smallholder farmers for generations and are suitable for meat production (Ibrahim *et al.*, 2021; Noviani *et al.*, 2013; Hakim *et al.*, 2019).

The characterization of livestock is the first approach to sustainable use of its animal genetic resources. Body dimensions have been used to indicate the breed, origin and relationship or shape and size of an individual as they give an idea of body conformation. Breed characterization in goats and sheep can be carried out based on body measurements and body indices (Marković *et al.*, 2019; Putra and Ilham, 2019). The morphometric characterization of livestock is essential for planning improvement, sustainable utilization, conservation strategies and breeding programs for a breed (FAO, 2012).

The Batur and Wonosobo sheep were still considered non-descript sheep in the country and many things of morphostructures have not been studied. While some studies reported that the Batur and Wonosobo have similar ancestors, namely Thin-Tailed sheep (Hakim *et al.*, 2019; Ibrahim *et al.*, 2020b; Prayitno *et al.*, 2008). Genetically, the Batur, Wonosobo and Thin-Tailed sheep have a close genetic relationship (Ibrahim *et al.*, 2020a). Certainly, with similar ancestors and relatively close genetic distance, it is expected that the sheep provide performance and productivity so close different. Therefore, the present study was undertaken to describe and discriminate the morphostructure of Batur and Wonosobo sheep with body measurements and body indices.

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MATERIALS AND METHODS

Research site and animals

The samples were collected from 2019 to 2020 in Wonosobo and Banjarnegara Regencies, Central Java Province, Indonesia. However, this study was conducted in July-October 2021 in the Laboratory of Meat, Drought and Companion Animals, Universitas Gadjah Mada. The body measurements of Wonosobo sheep (22 rams and 61 ewes) and Batur sheep (13 rams and 24 ewes) were collected from smallholder farmers in Wonosobo and Banjarnegara Regencies, respectively. All animals in this study have two permanent pairs of incisors conditions with an average of 1.5 years of age (non-pregnancy stage). The phenotypic characteristic of Wonosobo sheep and Batur sheep and their breeding site were illustrated in Fig 1.

Animal's measurements

The body measurements were taken from animals in a standing position with a raised head. Body measurements of animals were performed using a measuring stick and flexible measuring tape and taken based on FAO (2012) Guidelines. Fourteen body measurements of body length (BL), withers height (WH), rump height (RH), rump width (RW), chest circumference (CC), chest depth (CD), shoulder-width (SW), head length (HL), head width (HW), ear length (EL), ear width (EW), tail length (TL), tail width (TW) and tail circumference (TC) were measured in each animal as described in Fig 2. Moreover, nine body indices of length index (LI), thoracic index (TI), depth index (DI), height index (HI), thoracic development (TD), conformation index (CI), body index (BI), proportionality (Pr) and area index (AI) were computed in this study with mathematical formula (Boujenane, 2015; Khargharia *et al.*, 2015) as follows:

$$LI=\frac{BL}{WH}\times 100 \qquad HI=\frac{WH}{RH}\times 100 \qquad BI=\frac{BL}{CC}\times 100$$

$$TI=\frac{SW}{CD}\times 100 \qquad TD=\frac{CC}{WH}\times 100 \qquad Pr=\frac{WH}{BL}\times 100$$

$$DI=\frac{CD}{WH}\times 100 \qquad CI=\frac{CC^2}{WH} \qquad AI=\frac{WH}{BL}$$

Data analysis

The statistics parameter of mean, standard deviation and Pearson's coefficient of correlation (r) for body measurements and body indices were calculated with SPSS 25.0 computer program (IBM, USA). Therefore, factor analysis [Principal component analysis (PCA)] and discriminant analysis [Canonical discriminant analysis (CDA)] were computed using a similar computer program.

RESULTS AND DISCUSSION

Animal morphostructure and Pearson's coefficient of correlation

Nine body measurements of RW, CC, HL, HE, EL, EW, TL, TW and TC in Batur sheep were higher than in Wonosobo sheep (P<0.05) as presented in Table 1. Two body indices of HI and BI in Wonosobo sheep were higher than in Batur sheep (P<0.05), as presented in Table 2. Therefore, body indices of CI in Wonosobo sheep were lower than in Batur sheep. The Pearson's coefficient of correlation (r) value between WH and RH in both sheep breeds was highest than the other correlations (0.97 in Wonosobo sheep and 0.93 in Batur sheep), as presented in Table 3. In addition, the highest r value among body indices showed in Pr-AI (-0.99) for both sheep breeds, as presented in Table 4.

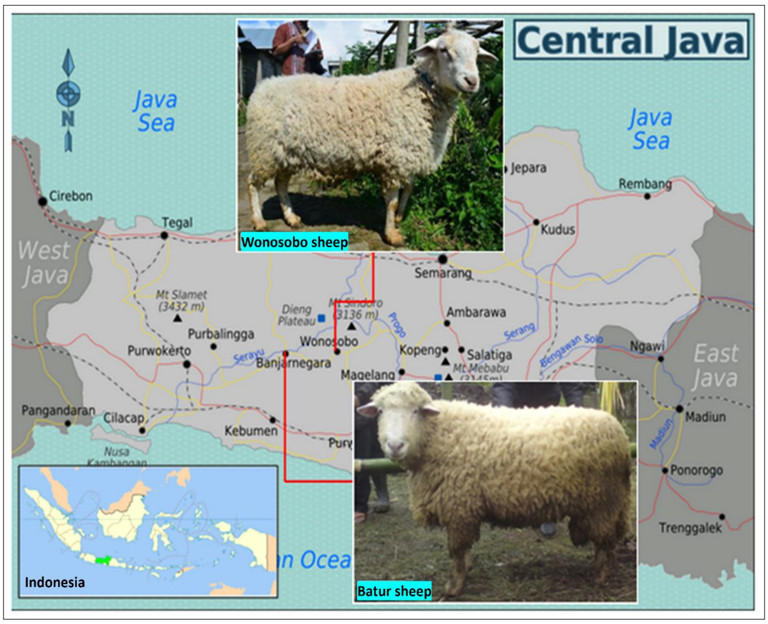

Fig 1: Wonosobo and Batur sheep physical characteristics and breeding site.

The body measurements in the present study were higher than the previous study reported by Haryanti *et al.* (2015) and Haren *et al.* (2018) in Wonosobo and Batur sheep, respectively. According to the BI value, Wonosobo and Batur sheep included brevigline (BI<85) animals type similar to Ripollesa sheep (83.90±6.10) (Esquivelzeta *et al.*, 2011). Handiwirawan *et al.* (2011) obtained LI value of 109.00±2.00 in Barbados Black Belly Cross (BC) sheep and lower than Wonosobo and Batur sheep. Therefore, the DI value in BC sheep was 52.0±0.9 and close to Batur sheep. The r-value of WH-RH in Uda (0.90) sheep (Yakubu and Akinyemi, 2010) was close to the present study.

Factor analysis

The factor analysis (PCA) of body measurements reveals three principal components (PCs) that explain 76.58% and 73.51% of the total variance in Wonosobo and Batur sheep morphostructures, respectively (Table 5). The PCA of body indices in sheep study reveals three PCs that explain 89.57% (Wonosobo) and 79.16% (Batur) of the total variance in sheep morphostructure (Table 6). Previous studies were revealed PCA of body measurements with a total variance of sheep morphostructure of about 59.00% (2PCs) in Ripollesa (Esquivelzeta *et al.*, 2011); 61.53% (4PCs) in Rampur-Bushair (Sankhyan *et al.*, 2018) and 96.65% (3PCs) in Pramenka (Marković *et al.*, 2019) sheep. Unfortunately, a study of the PCA of sheep's body indices is limited. Previous studies reported that the PCA of body indices

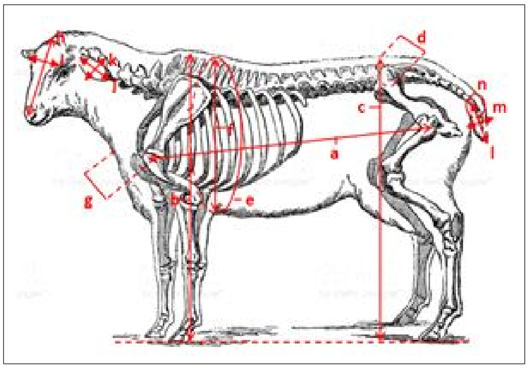

Fig 2: The body measurements scheme of BL (a), WH (b), RH (c), RW (d), CC (e), CD (f), SW (g), HL (h), HW (i), EL (j), EW (k), TL (l), TW (m) and TC (n) in a sheep.

Table 1: Means (±SD) of body measurements in Wonosobo and Batur sheep.

Body measure-	Wonosobo sheep		Batur sheep		Total	
-ments (cm)	Ram	Ewe	Ram	Ewe	Wonosobo	Batur
BL	77.09±9.51	68.99±7.94	76.23±16.21	70.13±5.46	71.14±9.07	72.27±10.74
WH	69.43±7.97	63.11±6.12	65.92±10.80	62.09±5.47	64.79±7.18	63.44±7.84
RH	67.80±7.68	62.34±5.17	66.27±10.03	62.32±4.33	63.79±6.36	63.71±7.01
RW	18.73±2.34	17.01±1.75	24.85±6.30	21.02±3.04	17.47±2.05[a]	22.36±4.75[b]
CC	93.41±12.66	84.44±9.19	4.00±22.18	88.00±10.89	86.82±10.90[a]	90.11±15.75[b]
CD	33.59±4.45	30.14±4.40	36.62±8.45	33.63±3.63	31.05±4.65	34.68±5.86
SW	26.57±4.84	23.38±3.19	25.54±6.83	22.65±4.13	24.23±3.93	23.67±5.33
HL	23.55±2.70	21.20±1.74	22.92±5.12	21.70±3.66	21.82±2.27[a]	22.13±4.20[b]
HW	14.45±1.90	13.02±1.65	15.38±3.62	13.02±1.96	13.40±1.82[a]	13.85±2.85[b]
EL	12.86±1.17	12.86±0.96	12.04±1.23	11.92±1.77	12.86±1.01[a]	11.96±1.59[b]
EW	7.05±0.63	6.63±0.46	8.19±1.74	7.35±0.79	6.74±0.54[a]	7.64±1.26[b]
TL	29.00±3.85	25.79±4.15	37.54±7.36	29.54±4.83	26.64±4.29[a]	32.35±6.92[b]
TW	7.50±1.34	6.92±1.16	10.31±1.70	8.83±2.35	7.07±1.23[a]	9.35±2.24[b]
TC	15.11±2.01	13.82±2.00	19.00±4.18	16.85±3.08	14.16±2.07[a]	17.61±3.60[b]

Note: N= Number of observations; Superscripts in the similar row differ significantly ($P<0.05$).

Table 2: Means (±SD) of body indices in Wonosobo and Batur sheep.

Body indices	Wonosobo		Batur		Total	
	Ram	Ewe	Ram	Ewe	Wonosobo	Batur
LI	111.53±12.43	109.57±10.07	114.91±9.64	113.27±7.46	110.09±10.70	113.85±8.19
TI	78.89±9.67	78.10±8.60	69.51±6.79	67.54±10.47	78.31±8.85	68.23±9.29
DI	48.56±5.75	47.94±6.98	55.19±5.94	54.31±5.38	48.11±6.65	54.62±5.51
HI	102.43±2.69	101.17±3.19	99.33±4.34	99.60±5.22	101.50±3.10[a]	99.51±4.87[b]
TD	134.65±13.13	134.64±16.89	141.46±17.07	142.02±15.14	134.64±15.90	141.82±15.61
CI	126.74±25.82	114.73±24.92	135.78±45.44	126.07±26.56	117.91±25.57[a]	129.49±34.07[b]
BI	83.20±8.79	82.26±10.04	81.71±6.05	80.31±6.85	82.51±9.68[a]	80.81±6.53[b]
Pr	90.64±9.30	92.05±8.77	87.64±7.94	88.64±5.61	91.68±8.88	88.29±6.43
AI	5393.86±1058.36	4384.59±872.33	5178.00±1778.41	4374.50±645.43	4652.11±1022.02	4656.81±1213.10

Note: N= Number of observations; Superscripts in the similar row differ significantly ($P<0.05$).

Table 3: Pearson's coefficient of correlation (r) among body measurements in Wonosobo (above diagonal) and Batur (under diagonal) sheep.

Variables	BL	WH	RH	RW	CC	CD	CW	HL	HW	EL	EW	TL	TW	TC
BL	-	0.67	0.66	0.68	0.55	0.82	0.73	0.62	0.46	0.32	0.60	0.75	0.05	0.50
WH	0.88	-	0.97	0.58	0.53	0.50	0.82	0.72	0.70	-0.10	0.55	0.63	-0.02	0.23
RH	0.87	0.93	-	0.67	0.62	0.57	0.85	0.74	0.71	-0.08	0.56	0.55	0.05	0.28
RW	0.81	0.70	0.80	-	0.86	0.70	0.84	0.67	0.51	0.16	0.46	0.23	0.26	0.57
CC	0.88	0.78	0.76	0.75	-	0.67	0.82	0.74	0.53	0.22	0.47	0.14	0.54	0.59
CD	0.83	0.78	0.78	0.79	0.80	-	0.67	0.46	0.37	0.20	0.49	0.43	0.16	0.40
CW	0.76	0.58	0.58	0.77	0.74	0.78	-	0.71	0.64	0.16	0.56	0.40	0.14	0.46
HL	0.46	0.43	0.42	0.28	0.31	0.28	0.16	-	0.69	0.16	0.57	0.53	0.44	0.64
HW	0.52	0.41	0.50	0.60	0.48	0.52	0.52	0.40	-	-0.08	0.50	0.40	0.16	0.26
EL	0.16	0.26	0.35	0.19	0.02	0.10	-0.04	0.01	0.33	-	0.26	0.17	0.06	0.22
EW	-0.01	-0.04	0.01	0.05	-0.07	-0.14	-0.02	-0.22	0.04	0.33	-	0.44	0.18	0.25
TL	0.61	0.58	0.61	0.56	0.47	0.45	0.41	0.15	0.35	0.27	0.22	-	-0.00	0.39
TW	0.15	0.01	0.13	0.30	0.29	0.06	0.18	-0.21	0.22	0.08	0.36	0.23	-	0.60
TC	0.73	0.63	0.72	0.60	0.64	0.63	0.50	0.46	0.51	0.19	0.07	0.59	0.17	-

Table 4: Pearson's coefficient of correlation (r) among body indices in Wonosobo sheep (above diagonal) and Batur sheep (under diagonal).

Variable	AI	TI	DI	HI	TD	CI	BI	Pr	AI
LI	-	-0.61	0.76	-0.16	0.39	0.29	0.43	-0.99	0.19
TI	0.46	-	-0.65	0.24	-0.12	0.12	-0.39	0.62	0.23
DI	0.49	0.08	-	-0.45	0.58	0.50	0.04	-0.75	0.08
HI	-0.22	-0.02	-0.17	-	-0.57	-0.38	0.43	0.17	0.39
TD	0.67	0.35	0.51	-0.08	-	0.89	-0.66	-0.38	-0.21
CI	0.57	0.27	0.45	0.17	0.88	-	-0.63	-0.28	0.20
BI	-0.03	-0.10	-0.25	-0.07	-0.76	-0.68	-	-0.43	0.35
Pr	-0.99	-0.43	-0.47	0.21	-0.66	-0.57	0.03	-	-0.18
AI	0.35	0.10	0.20	0.37	0.28	0.68	-0.07	-0.36	-

Table 5: Rotated component matrix, eigenvalues, total variance, cumulative, communalities, Kaiser-Meyer-Olkin (KMO) measure adequacy, ad Bartlett's test of sphericity in the body measurements of Wonosobo and Batur sheep.

Body measurements	Wonosobo sheep				Batur sheep			
	PC1	PC2	PC3	EC	PC1	PC2	PC3	EC
BL	0.67*	0.15	0.67	0.91	0.95*	0.09	-0.09	0.92
WH	0.97*	0.01	0.07	0.94	0.85*	0.21	-0.24	0.83
RH	0.96*	0.12	0.05	0.93	0.87*	0.30	-0.15	0.88
RW	0.62*	0.57	0.23	0.76	0.89*	0.09	0.13	0.82
CC	0.53	0.76*	0.16	0.88	0.92*	-0.11	0.06	0.85
CD	0.55*	0.29	0.50	0.64	0.90*	-0.08	-0.08	0.83
SW	0.82*	0.36	0.22	0.84	0.84*	-0.21	0.17	0.78
HL	0.70*	0.53	0.17	0.80	0.39	0.15	-0.68*	0.63
HW	0.79*	0.21	-0.10	0.68	0.61*	0.30	-0.04	0.46
EL	-0.19	0.17	0.81*	0.72	0.09	0.86*	-0.02	0.75
EW	0.57*	0.17	0.39	0.51	-0.06	0.58*	0.58	0.68
TL	0.57*	-0.13	0.54	0.64	0.61*	0.41	0.14	0.56
TW	-0.07	0.87*	-0.07	0.77	0.24	0.10	0.78*	0.68
TC	0.19	0.75*	0.33	0.70	0.75*	0.28	-0.12	0.65
Eigenvalues	5.78	2.86	2.08	-	7.06	1.65	1.58	-
Variance (%)	41.32	20.43	14.84	-	50.45	11.79	11.27	-
Cumulative (%)	41.32	61.74	76.58	-	50.45	62.24	73.51	-
KMO	0.75				0.82			
Bartlett's test	**				**			

Note: *Main component; EC: Extraction communality; **(P<0.05).

accounted for 86.84% (4 PCs) in Katjang does and 89.38% (4 PCs) in Pasundan cows (Putra *et al.*, 2020; Putra and Ilham, 2019), showing higher than in sheep study.

Discriminant analysis

The discriminant analysis (CDA) reveals six body measurements (RW, SW, EL, EW, RH and TL) and two body indices (TI and CI) that were selected as the discriminant variables (Table 7). According to the CDA, about 95.2% (Wonosobo) and 97.3% (Batur) of sheep can be classified into their original breeds group based on body measurements (Table 8). Meanwhile, about 80.7% (Wonosobo) and 75.7% (Batur) of sheep's study can be classified into their original breeds based on body indices. The discriminant plots of body measurements and body indices were illustrated in Fig 3 and 4, respectively.

The CDA showed that body measurements were more accurate for discriminating Wonosobo and Batur sheep than body indices. Ofori *et al.* (2021) obtained the r_c value of 0.62 (high) in the first canonical factor of body measurement

Table 6: Rotated component matrix, eigenvalues, total variance, cumulative, communalities, Kaiser-Meyer-Olkin (KMO) measure adequacy and Bartlett's test of sphericity in the body indices of Wonosobo and Batur sheep.

Body measurements	Wonosobo sheep				Batur sheep			
	PC1	PC2	PC3	EC	PC1	PC2	PC3	EC
LI	0.95*	0.11	0.14	0.94	0.96*	0.17	0.01	0.96
TI	-0.80*	0.22	0.41	0.85	0.55*	0.05	0.05	0.31
DI	0.83*	0.40	-0.08	0.86	0.47*	0.45	-0.12	0.44
HI	-0.22	-0.53	0.61*	0.69	-0.28	-0.01	0.83*	0.77
TD	0.30	0.91*	-0.20	0.96	0.52	0.84*	0.04	0.97
CI	0.17	0.96*	0.20	0.98	0.46	0.75*	0.45	0.97
BI	0.49	-0.80*	0.30	0.97	0.14	-0.97*	-0.04	0.97
Pr	-0.95*	-0.10	-0.13	0.94	-0.96*	-0.17	-0.03	0.94
AI	0.12	-0.00	0.93*	0.88	0.37	0.13	0.80*	0.80
Eigenvalues	3.55	2.90	1.61	-	3.08	2.49	1.56	-
Variance (%)	39.49	32.18	17.90	-	34.22	27.61	17.34	-
Cumulative (%)	39.49	71.67	89.57	-	34.22	61.83	79.16	-
KMO	0.64				0.53			
Bartlett's test	**				**			

Note: *Main component; EC: Extraction communality; **(P<0.05).

Table 7: Factor selected by stepwise discriminant analysis to characterize Wonosobo and Batur sheep.

Factor/Variables entered	Tolerance	F_{remove}	D^2	Wilk's λ
Body measurements (r_c=0.86)				
RW	0.35	109.72	4.27	0.52
SW	0.32	25.13	9.70	0.32
EL	0.86	26.58	9.55	0.33
EW	0.83	16.20	10.69	0.30
RH	0.35	10.62	11.38	0.29
TL	0.64	8.47	11.67	0.28
Body indices (r_c=0.51)				
TI	0.97	35.97	0.17	0.97
CI	0.97	7.51	1.26	0.79

Note: D^2: Mahalanobis distance; r_c: Canonical correlation.

Table 8: Percentage (%) of individual classification per breed based on discriminant analysis.

Factor	Breed	Predicted group membership (N)		Total (N)
		Wonosobo	Batur	
Body measurement	Wonosobo	95.2 (79)	4.8 (4)	100 (83)
	Batur	2.7 (1)	97.3 (36)	100 (37)
Body index	Wonosobo	80.7 (67)	19.3 (16)	100 (83)
	Batur	24.3 (9)	75.7 (28)	100 (37)

Note: N= Number of animal.

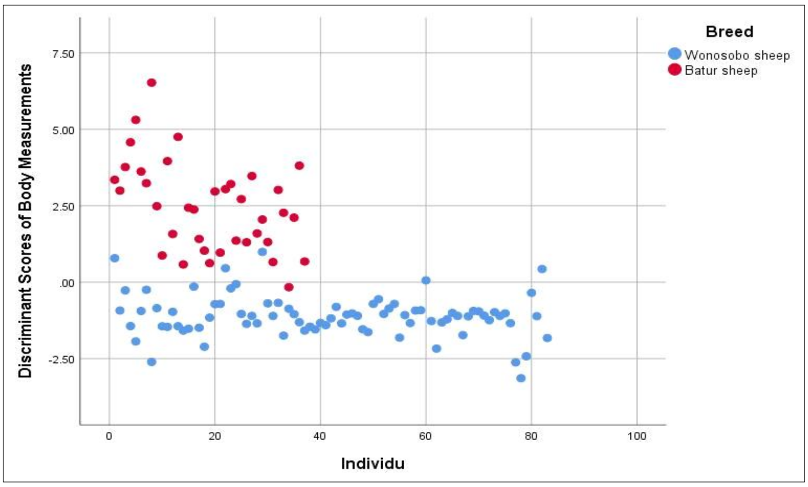

Fig 3: The discriminant plots of body measurements in Wonosobo and Batur sheep.

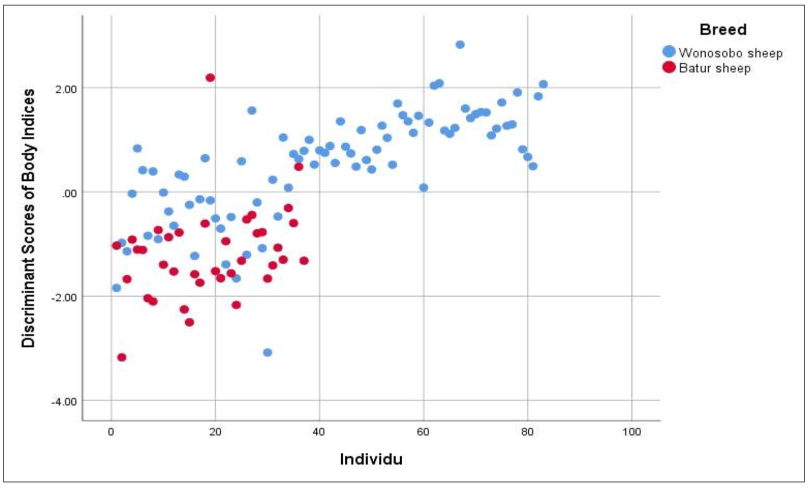

Fig 4: The discriminant plots of body indices in Wonosobo and Batur sheep.

in West African Dwarf goats and lower than in the present study. Thus, Asamoah-Boaheng and Sam (2016) obtained the r_c value of 0.89 (very high) in the first canonical factor of body measurements in sheep and similar to the present study. More than 90% of the morphostructure of sheep study were successfully classified into their original breeds group with six selected discriminant variables of body measurements. A previous study reported that the body measurements could classify many sheep breeds into their original breeds group (Asamoah-Boaheng and Sam, 2016). Moreover, 58% of Uda rams and 70.8% of Uda ewes can be classified into their original sex group based on two discriminant variables of HW and HL measurements (Yakubu and Akinyemi, 2010). The difference in body measurements, genetics (breed), location (geographical area), agro-climatic conditions and management system of animals can be caused by different results compared to previous studies.

CONCLUSION

In conclusion, about 95.2% of Wonosobo sheep and 92.7% of Batur sheep can be classified with body measurements (RW, SW, EL, EW, RH and TL). Meanwhile, about 80.7% of Wonosobo sheep and 75.7% of Batur sheep can be classified with body indices (TI and CI). Wonosobo sheep and Batur sheep can be accurately characterized by their body measurements.

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