Acta fytotechn zootechn, 27, 2024(4): 379-386
http://www.acta.fapz.uniag.sk

Original Paper

Principal Component Analysis for Morphometrics and Carcass Traits of Commercial Rabbits

Firda Tasya Kamila, Sutopo Sutopo, Dela Ayu Lestari, Sutiyono Sutiyono, Edy Kurnianto, Asep Setiaji*

Universitas Diponegoro, Faculty of Animal and Agricultural Science, Department of Animal Science, Indonesia

Article Details

Received: 2024-08-12 | Accepted: 2024-10-15 | Available online: 2024-12-31

https://doi.org/10.15414/afz.2024.27.04.379-386

This study was carried out to measure carcass characteristics in relation to the rabbits morphometric traits. This will provide valueable insights to develop strategies for selecting rabbits among three rabbit breeds: New Zealand White, Hycole, and Hyla. The parameters investigated included body weight, chest width, hip width, and chest girth. At slaughter, carcass traits such as hot carcass weight, cold carcass weight, reference carcass weight, and commercial cut points 1-5 were assessed. The correlation between morphometric measurements and carcass traits was evaluated using the Statistical Analysis System (SAS). The findings revealed that body weight exhibited the highest correlation with hot carcass weight, cold carcass weight, and reference carcass weight among the three rabbit breeds ($P<0.05$). Hycole has the highest variability (10.5%) and Hyla shows the least variability (3.12%). In NZW rabbits, BW has strong positive correlations with HC ($r=0.97$), CC ($r=0.96$) and RW ($r=0.96$). In Hycole rabbits, BW also has strong positive correlations with various traits such as CP1 ($r=0.93$), CP2 ($r=0.90$) and HC ($R=0.95$). In Hyla rabbits, BW is positively correlated with HC ($r=0.62$) and RW ($r=0.65$). NZW and Hyla rabbits for PC1 accounts for over 57% of the variation with body weight and carcass weight, however Hycole rabbits for PC1 explaining only 37.76% of the variation. High correlations were found between BW and carcass traits suggesting that selecting for increased body weight will improve carcass yield. Body weight has a strong prediction of carcass traits across all breeds, making it a crucial trait for selection in breeding programs.

Keywords: carcass traits, correlation, Hycole, Hyla, morphometric, NZW

1 Introduction

The development program of better for rabbits has increased quite well in the recent decade. Currently, the development of rabbits is very diverse, not only for pets but also for laboratory animals, fur production, and meat production. The commercial breed of rabbit is one of the commodities that has great potential in the livestock industry but has not been utilized optimally. The commercial breed of rabbit offers many advantages that can make it an alternative choice for consumers and the livestock industry (Setiaji *et al.,* 2022a). As a source of meat production, rabbit meat has low fat and cholesterol, but high protein (Zamaratskaia et al., 2023). The fat percentage of rabbit meat (6.2%) was lower compared to lamb (17.5%) and beef (18.3%), then the protein percentage of rabbit meat (18.7 %) was higher than beef reported (16.3%), respectively (Murti *et al.,* 2020). Another factor that makes rabbits ideal as meat producers is their compact body shape and dense meat.

Common rabbit breeds for commercial meat production, such as New Zealand White, Hyla, and Hycole, exhibit advantages in rapid growth and high productivity, making them well-suited for

* **Corresponding Author:** Asep Setiaji. Department of Animal Science, Faculty of Animal and Agricultural Science, Universitas Diponegoro, Jl. Prof Sudarto SH, Tembalang, Semarang 50275, Central Java, Indonesia. Tel/fax: +62-24-7474750. E-mail: asepsetiaji93@gmail.com

commercial purposes (Setiaji *et al.,* 2022b). Morphometric measurements serve as crucial tools for analysing size and shape variations in commercial rabbits, facilitating the assessment of growth and body conformation. These measurements are indicators of growth rate and are pivotal for understanding body weight changes in rabbits (Rotimi, 2021). Growth in farm animals typically manifests through increases in morphometric traits, leading to alterations in the conformation of various body parts, which are significant for meat production. Previous studies have shown that body size and conformation are important traits in commercial breeds of rabbits, with morphometric measurements being phenotypically and genetically intercorrelated (Yakubu and Ayode, 2009). Correlations among body measurements can establish associations critical for selecting and breeding rabbits with desirable traits (Chineke, 2005). For instance, studies have demonstrated that live body measures and raw meat yield has higher correlation value that could serve as a valuable index for selecting high meat-yielding strains (Ogah *et al.,* 2014). Such interrelationships among morphometric traits are essential not only for understanding growth patterns but also have practical applications in enhancing selection and breeding strategies for improved carcass traits.

Principal Component Analysis (PCA) is a technique that used to reduce data dimensionality and facilitate analysis by dividing a wide data or variables into smaller sets to differentiate between its subpopulations (Deribe *et al*., 2021). This method is particularly effective for recapitulates the correlations between traits and distinguishing differences among groups of animals. Results of PCA not only impact of an animals but also help in conservation and selection of multiple traits by breeders (Yunusa *et al*., 2013). Milanês *et al*. (2020) describes PCA was efficient in reducing wide data set into smaller linear combinations on multivariate analysis. This approach effectively summarize the data, especially when morphological characteristics exhibit interdependence. By reducing the dimensionality of explanatory, PCA is able to reduce wide amounts of related variables into lesser number of uncorrelated variables with the first few components will retain most of the variations (Egena *et al*., 2014; Deribe *et al*., 2021). This study was carried out to measure carcass characterics in relation to the rabbits morphometric traits. This will provide to develop strategies for selecting rabbits.

2 Material and methods

2.1 Animal and Their Management

A total of 39 bucks were used in this study. The rabbits compressed of 11 New Zealand White (NZW), 16 Hycole and 12 Hyla (Figure 1). The animals were reared for 16 weeks. The rabbits were reared at the teaching and research farm of Universitas Diponegoro. The rabbits were placed individually in closed house system with individual rearing cages, each of which measured 30 × 50 × 40 cm^3 such that one rabbit was accommodated in one cell. The Rabbits were fed diet containing 16% of crude protein, 12% of moisture, 2% of crude fat, 14% of crude fiber and 0.5% calcium. Water was provided ad libitum with automatic nipple. The rabbits were slaughtered at four months of age with the average body weight were 2.10 ± 0.17 kg.

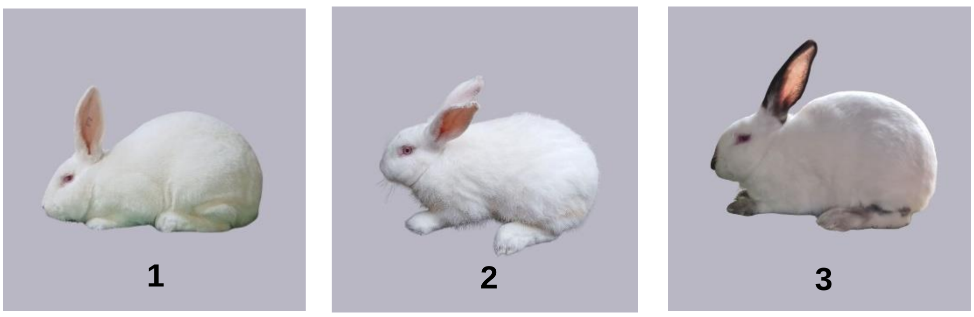

Fig. 1 Three commercial breeds of rabbit used in the study: New Zealand white, Hycole and Hyla, respectively from left to right. [1 = New Zealand White; 2 = Hycole; 3 = Hyla]

2.2 Selected Morphometric

Selected morphometric and live body weight of the rabbits were measured before slaughter. The parameters measured include body weight (BW) was measured from live body weight using a digital scale (kg); body length (BL) was measured from the point of the first spine to the point of the base of the tail, measured using a measuring tape (cm); chest width (CW) was measured from the distance between the right and left points of the sternum located behind the head measured with a digital vernier caliper (mm); hip width (HW) was measured from the distance between the left femur point and the right groin point measured with a digital vernier caliper (mm); chest girth (CG) was measured from the back the shoulder joint (oscapula) measured using a measuring tape (Adamu *et al.,* 2022). The selected morphometric traits depicted in Figure 2.

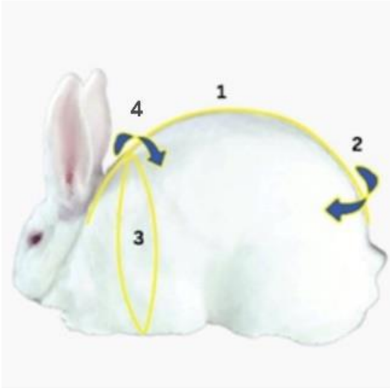

Fig. 2 The selected morphometric traits evaluated in the study [1 = body length (BL); 2 = hip width (HW); 3 = chest girth (CG); 4 = chest width (CW)]

2.3 Carcass Traits

The slaughtering and carcass traits were carried out following the Rabbits Science Association procedures (Blasco et al., 1993). The parameters measured include hot carcass weight (HC), cold carcass (CC), reference weight (RW), and commercial cut points 1-5 (CP1-CP5). The rabbits were slaughtered after 12 hours of fasting. Each carcass was bled, skinned, genitals and urinary bladder organs were removed after slaughtering. The carcasses, with the head, thoracic cage organs (heart, lungs, thymus, trachea, and esophagus), liver, kidneys, and the perirenal and scapular fat were weighed after slaughter called hot carcass weight (HC). And then the carcasses chilled at 4ºC for 8 hours. After that, the weight of the chilled carcass (CC) was measured. The head, liver, lungs, thymus, esophagus, heart, and kidneys were removed to obtain the reference carcass weight (RW), which only contained meat, fat, and bone. The commercial cut points were defined as follows; the section between the 7th and 8th thoracic vertebra following the prolongation of the ribs when cutting the thoracic wall (CP1); the section between the last thoracic and the first lumbar vertebra, following the prolongation of the 12th rib when cutting the thoracic wall (CP2); the section between the 6th and 7th lumbar vertebra, cutting the abdominal wall transversally to the vertebral column (CP3); separation of forelegs including insertion and thoracic muscles (CP4); separation of hind legs, including as coxae and posterior part of pars lateralis and pars medialis (CP5).

2.4 Statistical Analysis

The General Linear model was used to test the differences between breed for morphometric and carcass traits. The Pearson correlation was used to examine the relationship between morphometric and carcass traits. PCA was used to distill the complex relationships between morphometric and carcass traits. into interpretable component. All analysis was performed using Statistical Analysis System (SAS) OnDemand for Academics (SAS, 2021).

3 Results and discussion

The descriptive statistic of morphometric and carcass traits of New Zealand White, Hyla, and Hycole rabbits were presented in Table 1. For body weight (BW), all three breeds show similar averages, with the highest variability in Hycole (10.5%), with Hyla demonstrating the lowest variability (3.12%). The highest HC and CC were shown in NZW and lowest in Hycole rabbits, but all breeds have similar CV, indicating relatively consistent measurements within breeds. RW was not significant among breeds. Various CP1 to CP5 show slight variations, with NZW generally having the highest values, except for CP2. Overall, NZW rabbits tend to have larger and more consistent morphometric and carcass traits than Hycole and Hyla, which display greater variability in most traits. CP2 was shown the highest value of coefficient variance (20.74), that could indicate an important trait for selection and improvement. This study different Yakubu and Ayode (2009) with reported BW, HG and BL were more varies. This could be particially to some degree of environmental factors and the condition of each animal.

Table 1 Descriptive statistics of morphometric and carcass traits for three breed of rabbits

Traits	NZW		Hycole		Hyla	
	Mean ± SD	CV	Mean ± SD	CV	Mean ± SD	CV
BW	2.08 ± 0.17	8.4%	2.11 ± 0.22	10.5%	2.12 ± 0.07	3.12%
BL	32.25 ± 2.32^{b}	7.2%	34.86 ± 2.45^{a}	7.05%	32.23 ± 2.35^{b}	7.31%
CG	32.41 ± 1.50^{a}	4.6%	27.93 ± 2.41^{b}	8.63%	28.71 ± 1.46^{b}	5.09%
HW	5.61 ± 0.54^{a}	9.7%	4.99 ± 0.62^{b}	12.4%	4.87 ± 0.50^{b}	10.31%
HC	1.25 ± 0.12	9.3%	1.20 ± 0.16	13.5%	1.24 ± 0.06	4.85%
CC	1.22 ± 0.12	10.2%	1.15 ± 0.14	12.2%	1.20 ± 0.07	5.49%
RW	0.99 ± 0.10	10.2%	0.94 ± 0.14	14.5%	0.95 ± 0.05	5.37%
CP1	0.27 ± 0.03	9.4%	0.28 ± 0.03	12.1%	0.26 ± 0.02	9.46%
CP2	0.11 ± 0.03	23.8%	0.10 ± 0.02	22.3%	0.10 ± 0.01	8.38%
CP3	0.20 ± 0.03	13.7%	0.17 ± 0.04	22.2%	0.18 ± 0.02	9.46%
CP4	0.16 ± 0.01	8.2%	0.17 ± 0.03	15.5%	0.15 ± 0.02	12.69%
CP5	0.42 ± 0.04	10.6%	0.39 ± 0.06	14.7%	0.39 ± 0.05	12.93%

BW= body weight; BL= body length; CG= chest girth; HW= hip width; HC= hot carcass; CC= cold carcass; RW= reference carcass weight; CP1= cut point 1; CP2= cut point 2; CP3= cut point 3; CP4= cut point 4; CP5= cut point 5; SD= standar deviation; CV= coefficient variance.

Values bearing different superscript within the same row having differ significantly (P<0.05)

3.1 Correlation of New Zealand White Rabbits

The simple correlations for morphometric measurements and carcass traits of NZW rabbits in Table 2, were moderate to high across all traits. The BW had the highest correlation with HC (r= 0.97); CC (r= 0.96); and RW (r= 0.96), while the least is CG with CP2 (r= -0.35). The strong positive correlations indicate that as body weight increases HC, CC, and RW also tend to increase significantly (P<0.01), showing that BW is a strong overall predictor of carcass traits. BL has no effect for all carcass traits. This implies that BL does not strongly correlate with all carcass traits. CG has a negative correlation with CP2 (-0.35) and weak correlations with other traits. That indicates that CG not be a strong predictor of carcass traits. BL and CG have lower correlations with most of carcass traits. The relationship observed between live weight and various carcass traits found in this study was similar to the findings of Rajendrean *et al.* (2020), in the present study, significantly strong association was observed between the live weight and various carcass traits. Dalle Zotte (2002) reported there was direct relationship between body weight and carcass weight including hot carcass, cold carcass and reference carcass weight. Zapeda-Bastida (2019) identified a high positive correlation (0.917) between hot carcass and live weight. Morphometric measurement could be used for predicting carcass quality and selecting animals for meat production in specific markets. According to Mallam *et al*. (2022) a negative correlation between carcass traits means if one trait increases, the other will decreases. Due to their high meat to bone ratio yield, loin, rump and hind limb could be considered as a prime cut (Murshed *et al*., 2014).

Table 2 Estimate of correlation between morphometric measurements and carcass traits of NZW rabbits

BW	-											
BL	0.03	-										
CG	-0.15	0.41	-									
HW	0.05	0.61*	0.21	-								
HC	0.97**	0.09	-0.03	0.05	-							
CC	0.96**	0.03	-0.16	0.11	0.97**	-						
RW	0.96**	-0.01	-0.13	0.01	0.98**	0.96*	-					
CP1	0.68*	-0.20	0.16	-0.03	0.72*	0.64*	0.72*	-				
CP2	0.83*	0.32	-0.35	0.28	0.78*	0.82*	0.76*	0.28	-			
CP3	0.88*	-0.07	0.09	0.01	0.89*	0.80*	0.89*	0.72*	0.55	-		

CP4	0.55	0.30	0.25	0.23	0.55	0.52*	0.55	0.65*	0.4	0.41	-	
CP5	0.79*	0.09	-0.16	0.35	0.82*	0.86*	0.89*	0.5	0.71*	0.66*	0.67*	-
	BW	**BL**	**CG**	**HW**	**HC**	**CC**	**RW**	**CP1**	**CP2**	**CP3**	**CP4**	**CP5**

BW= body weight; BL= body length; CG= chest girth; HW= hip width; HC= hot carcass; CC= cold carcass; RW= reference carcass weight; CP1= cut point 1; CP2= cut point 2; CP3= cut point 3; CP4= cut point 4; CP5= cut point 5.
** Means having different upper case letters differ significantly (P<0.01)
* Means having different upper cse letters differ significantly (P<0.05)

3.2 Correlations of Hycole Rabbits

Table 3 shows the correlation between morphometric and carcass characteristics of Hycole rabbits. In this investigation, the correlation between the various measurements were shown to be both positive and significant (P<0.05). Numerous carcass attributes are significantly influenced by the BW. BW had a strong positive correlation with CP1 (0.93); CP2 (r= 0.90); CP3 (r= 0.79); CP4 (r= 0.66); CP5 (r= 0.87); HC (r= 0.95); CC (r= 0.81); RW (r= 0.96). Similar to BW, BL also shows favourable relationships with carcass characteristics, however these are often less. It is possible that the rabbits with bigger chest girths had somewhat smaller carcasses since CG has negative relationships with both HC and CC. Most carcass features have positive relationships with HW, suggesting that HW was linked to greater carcasses. BW demonstrates strong positive correlations with most carcass traits, indicating that heavier rabbits tend to have larger carcasses. The coefficient indicates that HC will tend as body measurements increase. This supports the genetic relationship important for selecting to increase carcass weight (Ogah, 2012). The previous studies, including those by Simek *et al.* (2019) have also found the genetic type significantly affecting on the majority of morphometric traits. Commercial cut point (CP1-CP5) generally exhibits positive correlations with carcass traits, with varying strengths. This suggest that rabbits with specific anatomical cut points may be indicative of larger carcass sizes. These correlations provide valuable insights into the correlation between morphometric measurements and carcass traits in rabbits, with potential implications for breeding and selection strategies to enhance carcass quality. According to Mallam *et al*. (2022) found that carcass traits such as loin, hind limb, and fore limb had a high and positive correlation with live weight. Wang *et al.* (2016) also reported a significant effect of genotype on commercial carcass.

Table 3 Estimate of correlation between morphometric measurements and carcass traits of Hycole rabbits

BW	-											
BL	0.30	-										
CG	-0.19	-0.5	-									
HW	0.42	0.09	0.23	-								
HC	0.95**	0.17	-0.14	0.46	-							
CC	0.81**	0.59	-0.12	0.37	0.85**	-						
RW	0.96**	0.16	-0.16	0.42	0.96**	0.86**	-					
CP1	0.93**	0.08	-0.04	0.5	0.91**	0.79*	0.94*	-				
CP2	0.90**	0.29	-0.23	0.30	0.88**	0.74*	0.90*	0.79*	-			
CP3	0.79**	0.05	-0.18	0.45	0.84*	0.74*	0.8	0.79*	0.79	-		
CP4	0.66*	-0.03	0.18	0.28	0.69*	0.55**	0.65	0.66	0.66	0.46	-	
CP5	0.87**	0.15	-0.19	0.28	0.91**	0.91**	0.87*	0.79	0.83	0.68*	0.5	-
	BW	**BL**	**CG**	**HW**	**HC**	**CC**	**RW**	**CP1**	**CP2**	**CP3**	**CP4**	**CP5**

BW= body weight; BL= body length; CG= chest girth; HW= hip width; HC= hot carcass; CC= cold carcass; RW= reference carcass weight; CP1= cut point 1; CP2= cut point 2; CP3= cut point 3; CP4= cut point 4; CP5= cut point 5.
** Means having different upper case letters differ significantly (P<0.01)
* Means having different upper cse letters differ significantly (P<0.05)

3.3 Correlations of Hyla Rabbits

The correlation study between the Hyla rabbits' carcass characteristics and morphometric measures was displayed in Table 4. There are notable positive connections between BW and a number of qualities, such as HC (r=0.62), RW (r=0.65), and CP1 (r=0.62). HW has a favourable correlation with both CC (r=0.47) and HC (r=0.42), indicating that WH was linked to better carcass characteristics. Strong correlations exist between CP1 and RW (r=0.84) and HC (r= 0.79). Moderate associations between CP2 and HC (r=0.63) and CC (r=0.59) highlight the significance of CP2 in carcass partitioning. While CP5 shows a moderate connection (r=0.53) with CG, CP4 did not exhibit notable relationships with other qualities. Similar to the observation of Sanah *et al.* (2024), morphometric measurements and carcass traits are good predictors of one another. In the present study, shows that values obtained for carcass quality HC, CC, and RW were significantly influenced by genotype (P<0.01). This indicates that as body weight increases, these carcass traits also tend to increase. BW and carcass traits among three breeds has a positive correlation which suggest that there was a direct relationship between those variables, with carcass weight increasing as live body weight increases (Ehibou and Kyado, 2000).

Table 4 Estimate of correlation between morphometric measurements and carcass traits of Hyla rabbits

BW	-											
BL	0.30	-										
CG	-0.19	-0.72	-									
HW	0.42	-0.42	0.25	-								
HC	0.62*	-0.20	-0.01	0.29	-							
CC	0.47	-0.18	-0.02	0.47	0.90**	-						
RW	0.65	-0.29	0.16	0.43	0.93**	0.89**	-					
CP1	0.62*	-0.43	-0.06	0.42	0.79*	0.63	0.84*	-				
CP2	0.07	-0.43	-0.06	0.42	0.61*	0.69*	0.59*	0.44	-			
CP3	0.37	-0.23	0.35	0.35	0.63*	0.59*	0.51	0.39	0.28	-		
CP4	0.46	0.19	-0.33	-0.21	0.33*	0.27	0.39	0.38	0.05	-0.33	-	
CP5	-0.34	-0.19	-.034	0.53	0.29	0.33	0.28	0.21	0.64	-0.06	-0.05	-
	BW	**BL**	**CG**	**HW**	**HC**	**CC**	**RW**	**CP1**	**CP2**	**CP3**	**CP4**	**CP5**

BW= body weight; BL= body length; CG= chest girth; HW= hip width; HC= hot carcass; CC= cold carcass; RW= reference carcass weight; CP1= cut point 1; CP2= cut point 2; CP3= cut point 3; CP4= cut point 4; CP5= cut point 5.
** Means having different upper case letters differ significantly (P<0.01)
* Means having different upper cse letters differ significantly (P<0.05)

3.4 Principal Component Anaylisis of Rabbits

A principal component of the morphometric and carcass characteristics was carried out and presented in Figure 4. to aid in the interpretation of the relationships. This axis is primarily defined by the variables HC, CC, RW, and BW. The aforementioned characteristics have a strong positive correlation with one another. Table 5. displayed the PCA across a variety of variables for three breeds of rabbits. A substantial amount of the variation (57.71%) in NZW rabbits is explained by the PC1, which is mostly impacted by characteristics including BW, HC, and RW. PCs 2 and 3 emphasize BL and CG and account for lesser percentages of the variation for both breeds. With PC1 accounting for just 37.76% of the variation, Hycole exhibits a distinct pattern that points to a more varied distribution. These distinctions show that, compared to Hyla, New Zealand White show more stable trait associations, led by carcass weight and body weight. The principal component on morphometric and carcass traits across three commercial rabbit breeds reveals critical insights into trait interrelationships. For NZW and Hyla breeds, PC1, accounting for over 57% of the variance, primarily links BW and various carcass traits HC, CC and RW, underscoring BW as a predictor of carcass yield. PC2 and PC3 further dissect the contribution of BL, HW, and CG, particularly reflecting differences in body dimensions and cut distribution. Conversely, the Hycole breed exhibits a more evenly spread variance across PCs, indicating a complex interaction of traits where body weight, though significant, is intertwined with hip width and carcass cut points, highlighting breed-specific variations in how body and carcass characteristics are interrelated. This nuanced understanding from PCA supports breed-specific selection strategies (Maluve *et al.* 2013; Rotimi, 2021) where prioritizing traits like body weight can enhance carcass yield efficiency, while accounting for breed differences in body morphology and cut proportions is essential for optimizing commercial rabbit production.

Table 5 Principal Component Analysis for morphometric and carcass traits

Variables	**NZW**			**Hycole**			**Hyla**		
	PC1	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
BW	0.15	-0.02	-0.04	0.24	-0.26	0.05	0.15	-0.02	-0.04
BL	-0.02	0.41	0.13	0.03	-0.05	-0.32	-0.02	0.42	0.13
CG	-0.05	0.06	0.59	-0.01	-0.16	0.40	-0.05	0.06	0.59
HW	-0.05	0.45	-0.04	-0.05	0.24	0.17	-0.01	0.45	-0.04
HC	0.14	-0.14	0.03	0.19	0.04	-0.33	0.14	-0.14	0.02
CC	0.14	0.01	-0.07	0.16	0.11	-0.02	0.14	0.01	-0.07
RW	0.15	-0.03	-0.03	0.19	0.03	0.03	0.14	-0.03	-0.03
CP1	0.09	-0.25	0.31	0.20	-0.03	-0.04	0.09	-0.25	0.31

CP2	0.12	0.19	-0.26	0.03	0.29	-0.03	0.12	0.19	-0.27
CP3	0.12	-0.10	0.11	0.08	-0.03	0.22	0.12	-0.10	0.11
CP4	0.07	0.07	0.31	0.19	-0.11	-0.29	0.06	0.07	0.31
CP5	0.12	0.11	-103	-0.08	0.42	-0.09	0.12	0.11	-0.10
Variance (%)	57.71	16.79	12.90	37.76	21.37	19.92	57.71	16.79	12.90

BW= body weight; BL= body length; CG= chest girth; HW= hip width; HC= hot carcass; CC= cold carcass; RW= reference carcass weight; CP1= cut point 1; CP2= cut point 2; CP3= cut point 3; CP4= cut point 4; CP5= cut point 5; PC1= first principal component; PC2= second principal component; PC3= third principal component.

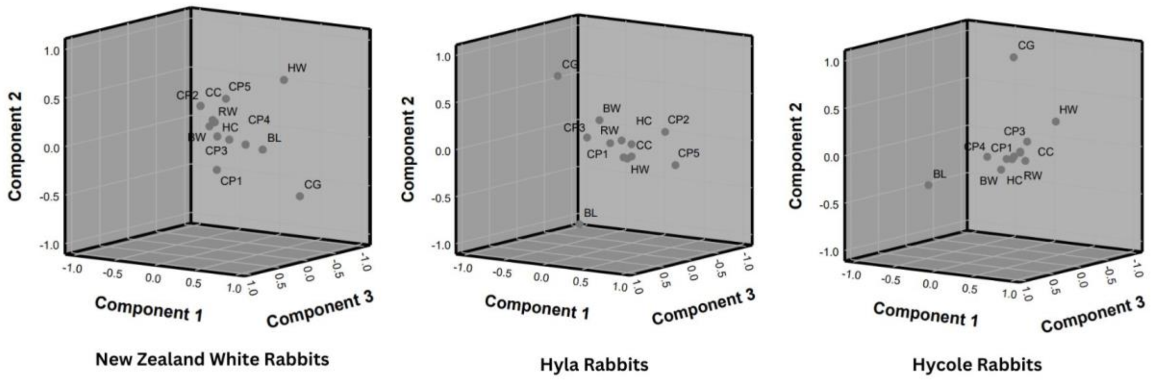

Fig. 3 Projection Principal Component Analysis of three Breed Rabbits

4 Conclusions

High correlations were found between BW and carcass traits suggesting that selecting for increased body weight will improve carcass yield. Body weight has a strong prediction of carcass traits across all breeds, making it a crucial trait for selection in breeding programs. This research can be the potential of using morphometric measurements and carcass traits to improve rabbit meat production.

Acknowledgments

This research has been supported by the Universitas Diponegoro (grant no. 223/UN7.F5/PP/III/2024)

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