Research Article

Identification of Bali Pigs Using Body Morphometric and Head Index by Applying Principal Component Analysis (PCA) Approach

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Abstract | Bali pig is an important livestock for meeting the meat needs of the community, especially in the Province of Bali, Indonesia. The characteristics of this animal include a slightly rough black fur, a long snout, curved back, and their stomach does not touch the ground when standing. This study aims to determine the morphometric characteristics and head index of Bali pigs using a Principal Component Analysis (PCA) approach to easily identify the phenotypic characteristics. The samples include 50 Bali pigs that are intensively reared in Musi Village, Gerogak District, Buleleng Regency, Bali Province, Indonesia. The measurement data were analyzed using PCA to reduce and interpret the measured variables. The results showed that the average hip height and width, rump length, body length, shoulder height, chest width and depth, head width and length were 55.68cm, 17.53cm, 10.62cm, 67.40cm, 54.92cm, 17.81cm, 41.24cm, 10.63cm, and 26.26cm, respectively. Furthermore, the result of measuring the index of the female and male heads was 40.76% and 39.41%. The results showed that Principal Component 1 (KU1) and 2 (KU2) had a variance of 5.834 and 1.834, respectively, while the percentage of variance was 58.338% and 18.340%, with a total value of 76.678%. The hip width, shoulder height, and chest width were significantly different ($p<0.05$) between male and female Bali pigs. In addition, the main characteristics of size for this specie include hip height, rump length, body length, shoulder height, chest width, and head width and length, while that of the shape include chest and hip-width

Keywords | Bali pig, Body morphometric, Head index, Hip height, Main component analysis.

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INTRODUCTION

The national demand for meat continues to increase every year and this is in line with the increasing population (Hafizah et.al, 2020). The sources of animal protein have become very diverse and meat is still seen as one of the important sources of protein considering the complete content of essential amino acids. In Indonesia, the highest amount of meat is still dominated by cattle and chicken, while the portion of pork is very small. Henuk and Bakti (2018) shows that, the share of national meat consumption is dominated by broiler chicken at 55%, beef 19%, native chicken 10%, pork 8%, goat and lamb 7%, and others around 1%.

Pigs are one of the livestock that has good roles and prospects to being developed in Bali Province, especially in non-Muslim residential areas, and are adjusted to the Regional General Spatial Planning and Regional Spatial Detail Plans. The market for pork and/or processed products

is still wide open to various countries, such as Singapore and Hong Kong. The export of pigs is second in place after chickens and it's yet to become the government's leading commodity. However, their focus until now is still dominant on large ruminants (Henuk and Bakti, 2018).

Bali pigs are germplasm that needs to be saved in order to prevent extinction due to their limited population. They are genetically slower to grow compared to imported breed pigs. Furthermore, there are two species of Bali pigs, namely those found in the eastern region which is believed to have originated from China (*Sus vittatus*). They have a bit rough black fur, a long snout, and a curved back but their stomach does not touch the ground. Meanwhile, the species that live in northern, western, central, and southern Bali have the characteristics of a downward curved back (lordosis), a large stomach, white stripes on the abdomen and legs, short muzzle, erect ears, adult pig body height of about 54cm, body length of about 90cm and tail length between 20-25cm (Figure 1). The mother pig (*bangkung*) has a very low belly that can even touch the ground when it's standing. It has nipples between 12-14 and can give birth to 12 tails at a time. In addition, the species is better known as the Bali Bali (Sihombing, 2006).

Figure 1: Adult male Bali pig.

When maintaining the Bali pig as one of the germplasms, it is necessary to first know the characteristics of the population. Morphometric analysis and genetic characterization are the first steps in animal conservation programs (Lanari et al., 2003). They can be used as a guide in making decisions to determine the uniqueness of the animal race. Furthermore, the phenotypic characteristics information based on morphometry, pigs in Indonesia can be used for further development without ignoring the purity of the local pig breed.

Identification of the morphometric characteristics of pigs in each farm can be used as the basis for selection purpose at the next stage. Pigs that have a high dissimilarity range can be crossed to increase production without losing the original morphometric characteristics of each farm. The morphometric measurements observed are hip height and width, rump length, ankle circumference, body length, shoulder height, chest width, and depth, as well as head index measurements such as the length and width. There are few studies on body morphometrics and head index of pigs (Panda et al., 2021; Prheeti et al., 2023; Baruzzi et al., 2023), however, to our knowledge such type of data is missing for Bali pig breed. This study aims to determine the morphometric characteristics and head index of Bali pigs using a Principal Component Analysis (PCA) approach to identify the phenotypic characteristics of Bali pigs.

MATERIALS AND METHODS

Animals

The samples include 50 Bali pigs that were reared intensively by the farming community in Musi Village, Gerokgak District, Buleleng Regency, Indonesia. Furthermore, the criteria were an adult male and female Bali pigs that were 1 year and above. This research has been approved by ethical committee of Faculty of Veterinary Medicine, Udayana University with approval number: B/70/UN14.2.9/PT.01.04/2023.

Sampling

The equipment used to measure the body and head measurements was a measuring tape that has a Butterfly brand and an Etherna caliper with an accuracy of 0.01cm. Primary data were collected from the results of body morphometric measurements and head index of male and female Bali pigs. The body parts and the way the measurements were taken as under:

1. Hip height (cm) was measured from the highest distance of the hips perpendicular to the ground using a measuring stick (Figure 2).

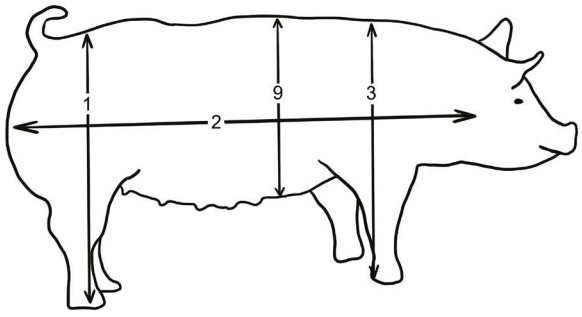

Figure 2: Measurement methods of hip height (1), body length (2), shoulder height (3) and chest depth (9).

2. Body length (cm) was measured by a straight line distance from the edge of the spinous process bone to the bone lump (os ichium) using a measuring stick (Figure 2). Shoulder height (cm) was measured from the highest distance of the shoulder through the back of the scapula, perpendicular to the ground using a measuring stick (Figure 2).

3. Hip width (cm) was measured at the hip joint of the pig using a measuring tape (Figure 3).

4. Rump length (cm) was measured from the back of the sacral bone to the top of the tailbone using a measuring tape (Figure 3).

5. Chest width (cm) was measured from the distance between the protrusion of the shoulder joint (os scapula) left and right using a measuring stick (Figure 3).

6. Head width (cm) was measured horizontally from the distance between the outermost part of the parietal bone with a measuring tape (Figure 3).

7. Head length (cm) was obtained by measuring the distance from inion to nasion with a measuring tape (Figure 3).

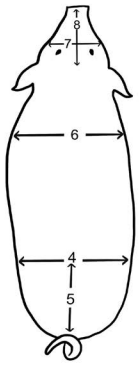

Figure 3: Measurement methods of hip width (4), rump length (5), chest width (6), head width (7) and head length (8).

8. Chest depth (cm) was measured from the distance of the highest point of the shoulder and the breastbone using a measuring stick (Figure 2).

The head length and width data was used to calculate the head index using the following formula:

$$\text{Head Index} : \frac{\text{Head width}}{\text{Head length}} \times 100\ \%$$

Statistical analysis

The results were analyzed descriptively to determine the normality and homogeneity of the data. Furthermore, the comparison of morphometric body and head index of male and female pigs was determined using the T-test and Mann-Whitney U test for data that were not normally distributed (Heath, 2000). The Principal Component Analysis (PCA) which was obtained from the diversification matrix (Gaspersz, 1992) was used to explain the structure of the variance-covariance matrix of a set of variables through a linear combination. In general, principal components can be useful for the reduction and interpretation of variables.

RESULTS

Morphometric Measurements of the Bali Pig

The results regarding body morphometric measurements and head index of 50 Bali pigs which were kept intensively by the community in Musi Village, Gerogak District, Buleleng Regency, Indonesia, were shown in Table-1. The minimum and maximum values for each measured variable vary widely. The minimum value for hip height and width, rump length, body length, shoulder height, chest width and height, and head width and length was 50.0cm, 14.0cm, 9.0cm, 58.0cm, 49.5cm, 14.0cm, 31.0cm, 8.5cm, and 24.0cm respectively. Furthermore, the maximum values for hip height and width, rump length, body length, shoulder height, chest width and depth, head with and length was 66.0cm, 27.0cm, 12.0cm, 84.0cm, 62.0cm, 26.0cm, 47.0cm, and 12.0cm and 29.0cm respectively, with consecutive average values of 55.68cm±3.223, 17.53cm±2.760, 10.62cm±0.818, 67.40cm±6.158, 54.92cm±2.911, 17.81cm±3.125, 41.24cm±3.826, 10.63cm±0.775, and 26.26cm±1.263 respectively.

Male and female Bali pig head index

The results of the analysis of the male and female Bali pig head index measurements are shown in Table 2. The results showed that the head index of female and male Bali pigs was 40.76% and 39.41% respectively. Furthermore, no significant difference ($p > 0.05$) was found for the head width and length variations in both female and male pigs.

PCA of body and head morphometrics

The results of the Principal Component Analysis (PCA) on body and head morphometrics of Bali pigs are shown in Table 3. The results of the analysis showed that Principal Component 1 (KU1) and 2 (KU2) had a variance (Eigenvalue) greater than 1, namely 5.834 and 1.834. KU1 and KU2 were able to explain 58.338% and 18.340% of data diversity. Thus the total of the two main components can be used to explain the diversity of the data by 76.678% (> 75%). The score equation for the components formed was

Table 1: Maximum – Minimum Value, Average and Standard Deviation of the Results of Morphometric Measurements of the Body and Head of the Bali Pig

Variable	Number of samples	Minimum Value (cm)	Maximum Value (cm)	Average (cm)	Std. Deviation
Hip height	50	50.0	66.0	55.680	3.2226
Hip width	50	14.0	27.0	17.530	2.7598
Rump length	50	9.0	12.0	10.620	0.8179
Body length	50	58.0	84.0	67.400	6.1578
Shoulder height	50	49.5	62.0	54.920	2.9109
Chest width	50	14.0	26.0	17.810	3.1248
Chest depth	50	31.0	47.0	41.240	3.8256
Head width	50	8.5	12.0	10.630	0.7747
Head length	50	24.0	29.0	26.260	1.2627

Table 2: Results of Measurement of Male and Female Bali Pig Head Index

Variable	Sex	N	Mean (cm)	Std. Deviation	P
Head width	Female	40	10.638	0.7678	0.491
	Male	10	10.600	0.8433	
Head length	Female	40	26.100	1.1994	0.878
	Male	10	26.900	1.3703	
Head index	Male:39.41				
	Female:40.76				

Table 3: Main Components, Total Diversity and Eigen Value of Bali Pigs

Variable	Main Component 1 (Size)	Main Component 2 (Shapes)
Hip height	0.892	-0.030
Hip width	-0.116	0.625
Rump length	0.867	-0.110
Body length	0.889	0.152
Shoulder height	0.828	0.334
Chest width	0.504	0.784
Chest depth	0.853	0.198
Head width	0.831	-0.096
Head length	0.927	0.147
Percentage of Diversity	58.338	18.340
Cumulative Percentage of Eigenvalues	58.338 5.834	76.678 1.834

Table 4: Comparison of Body and Head Morphometrics of Male and Female Bali Pigs

	Hip height	Hip width	Rump length	Body length	Shoulder height	Chest width	Chest depth	Head width	Head length
Mann-Whitney U	175.00	7.500	183.00	148.00	109.00	2.00	134.00	178.00	135.00
Wilcoxon W	995.00	827.500	238.000	968.00	929.00	822.00	954.00	233.00	955.00
Z	-0.610	-4.705	-0.421	-1.264	-2.221	-4.838	-1.618	-0.551	-1.606
Asymp. Sig. (2-tailed)	0.542	0.000	0.673	0.206	0.026	0.000	0.106	0.581	0.108

calculated based on the coefficient values for each variable. The KU1 score was calculated as follows:

KU1 = 0.892 hip height – 0.116 hip width + 0.867 rump length + 0.889 body length + 0.828 shoulder height + 0.504 chest width + 0.853 chest depth + 0.831 head width + 0.927 head length

While KU2 score was calculated as follows:
KU2 = - 0.030 hip height + 0.625 hip width – 0.110 rump length + 0.152 body length + 0.334 shoulder height + 0.784 chest width + 0.198 chest depth – 0.096 head width + 0.147 head length

Comparison of the body and head morphometrics

The morphometric comparison of the body and head of male and female Bali pigs was carried out by Mann-Whitney U analysis and results were summarized in Table 4. The data exhibited that hip width, shoulder height, and chest width had a significant difference ($p < 0.05$) between male and female Bali pigs. However, there was no significant difference ($p > 0.05$) between the hip height, rump length, body length, chest depth, head width, and head length between male and female Bali pigs.

DISCUSSION

Pigs are meat-producing livestock that has a high potential to fulfil the meat needs of the community because they have a fast-breeding ability that is faster than other livestock. These animals generally have fast growth and are very efficient in converting feed into meat with a high percentage of a carcass. Pigs produce higher carcasses (65-80% of body weight), compared to cattle (50-60% of body weight), sheep and goats (45-55% of body weight), and buffaloes (38% of body weight) (Riwukore and Habaora, 2019). Out of the 87 world-famous pig breeds, at least 10 have been developed in Indonesia, including Landrace, Yorkshire, Duroc, Tamworth, and Saddle Back. These species are generally in the form of crosses cultivated in commercial companies so that pure breeds are difficult to find (Aritonang, 1981).

Phenotypic differences can be used to determine genetic distance through diversity analysis (Komenes, 1999), and can be identified by measuring body parts or morphometrics. Furthermore, body size measurements are used to distinguish variations in both body size and shape. Analysis of diversity and correlation is widely used in characterizing the relationship between phenotypic and genetic traits (Salako and Ngere, 2002). The characteristics include elements that characterize the population. Several parameters, such as body size, are used as a basic measurement of the characteristics of an animal for production and reproduction purposes. This includes body length, chest circumference, body weight at various periods, hip height and width, and leg circumference (Budinuryanto, 1991).

The body and head morphometric data of Bali pigs showed an average hip height of 55.68cm±3.223, hip-width 17.53cm±2.760, rump length 10.62cm±0.818, body length 67.40cm±6.158, shoulder height 54.92cm±2.911, chest width 17.81cm±3.125 and depth 41.24cm±3.826, head width 10.63cm±0.775 and length 26.26cm±1.263. These results can be used to identify the Bali pig phenotype and also facilitate an inventory of data regarding their phenotypic profile in order to see their kinship with other pigs in Indonesia. In addition, various kinds of morphometric measurements have important roles in identifying various breeds of livestock and also determine the characteristics of the animal race (Yakubu et al., 2010).

Bali pigs have a smaller size compared to Duroc which has a shoulder and hip height of 84.53±4.324cm and 89.09±4.055cm, head width and length of 30.63±2.058cm and 36.20±2.201, the neck circumference of 98.93±5.942cm, chest depth of 48.13±3.874cm and hip width of 27.04±2.247cm. The Berkshire pigs also have smaller body sizes than Yorkshire, Duroc, and Landrace pigs except for a body length, shoulder height, and hip width of 91.07±10.397cm, 80.95±9.483cm, and 26.62±2,560cm respectively (Banjarnahor et al., 2014). Comparing the body sizes of these four species, the Bali pig is much smaller and this is due to their national differences. Soeparno (1992) stated that the differences in body composition among livestock breeds are mainly due to the differences in the adult body size. Sumantri (2007) and Gunawan (2008) also stated that body size is influenced by feed and genetic factors, maintenance management, and mating patterns such as inbreeding. Furthermore, environmental and genetic factors have a close relationship to express individual genetic capacity perfectly when ideal environmental conditions are meant.

The measurements showed that the head index of both male and female Bali was 40.76% and 39.41%. Variations in head width and length in both female and male pigs were not significant ($p > 0.05$). The head index measurement was used to determine the head conformation of an animal, where it can be used to estimate the physiological feeding ability of livestock. This can also be used as a parameter in determining their appropriate feeding management and to estimate the closeness of the family relationship, where each animal has a different head conformation (Salgado et al., 2021).

Our study showed a significant difference ($p < 0.05$) in hip width, shoulder height, and chest width between male and

female Bali pigs. However, there was no significant difference ($p > 0.05$) in hip height, rump length, body length, chest depth, head width, and head length. Swatland (1984) and Aberle (2001) stated that growth can be assessed as the increase in height, length, circumference, and weight of a young animal that fed, watered, and properly placed. According to Kay and Housseman (1987), androgen hormones in male animals can stimulate growth hence they tend to grow faster than females.

Tillman et al. (1991) stated that growth has fast and slow stages. The fast stage occurs before sexual maturity and the late stage is in the early phase and when the body's maturity has been reached. Furthermore, Darmayanti (2003) and Nurhayati (2004) showed that bodyweight is positively related to body measurements. Mulliadi (1996) further explained that the measurement of body size as a quantitative trait was carried out based on the general size of livestock. These measurements are used to determine differences in livestock populations and their morphogenetics within a region or country.

According to Fourie et al., (2002), size is an important indicator that is used to evaluate growth but cannot be used for animal body composition. Chest circumference and body length are the most commonly used measurements which have the greatest influence on body weight. The chest circumference also had a positive correlation with a growth rate which resulted in an increase in shoulder height and frame size. According to Darmadi (2004), this factor affects live weight more than body length.

The results of Principal Component Analysis (PCA) showed that the dominant contributing variables as size characteristics in Bali pigs were hip height, rump length, body length, shoulder height, chest depth, and head width and length. This were indicated by high eigenvalues in the equation of the size scores, respectively 0.892, 0.867, 0.889, 0.828, 0.853, 0.831 and 0.927. Meanwhile, the variables that played a dominant role as a shape feature were the chest and hip-width. This is indicated by the high Eigenvalues in the form score equations of 0.784 and 0.625, respectively. These size and shape characteristics can be used to differentiate from other pig species where the shape (phenotypic) is influenced by genetic and environmental factors (Hardjosubroto, 1998).

The first and second main components (KU 1), namely size and shape had the highest total diversity of 58.338% and 18.340%, and an Eigenvalue of 5.834 and 1.834dc. These results are in accordance with the opinion of Wiley (1981) which states that the first (X-axis) and second axis (Y-axis) represents the overall size and shape. It also explains the total diversity of 50% to 90% and as little as 1%. Furthermore, Everit and Dunn (1998) explained that the second principal component is of interest to taxonomists because it is more heritable.

Priyanto et al. (2000) stated that the coefficient of low, moderate, and high diversity ranged from 0.1% to 25%, 25.1% to 50%, >50.1%. However, the coefficient of diversity did not exist zero percent. According to Hayashi et al. (1981), the complexity and diversity of living organisms have made multivariate statistical methods an important tool for studying variation and evolution. An example is the Principal Component Analysis (PCA) which aims to reduce data and interpret it (Gaspersz, 1992). This analysis is used to determine discrimination among livestock populations (Hayashi et al., 1982). The main components are obtained based on the variance and correlation matrix. Furthermore, the power of this comparative analysis is greater when the main components are obtained from the diversification matrix. The first and second principal components are also an indication of the size and shape of the animal (Hayashi et al., 1988). In animal anatomy research, the second main component as a shape vector can be used to provide more specific information about the specific characteristics of a particular animal. However, the first main component as a size vector was not emphasized (Everitt and Dunn, 1991).

CONCLUSION

The hip width, shoulder height, and chest width showed significant differences between male and female Bali pigs. However, there were no significant differences in hip height, rump length, body length, chest depth, head width, and head length. The main characteristics of size in this species are hip height, rump length, body length, shoulder height, chest depth, head width, and head length. Meanwhile, the variables that acted as shape characteristics were chest width and hip-width.

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CONFLICT OF INTEREST

The authors have no conflict of interest.

NOVELTY STATEMENT

This is the first report of morphometric characteristics and head index of Bali pigs using a Principal Component Analysis (PCA). The morphometric characteristics is used to identify the phenotypic characteristics of Bali pigs.

AUTHOR CONTRIBUTION

LGSSH Designed the research design, NLES, NNWS and IMM collected and analyzed the data, LGSSH, IG-NBTL, and IWNFG wrote the manuscript draft. All authors read and revised the final draft of the manuscript.

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