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Meat Quality Comparison in Bali, Wagyu, and Their Cross-Breed Cattle Using Ultrasound Imaging

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ABSTRACT. This study aimed to compare the meat quality of different beef cattle breeds using ultrasound imaging. A total of 28 cattle, aged 1-2.5 years, from three breeds were analyzed: Wagyu (n=7), Bali (n=10), and Wagyu×Bali cross-breeds (n=11). Meat quality traits, including longissimus dorsi thickness (LDT), backfat thickness (BFT), intramuscular fat (IMF), and marbling score (MS), were assessed using ultrasound imaging. The association between breed and meat quality was analyzed using a completely randomized design (CRD) followed by Tukey's test. Additionally, principal component analysis (PCA) was employed to identify clusters of meat quality potential among the different breeds. The results indicated that Wagyu×Bali cross-breeds exhibited the highest LDT (46.380±4.770 mm), though the difference was not statistically significant (P≥0.05) compared to either Bali or Wagyu cattle. However, significant differences (P≤0.05) were observed between Bali and Wagyu cattle. For BFT, MS, and IMF, Wagyu cattle outperformed both Bali cattle and Wagyu×Bali cross-breeds, with values of 5.490±0.806 mm, 6.010±0.998, and 49.05±8.140%, respectively. The PCA revealed two primary clusters: the first cluster, comprising Wagyu cattle, accounted for 75.6% of the diversity and was characterized by BFT, IMF, and MS as key variables. The second cluster included Bali cattle and Wagyu×Bali cross-breeds, representing 21.5% of the diversity, without any specific meat quality variable as a defining marker. Ultrasound imaging effectively estimated meat quality in Bali cattle and their cross-breeds, demonstrating its potential as a tool for meat quality assessment across different breeds.

Keywords: Bali cattle, meat quality, principal component analysis (PCA), ultrasound imaging, Wagyu×Bali cross-breed

INTRODUCTION

Protein is an essential nutrient fundamental for human growth and development, with meat being a widely consumed and popular source. The quality and nutritional value of meat are influenced by several factors, including the type of muscle cut (Jung *et al*., 2016). Additionally, genetics, species, breed, sex, age, diet, including additives (such as hormones, antibiotics, and minerals), and pre-slaughter stress are factors that can significantly affect meat quality (Nasrul Haq *et al*., 2015). Consumers typically base their preferences for meat on its quality attributes, such as color, tenderness, juiciness, and aroma (Narsaiah and Jha, 2012). Among these, intramuscular fat (marbling) plays a crucial role in determining meat juiciness, flavor, and tenderness (Gotoh *et al*., 2018).

Bali cattle (Bos javanicus), one of Indonesia's native domesticated breeds, hold significant potential for producing high-quality meat (Muatip *et al*., 2019). Genetically, Bali cattle are closely related to the banteng, yet they are distinctly different from Bos taurus and Bos indicus, as shown by D-loop MtDNA gene analysis (Jakaria *et al*., 2019). This makes Bali cattle uniquely Indonesian.

Efforts to enhance the quality of beef, particularly from Bali cattle, have included various strategies, one of which is cross-breeding. The goal of cross-breeding is to combine advantageous genes from different breeds to improve livestock productivity and, over time, develop new breeds with enhanced traits. Successful cross-breeding requires careful consideration of the beneficial characteristics of each breed involved, including growth traits, carcass quality, and reproductive performance. While many cross-breeding efforts have been reported, such as Wagyu×Angus (Liu *et al*., 2021), the Wagyu×Bali cross-breed remains underexplored. The cross-breeding of Wagyu and Bali cattle is anticipated to improve meat quality in native cattle, especially Bali cattle.

Meat quality assessment in cattle is typically conducted either through direct cutting or non-invasive methods, such as ultrasound imaging. Ultrasound has demonstrated high accuracy in measuring rump fat (92%), rib fat (90%), and longissimus muscle (87%) (Robinson *et al*., 1992). For instance, the thickness of fat and the longissimus dorsi area in Hanwoo cattle has been measured using ultrasound (Shin *et al*., 2012). Jakaria *et al*. (2017) reported that ultrasound imaging could estimate carcass quality traits in Bali cattle, including backfat thickness, longissimus

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dorsi thickness, rump fat thickness, rump thickness, marbling score, and intramuscular fat percentage on the 12th-13th ribs.

The principal component analysis (PCA) method has been widely used to characterize quantitative traits in various livestock species, including cattle (Gushairiyanto and Depison, 2021), pigs (Tazi *et al*., 2019), and sheep (Zhu *et al*., 2015). However, phenotypic characterization of meat quality in Bali cattle and Wagyu×Bali cross-breeds has not been extensively studied. This characterization is crucial for understanding population structure, devising effective conservation plans, optimizing genetic resource utilization, and planning the future development of Bali cattle and Wagyu×Bali cross-breeds. Therefore, this study aims to characterize the meat quality of Bali cattle, Wagyu cattle, and their cross-breeds using ultrasound imaging.

MATERIALS AND METHODS

Animals

This study utilized a total of 28 cattle, aged 1 to 2.5 years, from various beef cattle breeds. The study sample included Wagyu cattle (n=7) obtained from BET Cipelang, West Java; Bali cattle (n=10) sourced from BPTP East Nusa Tenggara; and Wagyu × Bali cross-breeds (n=11) acquired from the UPT Livestock Breeding and Animal Feed Production facility in East Nusa Tenggara, Indonesia.

Traits Evaluated

The meat quality traits assessed in this study included longissimus dorsi thickness (LDT), backfat thickness (BFT), percentage of intramuscular fat (IMF), and marbling score (MS). These parameters were measured using an ultrasound imaging method (Veterinary Ultrasound Scanner WED-3000V model) at the 12th-13th ribs position, following the protocol outlined by Jakaria *et al*. (2017).

Statistical Analysis

The meat quality data were adjusted for age (2-2.5 years) following the method of Setyani *et al*. (2021). The correction formula applied was:

$$X_{corrected} = \left[\frac{\bar{X}_{standard}}{\bar{X}_{observation}}\right] \times X_{observation}$$

Where:

$X_{corrected}$ = the corrected data,
$\bar{X}_{standard}$ = standard group mean,
$\bar{X}_{observation}$ = observed group mean,
$X_{observation}$ = observation value.

The ultrasound imaging results were analyzed using Image-J NIH software (ImageJ®, NIH, USA). The marbling score (MS) was calculated based on the AUSTRALIAN MEAT and MSA standards (http://www.wagyu.org.au/marbling/). The association between breed and meat quality traits was analyzed using a completely randomized design (CRD) and Tukey's test via Minitab Software (Version 19). The model used for the analysis was as follows:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

Where:

Y_{ij} = observed value
μ = mean
α_i = breeds effect
ε_{ij} = error

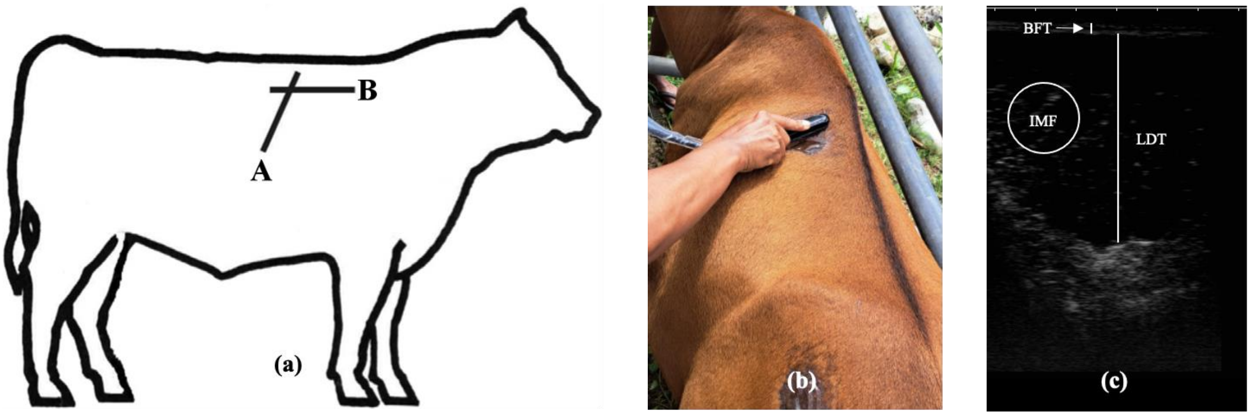

Figure 1. Determination of meat quality using ultrasound imaging. (a) Ultrasound scan point at the 12th-13th ribs position (A=transverse, B=longitudinal); (b) Ultrasound on Bali cattle transversely; (c) Ultrasound image result transversely

Principal component analysis (PCA) was conducted using the R software package (Giaretta *et al*., 2018) to explore the clustering of meat quality traits among the different breeds.

RESULT AND DISCUSSION

Ultrasound Imaging of Meat Quality

The analysis of meat quality across different breeds of beef cattle revealed significant differences (P≤0.05) in the variables measured (Table 1). As shown in Table 2, the highest longissimus dorsi thickness (LDT) was observed in the Wagyu×Bali cross-breed, though the difference was not statistically significant (P≥0.05) compared to both Bali and Wagyu cattle. However, Bali and Wagyu cattle exhibited significantly different (P≤0.05) LDT values. For other meat quality traits, including backfat thickness (BFT), marbling score (MS), and intramuscular fat (IMF), Wagyu cattle showed significantly higher values (P≤0.05) than both Bali cattle and the Wagyu×Bali cross-breed.

Table 1. Ultrasound imaging of meat quality based on various breeds

Breeds	LDT (mm)	BFT (mm)	MS	IMF (%)
Bali	40.230^{a}±8.000	1.642^{a}± 0.351	2.063^{a}± 0.548	3.95^{a}± 1.365
Wagyu	49.050^{b}±8.140	5.490^{b}± 0.806	6.010^{b}± 0.998	13.25^{b}± 2.219
Wagyu x Bali cross-breed	46.380^{ab}±4.770	1.346^{a}± 0.364	1.744^{a}± 0.417	3.156^{a}± 1.038

Note: LDT=*Longissimus dorsi* thickness, BFT=Back fat thickness, MS=Marbling score, IMF=Intra muscular fat. ^{a,b,ab}= Significant (P≤0.05)

Contrary to these findings, Setyani *et al*. (2021) reported higher LDT values for Bali cattle, ranging from 51.99±5.03 mm to 53.03 ±6.10 mm, BFT values between 2.19±0.05 mm and 2.38±1.03 mm, MS values from 1.17±0.31 to 1.24±0.23, and IMF percentages between 1.72±0.73% and 1.91±0.55%. Similarly, Jakaria *et al*. (2017) found that Bali cattle aged three years had LDT values of 53.94±5.40 mm, BFT values of 5.39±0.54 mm, MS values of 4.50±1.05, and IMF values of 13.48±3.42%. The differences in these findings may be attributed to the environmental and genetic variations, as the Bali cattle used in the current study were from East Nusa Tenggara Province (NTT), which is characterized by a tropical semi-arid climate with a harsher environment compared to the slightly wetter climate of Bali Province (Fuah *et al*., 2015; Setiawan, 2012). Environmental factors such as altitude and the quality of forage feed can significantly affect physiological responses and meat quality, including muscle mass and fat deposition (Barahona *et al*., 2020; Suhendro *et al*., 2022).

Wagyu cattle in this study had lower BFT and MS values compared to those reported by Mears *et al*. (2001), where BFT values of 12.8 mm for steers and 14.3 mm for heifers were documented, along with MS values of 8.4 for steers and 7.8 for heifers. However, the IMF percentage in this study was higher than the 31.71% reported by Motoyama *et al*. (2016), likely due to differences in the ultrasound scanning position (12th-13th ribs in this study versus 6^{th}-8^{th} ribs in the previous study) and the adaptation of the Wagyu cattle to the Indonesian environment. Wagyu cattle are known for their distinctive meat quality, characterized by extensive marbling (Oikawa, 2018).

This study is the first to report on the meat quality of the Wagyu×Bali cross-breed. Cross-breeding programs aim to enhance meat quality by combining beneficial traits from different breeds. For instance, Liu *et al*. (2021) reported that Wagyu×Angus cross-breeds (Wagyu-sired calves) had an IMF percentage of 10.0±0.90%, which is higher than the results observed in this study. Additionally, Maulid *et al*. (2020) found that the tenderness of Red Brahman cross-breeds and Droughtmaster cattle did not differ significantly, though sex (steer vs. heifer) had a notable effect on tenderness. Simmental bull-calves and their cross-breeds also exhibited high carcass quality (Kubatbekov *et al*., 2020).

Ultrasound imaging is a practical, rapid, and accurate method for predicting carcass composition without slaughtering the animal. The accuracy of this method ranges from 70-85% (Melendez and Marchello, 2014). Jakaria *et al*. (2017) reported a high correlation (0.291-0.938) between ultrasound measurements and actual carcass quality.

Meat Quality Profiles in Different Breeds

The principal component analysis (PCA) of meat quality traits from different breeds of beef cattle is presented in Figure 2. The first component accounted for 75.6% of the variance, while the second component explained 21.5% of the variance. Figure 2 shows two main clusters: the first cluster consists of Wagyu cattle, characterized by BFT, IMF, and MS as markers, while the second cluster comprises Bali cattle and Wagyu×Bali cross-breeds, which were not characterized by any specific meat quality trait. Despite this, Bali cattle have been reported to have high tenderness (Martiana *et al*., 2020) and a high carcass percentage, reaching 54.76% (Suryanto *et al*., 2017).

Several studies have utilized PCA for trait characterization in animals, including the grouping of zoometrical traits in Uda sheep (Yakubu *et al*., 2009), the evaluation of production and meat quality traits (Abreu *et al*., 2020), the clustering of morphometric indices in female Bali cattle (Warman *et al*., 2023), and the grouping of body measurements in Nguni cows (Tyasi and Putra, 2022). Gushairiyanto and Depison (2021) identified body weight as a key factor in determining morphometric characteristics in Bali cattle. For meat quality traits, Giaretta *et al*. (2018) found that PCA was significantly correlated with marbling, USDA score, and IMF.

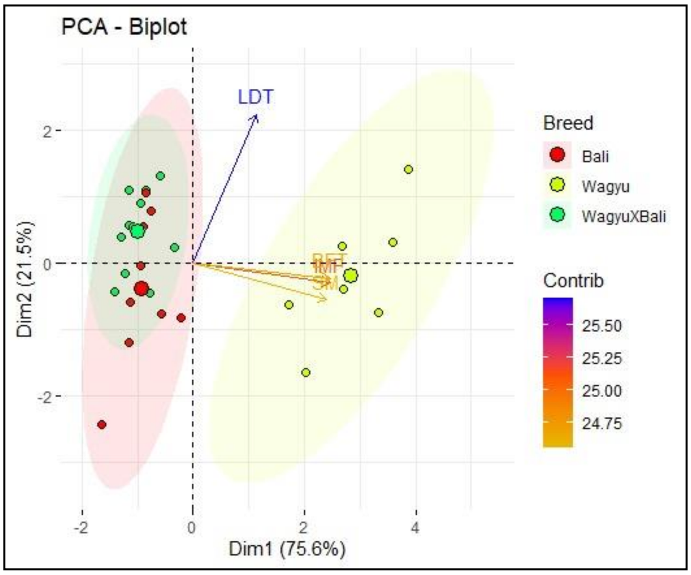

Figure 2. Principal component analysis (PCA) results. LDT=*Longissimus dorsi* thickness, BFT=Back fat thickness, MS=Marbling score, IMF=Intra muscular fat.

CONCLUSION

In conclusion, the LDT of Wagyu×Bali cross-breeds did not differ significantly (P≥0.05) from either Bali or Wagyu cattle. However, Wagyu cattle had significantly higher BFT, MS, and IMF values (P≤0.05) compared to Bali cattle and Wagyu×Bali cross-breeds. Wagyu cattle were distinctly characterized by BFT, IMF, and MS as markers of meat quality, while Bali cattle and Wagyu×Bali cross-breeds were not associated with specific meat quality traits. Ultrasound imaging proved to be an effective tool for estimating meat quality in beef cattle.

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