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CARCASS CHARACTERISTICS AND MEAT QUALITY OF CROSSBRED (BRAHMAN × LAI SIND) AND (RED ANGUS × LAI SIND) BULLS KEPT IN SMALL SCALE FARMS

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ABSTRACT: This study aimed to evaluate carcass characteristics and meat quality of cross-bred (Brahman × Lai Sind, BL) bulls and cross-bred (Red Angus × Lai Sind, AL) bulls. A total of 30 bulls, 15 head/crossbred genotype were fattened for 90 days before slaughtering at 24 months of age. Carcass traits and meat quality were accordingly measured in 30 slaughtered animals. Results showed that the slaughter weight, carcass weight, carcass dressing, meat percentage, loin muscle area were higher for AL bulls than for BL bulls (p<0.05). The color of the meat was not affected by genotype with exception of L* at 48, 168 and 336 hours after slaughter, and this value was higher in AL than in BL bulls (p<0.05). The pH of the meat was not different between genotypes (p>0.05) but decreased quickly at 24 hours after slaughter (p<0.05), then maintained not significantly during storage times. The drip loss, cooking loss and tenderness of the meat were affected by cattle genotype and these values were lower in AL bulls than in BL bulls (p<0.05). In conclusion, crossbred (Red Angus × Lai Sind) bulls were higher carcass characteristics, and were better meat quality than crossbred (Brahman × Lai Sind) bulls.

Keywords: Brahman, Crossbred animals, Lai Sind cattle, Red Angus, Meat quality, Tenderness.

INTRODUCTION

Beef is the third most consumed meat in the world after poultry and pork at 6.4, 14.0 and 12.2 kg/person/year, respectively (OECD, 2019). Beef consumption continues to increase with population and income growth consumer input. By 2027, it is estimated that beef consumption in developed and developing countries will be 8% and 21% higher than the 2015–2017 average, respectively (OECD-FAO, 2019). Currently, consumer demand for beef products is not only concerned with the quantity but also the quality of meat and tenderness (Kim et al., 2020; Fořtová et al., 2022). The world and domestic markets are becoming more and stricter in terms of 120 meat quality standards (Hocquette and Gigli, 2005). Faced with that fact, the issue of improving beef quality is one of the main concerns of the livestock production today (Hocquette and Gigli, 2005). Factors such as breed, sex, age at slaughter, and rations affect meat quality, in which breed is considered one of the important factors affecting meat quality (Waritthitham et al., 2010). Meat quality characteristics such as tenderness, color, flavor, juiciness, water holding capacity, drip loss have impact satisfaction of consumer (Cafferky et al., 2019).

In Central Highland region of Vietnam, beef cattle production plays an important role in term of family income and sustainable development in industrial crop-livestock systems. Number of cattle in this region consisted of 13.3% of total cattle in the country (GSO, 2021) and most of animals are kept in small scale farms. However, beef cattle raising is based on the local breeds such as local Yellow cattle, and F1 (local Vietnamese yellow-*Bos indicus* and Sindh -*Bos indicus*) so called *Lai Sind*. These breeds have small body size, e.g. the mature body weight of local yellow cattle is 182.2 kg and Lai Sind of 244 kg (Van et al., 2009). Their productivity is also low and the quality of beef is poor due to slow growth and prolonged slaughter age (Karimov et al., 2016). With the aim of improving beef productivity and quality to meet the demand of beef was increasing in the country, including Central Highland region, have many policies on insemination of specialized beef breeds such as Red Angus, Droughmaster, Charolais and Brahman for crossbreeding with domestic cattle breeds in order to create a hybrid cattle with high potential yield and meat quality (Quyen et al., 2018).

In many studies, the results showed that growth performance, carcass traits and meat quality of crossbred cattle were significantly improved when compared with Vietnamese local beefs (Hue et al., 2008; Dung, 2012; La et al., 2017; Quyen et al., 2018; Vu et al., 2021; Hai et al., 2022). Many studies have been evaluating carcass traits and meat quality of crossbreds between Red Angus, Droughmaster, Charolais and Brahman with Lai Brahman (La et al., 2017; Quyen et al., 2018; Linh et al., 2022). Linh et al. (2022) studied on the meat quality of crossbred genotypes of (Charolais × Lai

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Brahman), (Droughtmaster × Lai Brahman) and (Red Angus × Lai Brahman) and found that crossbred genotypes had no effects on some meat quality traits.

However, the studies on carcass traits and meat quality of those exotic bulls crossing with Lai Sind were limited (Hue et al., 2008; Dung, 2012). The aim of this study, therefore, was to evaluate the carcass characteristics and meat quality of two crossbred (Brahman × Lai Sind) and (Red Angus × Lai Sind) bulls kept in small scale farms in the Central Highland region, Vietnam.

MATERIALS AND METHODS

This experiment was carried out in small scale farms in Ea Kmut commune, Ea Kar district and in the Faculty of Animal Science and Vet Medicine, Tay Nguyen University, Buon Me Thuot City, Dak Lak province.

Animal experiments

Total 30 bulls of 2 genotypes: 15 BL (Brahman x Lai Sind) and 15 AL (Red Angus x Lai Sind) were raised individually in a barn with an area of 5 m^2/head. They were fattened for 3 months from 21^{st} to 24^{th} months of age. During fattening, animals were fed 60% ensiled VA06 grass and 40% concentrate proportionally combining rice bran, corn meal, soybean meal, urea and mineral salts for 90 days before slaughter. The research protocol was approved by the Scientific Committee of Tay Nguyen University dated 17 June'2021, Decision No: 1228-QĐ-ĐHTN

Slaughtering, meat sampling

Thirty bulls of 420-450 kg body weight were fasted for 24 hours and weighed (slaughter weight) before stunning with an electric current of 220 volts at the slaughter house. After taking out some body parts, the left half carcass was remained for meat sampling. Loin muscle (*Longissimus dorsi*) samples were taken at the 6-13^{th} ribs and stored in a cold chamber at 2-4°C prior to meat quality measurements.

Measurements

Carcass traits: Carcass weight and dressing, meat weight and percentage, bone weight and percentage and loin muscle area were measured at the laboratory of the Faculty of Animal Husbandry - Veterinary Medicine, Tay Nguyen University.

pH of meat: pH was determined by pH meter Testo 230 (German) at 1 hours (pH_1); 24 hours (pH_{24}); 48 hours (pH_{48}); 96 hours (pH_{96}); 168 hours (pH_{168}) and 336 hours (pH_{336}) hours after slaughter with 3 replicates. The pH_1 was measured at 1h after slaughter by taking 10g of minced loin muscle into a 400 ml beaker, adding 100 ml of distilled water, homogenizing the sample and centrifuging at 7000 rpm, and measuring the pH of the solution as quickly as possible. Similarly, values of pH_{24}, pH_{48}, etc. were measured on meat samples stored at 4 ^{0}C.

Drip loss: Meat samples were cut from the loin muscle with a size of thickness of 2.5 cm, width 2 cm and length 5 cm. They were weighed, put in a storage bag, sealed and stored at 2 – 4 ^{0}C according to Brondum et al. (2000). At 24, 48, 96, 168 and 336 hours after preservation, the sample should be taken immediately from the storage bag, lightly patted dry and weighed according to Brondum et al. (2000) and Honikel (1998). Drip loss was calculated according to the formula:

Drip loss (%) = $\frac{P1-P2}{P1}x100$

In which: P1(g): initial weight

P2 (g): final weight

Cooking loss: Meat samples were cut from the loin muscle with size of thickness of 2.5 cm, width 2 cm and length 5 cm, immediately weighed (initial weight), put in a polyethylene bag, heated in a water bath at 75^{0}C for 60 minutes, taken and weighed again (final weight). Cooking loss was calculated as following:

Cooking loss (%) = $\frac{P1-P2}{P1}x100$

In which: P1(g): initial weight

P2(g): final weight

Meat color: Meat color was measured in the loin sample with a Minolta CR-410 colorimeter (Japan) followed to Honikel (1998) and Baublits et al. (2006). The color was expressed as L*, a* and b* readings according to standard luminance D and standard angle of view 65° (CIE, 1976 cited by Honikel, 1998; Baublits et al., 2006).

- L* = 0 (black), L* = 100 white light (white light similar to BaSO4 or MgO burnt)
- b* = - 60 (green), +60 (yellow)
- a* = - 60 (blue), + 60 (red)

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Tenderness (N/cm²): Tenderness was measured by Shear Force Warner-Bratzler method. Samples of 80 - 100 g were weighed, placed in polypropylene bags and heated in a water bath at 80 ^{0}C for 30 min, and then removed from the water. After cooling, use a steel pipe with a diameter of 1.25 cm to drill out 5-10 meat ingots, meat samples were taken along the direction of the fibers. The cutting force was determined on the meat ingots by Warner - Bratzler 2000D (USA) at the time of 12, 24, 48; 168 and 336 hours with 10 replicates/time.

Loin muscle area: The loin muscle samples were taken at the 12-13th rib and stored at 2 – 4 ^{0}C for 24 hours. Loin muscle area was measured by plastic paper and calculated according to the formula:

$$S = \frac{A2*S1}{A1} x100$$

In which: S: Loin area (cm²); S1: Plastic area before using (cm²); A1: Plastic weight before using (g); A2: Plastic weight after using (g)

Data analysis

Data were presented in the form of the mean (M), standard error of the mean (SEM). The data were statistically processed by analysis of variance (ANOVA) by General Linear Model in Minitab v. 16.2 (2010). The difference between the mean values was determined by the Tukey method at a confidence level of 95%. Statistical model:

$Y_{ij} = \mu + G_i + e_{ij}$

Where: μ is the average value; G_i is the effect of genotype (or storage times); e_{ij} is the experimental error.

RESULTS

Carcass characteristics

Effect of genotype on carcass characteristics of crossbred bulls meat presented in Table 1. Data in Table 1 showed that cattle genotype affected the carcass traits, including the carcass dressing, the meat percentage and the loin muscle area. Those traits were higher in AL than in BL ($p < 0.05$). Values of the carcass dressing, meat percentage and loin muscle area in BL were 52.30%, 42.20% and 79.73 cm², respectively, and lower than those in AL 54.4%, 45.0% and 85.6 cm², respectively.

Changes in pH of meat during storage

Effect of storage time duration and two genotypes of cattle beef indicated in Table 2. Data showed no effect of genotype on pH value of meat at any times of storage ($p>0.05$). Values of pH ranged 5.39-6.61 in BL meat and 5.43-6.65 in AL meat. However, pH values of meat effected by storage times ($p<0.05$) in both meats of genotypes. pH decreased dramatically in the 1st day (24hrs) of storage ($p<0.05$), and gradually declined from the 2nd day to 14th day after storage at 2-4^{0}C. The pH dropped 1.14 units in BL (6.61 to 5.47) and 1.15 units in AL (6.65 to 5.50) at the 1st day of storage (pH_{24}). However, after day 1st to day 14th the values of pH declined slowly 0.07 units in BL and 0.04 units in AL, but were not statistically different among them.

Changes in the color of meat during storage

The colors of two crossbred meats and their stored meat during 14 days after slaughter presented in Table 3. With exception of L* at 48, 168 and 336 hours, all color parameters were not affected by genotype ($p>0.05$). The L* values at 48, 168 and 336 hours were higher in AL than in BL (at 48 hrs 38.91 vs 37.96; at 168 hours 39.57 vs 38.81 and 336 hrs 40.49 vs 39.72, respectively). However, the color of meat was affected by duration of storage in 2 genotypes ($p<0.05$). In general, prolonging times of storage increased values L*, a* and b*, especially at the 1st – 2nd day of storage. The L* value of the meat increased by 2.49 units in BL and 3.97 units in AL during first 2 days of storage, and after that day to 14th day these values increased by only 1.76 units in BL and 1.88 units in AL. The values a* and b* have been changed at the same pattern of L*.

Loss of water during storage, cooking and tenderness of meat

Effect of genotype and duration of storage on the drip loss, the cooking loss and the tenderness of loin muscle presented in Table 4. The drip loss, the cooking loss and the tenderness were affected by genotype and time duration of storage ($p<0.05$) with exception of the drip loss at 24 hours ($p>0.05$). Generally, these values were higher in BL than in AL ($p<0.05$) at any time of meat storage. Furthermore, prolonging storage time increased the values of drip loss and the cooking loss in both genotypes. The drip loss at 24 hours and 336 hours were 0.98% and 5.01% in BL, respectively, and 0.92% and 4.69% in AL, respectively. The cooking loss at 24 hours and 336 hours were 28.95% and 33.33% in BL, respectively, and 27.99% and 32.2% in AL, respectively.

The tenderness of meat of two genotypes increased quickly in first 2 day of storage, and then declined gradually from day 4th to day 14th. The values of the meat tenderness (WBSF - Warner-Bratzler Shear Force) at 24, 48 and 336 hours were 73.26, 93.60 and 69.09 N/cm² in BL, respectively; and 70.3, 91.0 and 67.16 N/cm² in AL, respectively.

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Table 1 - Effect of genotype on carcass characteristics of crossbred bulls

Parameters / Genotypes	Brahman × Lai Sind (BL)	Red Angus × Lai Sind (AL)	SEM	p-value
Slaughter weight (kg)	417.3^{b}	457.3^{a}	8.694	0.003
Carcass weight (kg)	218.16^{b}	250.5^{a}	4.835	0.001
Carcass dressing (%)	52.3^{b}	54,40^{a}	0.49	0.001
Meat weight (kg)*	176.3^{b}	205,8^{a}	4.54	0.001
Meat percentage (%)	42.2^{b}	45.00^{a}	0.484	0.001
Bone weight (kg)	45.25^{b}	53.00^{a}	0.997	0.001
Bone percentage (%)	10.97	11,59	0.264	0.107
Loin muscle area (cm^2)	79.73^{b}	85.6^{a}	0.725	0.001

*Without skin, fat and bone; ^{a,b}: Means in the same row without common letter are different at $p<0.05$.

Table 2 - Effect of genotype and storage times on pH of the meat

Meat pH / Genotype	Brahman × Lai Sind (BL)	Red Angus × Lai Sind (AL)	SEM	p-value
pH_1	6.61^{A}	6.65^{A}	0.021	0.485
pH_{24}	5.47^{B}	5.50^{B}	0.017	0.205
pH_{48}	5.45^{B}	5.48^{B}	0.013	0.284
pH_{96}	5.43^{B}	5.47^{B}	0.097	0.216
pH_{168}	5.41^{B}	5.46^{B}	0.016	0.056
pH_{336}	5.39^{B}	5.43^{B}	0.016	0.098
SEM	0.016	0.017		
p-value	0.001	0.001		

^{A,B}: Means in the same column without common letter are different at $p<0.05$

Table 3 - Effect of genotype and storage times on meat color

Storage times (Hrs.) / Genotype		Brahman x Lai Sind (BL)	Red Angus x Lai Sind (AL)	SEM	p-value
L* (light)	12	35.47^{D}	35.82^{B}	0.2023	0.236
	24	37.30^{C}	36.77^{B}	0.2321	0.112
	48	37.96^{B}	38.91^{A}	0.2434	0.016
	96	38.59^{AB}	39.20^{A}	0.2518	0.096
	168	38.81^{AB}	39.57^{A}	0.2526	0.044
	336	39.72^{A}	40.79^{A}	0.2971	0.017
	SEM	0.4712	0.608		
	p-value	0.008	0.044		
a* (red color)	12	18.90^{B}	18.95^{B}	0.2016	0.853
	24	18.87^{C}	19.17^{B}	0.2396	0.394
	48	20.20^{A}	20.27^{B}	0.2764	0.866
	96	20.51^{A}	20.55^{A}	0.3201	0.930
	168	20.95^{A}	20.72^{A}	0.2315	0.482
	336	20.37^{A}	20.47^{A}	0.2287	0.759
	SEM	0.339	0.241		
	p-value	0.002	0.001		
b* (yellow color)	12	5.90^{D}	6.08^{B}	0.133	0.329
	24	6.83^{C}	6.72^{B}	0.2343	0.735
	48	7.74^{B}	8.144^{A}	0.158	0.193
	96	8.57^{A}	8.38^{A}	0.160	0.087
	168	8.44^{A}	7.88^{A}	0.376	0.210
	336	8.61^{A}	8.85^{A}	0.166	0.091
	SEM	0.197	0.149		
	p-value	0.001	0.001		

^{a,b}: Means in the same row without common letter are different at $p<0.05$; ^{A,B,C,D}: Means in the same column within parameter without common letter are different at $p<0.05$

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	168	38.81^{AB}	39.57^{A}	0.2526	0.044
	336	39.72^{A}	40.79^{A}	0.2971	0.017
	SEM	0.4712	0.6080		
	p-value	0.008	0.044		
a* (red color)	12	18.90^{B}	18.95^{B}	0.2016	0.853
	24	18.87^{C}	19.17^{B}	0.2396	0.394
	48	20.20^{A}	20.27^{B}	0.2764	0.866
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	336	20.37^{A}	20.47^{A}	0.2287	0.759
	SEM	0.339	0.241		
	p-value	0.002	0.001		
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	336	8.61^{A}	8.85^{A}	0.166	0.091
	SEM	0.197	0.149		
	p-value	0.001	0.001		

^{a,b}: Means in the same row without common letter are different at p<0.05; ^{A,B,C,D}: Means in the same column within parameter without common letter are different at p<0.05

Table 4 - Effect of genotype and storage time on drip loss, cooking loss and tenderness of the meat

Storage times (Hrs.) \ Genotype		Brahman x Lai Sind (BL)	Red Angus x Lai Sind (AL)	SEM	p-value
Drip loss (%)	24	0.98^{E}	0.92^{E}	0.032	0.166
	48	2.15^{Da}	1.75^{Db}	0.113	0.019
	96	2.89^{Ca}	2.58^{Cb}	0.068	0.002
	168	4.38^{Ba}	4.13^{Bb}	0.074	0.029
	336	5.01^{Aa}	4.69^{Ab}	0.102	0.033
	SEM	0.094	0.070		
	p-value	0.001	0.001		
Cooking loss (%)	24	28.95^{Ea}	27.99^{Cb}	0.273	0.019
	48	29.79^{Da}	28.79^{Cb}	0.271	0.014
	96	30.92^{Ca}	29.91^{Bb}	0.291	0.020
	168	32.57^{Ba}	31.60^{Ab}	0.303	0.031
	336	33.33^{Aa}	32.20^{Ab}	0.358	0.034
	SEM	0.239	0.353		
	p-value	0.001	0.001		
WBSF (N/cm^2)*	24	73.26^{Ca}	70.30^{Cb}	0.401	0.039
	48	93.60^{Aa}	91.00^{Ab}	0.624	0.006
	96	85.13^{Ba}	81.37^{Bb}	1.025	0.015
	168	72.33^{Da}	69.76^{Db}	0.820	0.035
	336	69.09^{Ea}	67.16^{Eb}	0.535	0.016
	SEM	0.738	0.668		
	p-value	<0.001	<0.001		

^{a,b}: Means in the same row without common letter are different at p<0.05; ^{A,B,C,D}: Means in the same column within the parameter without common letter are different at p<0.05; * *WBSF : Warner-Bratzler Shear Force*

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DISCUSSION

Carcass characteristics

In this study, the slaughter weight, carcass dressing and meat percentage were affected by genotype, and these of crossbred (Red Angus x Lai Sind) bulls of 457.3 kg were higher than (Brahman x Lai Sind) bulls of 417.3 kg. These findings are agreement in previous results (Bartoň et al., 2006; Frederico et al., 2016; Barcellos et al., 2017; Linh et al., 2021). The authors concluded *Bos taurus* beef cattle usually have the slaughter weight and carcass dressing and meat percentage higher than *Bos indicus*. In this study, the Red Angus originated from *Bos taurus* and was popular cattle in US, Australia, etc., and the Brahman originated from *Bos indicus* cattle from India. Linh et al. (2021) studied the carcass traits of 3 cattle crossbreds between Lai Brahman cows and Charolais, Red Angus or Droughtmaster bulls of 21 months of age and found the effect of genotype on the carcass dressing and the meat percentages. The carcass dressing and the meat percentage of crossbred (Charolais × Lai Brahman - CB) were higher than crossbred (Red Angus × Lai Brahman - AB) and the crossbred (Droughtmaster × Lai Brahman - DB). The carcass dressing of CB, AB and DB were 62.1% vs 60.3% and 60.6%, respectively, and their meat percentages were 45.2% vs. 43.9% and 42.6%, respectively. Quyen et al. (2018) showed the carcass dressing in crossbred (Red Angus x Lai Sind - AL) was higher than crossbred (Brahman x Lai Sind -BL), and were 52.07% vs 48.09%. Similarly, La et al. (2017), Dat et al. (2008) and Chase et al. (2001) reported that the slaughter weight, the carcass dressing in crossbred cattle was genetically influenced by genotype. La et al. (2017) reported that the carcass dressing of crossbred (Brahman x Lai Sind) was lower than in crossbred (Limousin x Lai Sind) and (Droughmaster x Lai Sind), and were 49.7% vs 53.3% and 51.4%, respectively. In addition, Suryanto et al. (2014) showed that the carcass dressing and the meat percentage were influenced by cattle genotype and feeding diets. Vaz et al. (2002) showed that crossbred (¾ Charolais x ¼ Nelore) had a higher the slaughter weight than crossbred (¾ Nelore x ¼ Charolais), the carcass dressings were different of 53.66% and 54.62%, respectively ($p<0.05$).

In present study, the loin muscle area was affected by cattle genotype. This finding was agreement in previous studies of Bartoň et al. (2006), Quyen (2009) showed the loin muscle area between 8-9th rib of Angus of 17 months of age was lower Charolais of the same age (106.5 cm^2 vs 100.1 cm^2, respectively). Quyen et al. (2018) also indicated there were differences in the loin muscle areas of three genotypes crossbred (Droughtmaster × Lai Sind), (Brahman x Lai Sind) and Lai Sind at 24 months of age. The loin muscle areas of crossbreds (Droughtmaster × Laisind), (Brahman x Lai Sind) and Lai Sind were 123.68; 95.96 and 81.13 cm^2 respectively. However, Linh et al. (2021) found no effect of cattle genotype on the muscle area of three crossbreds (Charolais x Lai Brahman; Droughmaster x Lai Brahman; Red Angus x Lai Brahman). These values of the muscle area of 10-11th rib were 93.0, 85.8 and 94.2 cm^2, respectively.

pH value

The pH value of meat is related to meat quality. After slaughter, the process of anaerobic glycogenolysis produces lactic acid in the muscle, which reduces the pH of the meat. In this study, pH value of the meat was not affected by cattle genotype but affected by time storage. These results were agreement in many precent studies (Barcellos et al., 2017; Cafferky et al., 2019; Linh et al., 2022). All authors indicated that the pH of beef was not genetically influenced by cattle breeds. Linh et al. (2022) reported that pH values of the meat of three genotypes (Charolais x Lai Brahman, Droughmaster x Lai Brahman and Red Angus x Lai Brahman) were not affected by cattle genotypes. The authors showed that pH_{24}, pH_{48} of the meat ranged 5.4-5.6 and 5.3-5.5, respectively. Similarly, Li et al. (2014) indicated that pH_{48} of crossbred (Red Angus x Chinese yellow cattle) of 18 months old was 5.7. Cafferky et al. (2019) reported no difference in the pH_{48} of the meat of Angus, Charolais and Hereford and were 5.55; 5.54 and 5.53, respectively. In addition, Wu et al. (2014) classified pH of the cattle meat into low pH ≤ 5.5 (5.42 – 5.71), medium pH 6.2 (5.86 – 6.19) and high pH ≥ 6.2 (6.29–6.99) depending accordingly on the time of pH measurement. In this classification, the pH values measured in our experiment were in the average range. On the other hand, the Instituts de l'Elevage (2006) declared a final pH (5.5-5.7) as beef in a normal state and the meat was bright red (RFN), a final pH (5.2 - 5.5) was pale beef (PSE), and final pH 6.3 - 6.7 was DFD beef (dark, hard, dry beef). In this study, final pH of two meat types ranged 5.4-5.5 and the meat felled in pale beef (PSE). However, Honikel (1998) classified that if pH_{48} of the meat ranged 5.4-5.8 then the meat was normal (RFN) and $pH_{48} <5.3$ then the meat was PSE. In our study, pH_{48} of two genotypes ranged 5.45-5.46, and then the meat was classified to RFN.

Meat color

In this study, the color was not affected by genotype and increased gradually with the storage times. These findings were similar to previous studies (Mazzucco et al., 2016; Cafferky et al., 2019), who reported that cattle genotype did not affected the meat color when the authors have studied on Charolais, Angus and Hereford, and their crossbreds. However, Setthakul et al. (2008) indicated that the colors of crossbred (Brahman x Thai) and (Charolais × Thai) meat were different. Cuvelier et al. (2006) found that the value L* at 48hrs was highest in Blanc-Blue-Belgium beef (L* = 41.9) then Limousin beef (L* = 39.7) and lowest in Angus meat (L* = 37.4). According to Honikel (1998), the value L* ranged 35-40 then the beef was a normal, L*= 28 then the beef was dark meat. The value L* in this study ranged 35.5-41.3, therefore the meat of two genotypes crossbred (Brahman x) Lai Sind) and (Charolais x Lai Sind) was a normal. On the other hand, Muchemje et al. (2009) recommended the value L* 37-40.7 for dark meat, and then beef of two genotypes in this study was a dark. However, differences in L* at 48 hours and 336 hours in our study between two cattle genotypes did not clearly understand the reasons. According to Rooyen et al. (2017), the value a* = 12 was considered as the minimum threshold

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for meat to be accepted by consumers. The results of our study show that the values a* of meat of two genotypes crossbreds (Brahman × Lai Sind) and (Charolais × Lai Sind) at all storage times were greater than the minimum threshold value. Therefore, the meats of crossbreds (Brahman x Lai Sind) and (Charolais × Lai Sind) in our study were within the acceptable limits for consumers.

Drip loss and cooking loss

The drip loss was affected by cattle genotype and by storage times in this study. The drip loss at 48 hours in our study was 1.61-2.15% and at 336 hours 4.66-5.01%. This finding was similar in previous studies of Linh et al. (2022), who reported that the drip loss at 24 hours of crossbred (Droughmaster × Lai Brahman) meat was higher than crossbreds (Charolais × Lai Brahman) and (Angus x Lai Brahman) meat. However, Hai et al. (2022) found no difference in the drip loss of three genotypes crossbreds AB, DB and CB meat. The drip losses at 48 hours and 192 hours of AB, DB and CB were 3.78, 5.1 and 4.01% at 48 hours, and 4.99, 6.17 and 5.84% at 192 hours, respectively. According to Traore et al. (2012), the drip loss at 48 hours after slaughter could be classified as follows: low drip loss was < 2.6%, average drip loss was 2.6 to 4.0% and as high as >4.0%. According to this classification, the meat of two genotypes in our study belongs to the group of meat with a low drip loss. As the drip loss, the cooking loss also was affected by cattle genotype and storage times in this study. The cooking loss at 48 hours were higher in BL meat than in AL meat (29.79% vs 28.79%). This finding was agreement in previous study of Hue et al. (2008), who reported that the cooking losses of the meat were affected by genotype. The cooking loss at 48 hours of Lai Sind meat (31.48%) and crossbred (Brahman x Lai Sind) meat (33.49%) was higher than (Charolais × Lai Sind) meat (27.66%). However, the finding in our recent study was not similar to the findings of some previous studies (Linh et al., 2022; Hai et al., 2022). Those authors studied meat quality of some cattle crossbreds such as CB, AB, DB and concluded that the cooking loss did not affected by cattle genotype. Linh et al. (2022) reported that the cooking loss at 48 hours of CB, DB and AB meats were not different and were 28.9, 29.6 and 29.3%, respectively. Similarly, Hai et al. (2022) reported also the cooking loss at 48 hours of CB, DB and AB were 29.14, 30.42 and 28.21%, respectively.

Tenderness

Tenderness was an important parameter that determines the quality of meat. Tenderness was the human perception when biting and chewing meat. The cutting force of meat depended on many factors such as: breed, age of slaughter, feeding method, time and method of meat preservation. Tenderness was a key quality characteristic that was highly correlated with general consumer acceptance of beef.

In this study, the tenderness was genetically affected by cattle genotype and the value of WBSF of AL beef was lower than that of BL meat at all storage times ($p<0.05$). This finding was similar to the results of Hue et al. (2008), who reported that the tenderness at 48 hours of crossbred (Charolais x Lai Sind) beef was lower than that of Lai Sind meat and crossbred (Brahman x Lai Sind) meat. Some authors (Luc et al., 2009; Machado et al., 2015) found that *Bos taurus* meat often have less tenderness than *Bos indicus* meat. In this study, as above-mentioned Red Angus originated from *Bos taurus*, while Brahman was *Bos indicus*. However, some studies found no effect of cattle genotype on the tenderness of three crossbreds CB, DB and AB meats (Linh et al., 2022; Hai et al., 2022). The authors reported that the tenderness values at 48 hours of CB, DB and AB meats were 80.9-82.9, 83.77-90.0 and 79.5-81.5 N, respectively. During storage, the tenderness of beef increased gradually and reached a maximum at 48 hours after slaughter, and decreased gradually with storage times in our recent study. These findings were agreement in some present studies (Hai et al., 2022; Linh et al., 2022). Shackelford et al. (1997) classified the tenderness of beef cattle meat into 3 categories based on the value of WBSF at 40 hours: "tender" with shear force <6 kg, "medium" 6 to 9 kg and "tough" >9 kg . Thus, the meat of crossbreds (Brahman x Lai Sind) and (Red Angus x Lai Sind) in our study belongs to the beef category of medium tenderness.

CONCLUSIONS

In present study, the carcass traits such as the carcass dressing, meat percentage and loin area were affected by cattle genotype, and these values were higher in crossbred (Red Angus x Lai Sind) bulls than those in (Brahman x Lai Sind) bulls at 24 months of age. As meat quality, the values of pH and the color of the meat were not affected by cattle genotype but affected by time storage. However, the drip loss, the cooking loss and tenderness were affected by cattle genotype. In term of these indicators, the meat of crossbred (Red Angus x Lai Sind) bulls has higher quality than that of crossbred (Brahman x Lai Sind). In summary, crossbred (Red Angus x Lai Sind) bulls have better the carcass characteristics and meat quality than crossbred (Brahman x Lai Sind) bulls.

DECLARATION

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Author contributions

N.T.K. CHI, and P.T. HUE conceived and designed the experiments; P.T. HUE, N.T.K. CHI, and T.Q. HANH performed the experiments; N.T.K. CHI, P.T. HUE, and L.D. NGOAN analysed the data, N.T.K. CHI, and P.T. HUE, T.Q. HANH, L.D. NGOAN wrote the paper; all authors reviewed and approved the final manuscript.

Conflict of interest

The authors declared no conflict of interest.

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