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Variation among beef cuts of fattened Charolais crossbreds raised under Thai tropical environmental conditions

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Abstract

Importance of the work: Knowing the variation and correlation between beef cuts would benefit fattening beef production, genetic improvement, carcass management and marketing.

Objectives: To estimate the variation of and correlation between beef cuts of commercial Charolais crossbred cattle raised under tropical environmental conditions in Thailand.

Materials & Methods: Data of beef cuts from the forequarters and the hindquarters of 7,936 Charolais crossbred cattle intensively fattened were obtained from 2,471 Thai farmers. Phenotypic (V_p) and additive genetic (V_a) variances among animals were estimated for all cuts using a mixed linear model. Heritabilities for beef cuts were computed as the ratio between V_a and V_p. Phenotypic correlations between beef cuts were computed. Values were reported as mean ± SD.

Results: T-bone (10.93 ± 1.80 kg) was the heaviest cut, while the lightest was Silver Shank (0.56 ± 0.08 kg). Ribeye had the largest coefficient of variation, and Silver Shank had the smallest. The weight of each beef cut varied across cutting dates ($p < 0.05$) and among individual cattle (the V_a-to-V_p ratio ranged from 0.75 (Fore Shank) to 0.96 (Tenderloin). The correlation estimates ranged from 0.17 (Ribeye and Silver Shank) to 0.77 (Paleron and Silver Shank) for forequarter cuts and from 0.32 (Tenderloin and T-bone) to 0.86 (Bottom Round, Top Round and Knuckle) for hindquarter cuts.

Main findings: Beef cuts of Charolais crossbreds fattened under Thai tropical conditions had substantial amounts of variation that depended on the cutting date and individual animals. Smallholders and cooperatives need to consider the variability of and correlations between beef cuts to develop effective production and marketing strategies.

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Introduction

The quality of beef cuts is important for marketing and business, not only for domestic consumption but also in international markets (Mottin et al., 2019; Felderhoff et al., 2020, Liu et al., 2022). Consistency in the size of beef cuts is important for marketing because it enhances consumer satisfaction, facilitates cooking convenience, meets food service industry requirements, supports export trade and contributes to brand reputation and competitiveness (Aaslyng et al., 2003; Ahn and Grün, 2013). However, the size of beef cuts can be influenced by multiple factors, including breed, age, weight, gender, muscling, butchering technique, trimming, deboning and consumer preferences (Resconi et al., 2014; Clinquart et al., 2022). Thus, knowledge of the variation and correlation between beef cuts could benefit producers, processors and consumers by maximizing utilization, meeting market demands, improving consistency and quality, enhancing profitability and providing information for breeding and genetic selection decisions.

Crossbreeding between European (*Bos taurus*) and local cattle (*Bos indicus*) breeds has been utilized to increase the economic potential of beef cattle in tropical countries. Although crossbred cattle generally have more advantages for growth and carcass traits than local cattle, they show large phenotypic variation, perhaps aided by substantial genetic differences inherited from their parents (Koonawootrittriron et al., 2015; Mendonça et al., 2019). Consistently achieving high carcass quality and quantity from fattening cattle requires a holistic approach that includes genetics, nutrition, management, slaughter, cutting, processing and quality assurance programs (Clinquart et al., 2022; Sakowski et al., 2022).

Thailand is a tropical country in Southeast Asia that has high ambient temperatures (27.9°C) and high humidity (73.6%) almost all year round (Sae-tiao et al., 2019). Charolais (a French cattle breed) was introduced to Thailand in 1964. Charolais frozen semen was used to artificially inseminate Thai native and Brahman cows at Kasetsart University, Bangkok, Thailand. Their crossbred progenies showed better general appearance, growth and carcass yield than crossbreds from other breeds (Hereford, Holstein and Brown Swiss). Crossbreeding between Charolais and local cattle (Thai native, Brahman and their crossbreds) was preferred by Thai beef cattle producers (Koonawootrittriron et al., 2011), including members of the Pon Yang Khram Livestock Breeding Cooperative National Security Command Ltd. (PYK), the largest and best-known beef cooperative in Thailand. To maximize profit, Charolais crossbreds were suggested to be fattened intensively for 12–15 mth to gain body weight and accumulate intra-muscular fat or marbling (Osothong, 2015). These Charolais crossbred cattle were in large demand from domestic and export markets (Bunmee et al., 2018).

In Thailand and probably other tropical countries, most fattened-beef cattle producers (> 80%) are smallholders (having less than 10 fattening cattle per farm). They normally buy crossbred cattle without pedigree and history information from other producers or intermediaries and fatten the beasts for a period that depends on the market at that time. Then, they sell their fattened cattle to cooperatives or intermediaries to earn income. Large variation in beef quality and quantity results from cattle genetic background, farm management and environmental factors during the fattening period (Khy et al., 2000; Tessema et al., 2013; Clinquart et al., 2022; Sakowski et al., 2022). This variability could create additional difficulties for marketing and maintaining preferred customers. Unfortunately, there is limited information related to the variation among and correlation between beef cuts in commercially fattened cattle. Thus, the current investigation aimed to identify variation and estimate correlations between beef cuts in commercial crossbred cattle under tropical conditions in Thailand to benefit producers, processors and consumers.

Materials and Methods

Animals and dataset

The dataset was provided by PYK, Sakon Nakhon province, Thailand (17.07349ºN, 104.19833ºE). The data included carcass information from 7,936 Charolais crossbred (50% to 87.5% Charolais) cattle intensively fattened for 12.62 ± 2.68 mth by 2,471 farmers in various provinces from Northeastern Thailand, including Sakon Nakhon, Nakhon Phanom and Mukdahan. Cattle were sold to PYK after fattening had finished. Subsequently, cattle were slaughtered and butchered. Unfortunately, nearly all fattened cattle (94%) had no recorded birth date. Consequently, the number of teeth was used to the approximate age (Pace and Wakeman, 2003).

Farmers fattened their cattle following the rules set down by PYK. Cattle were recorded using their PYK individual identification number. Farmers were suggested to grow grass (*Panicum maximum* T.D. 56, and *Panicum maximum* trychoglume), and then cut (at around 45 d after seed emergence) and carry it to feed animals using approximately 2% of animal body weight per day. During the dry season (November–April) or when green forage (GF) was limited, cattle were fed with rice straw (approximately 1% of cattle body weight). Concentrate feed (CF, 12% crude protein) was produced by the PYK from agricultural by-products and feed ingredients (cassava, broken rice, rice bran, palm oil meal, urea, molasses, shell and limestone rock phosphate) and sold to farmers. The PYK prohibited the use of products from genetically modified organisms, livestock products, corn, dried blood, bone, milk replacers, hormones, antibiotics, growth promoters and chemical agents. Feeding regimes were based on the body weight of the fattening cattle. For example, a ratio of 6 kg/d CF-to-6 kg/d GF was applied for cattle weighing 300 kg, 6.5 kg/d CF-to-8 kg/d GF for cattle weighing 400 kg, 7 kg/d CF-to-10 kg/d GF for cattle weighing 500 kg and 7.5 kg/d CF-to-12 kg/d GF for cattle weighing 600 kg.

The PYK, operating under the supervision of veterinarians and extension staff, provided comprehensive services for cattle management, including recording, health care, treatments, deworming, vaccinations and artificial insemination. Deworming was administered through an injection of Ivomec-F® (Merial, Boehringer Ingelheim; 1% ivermectin and 10% clorsulon) at a dosage of 1 mL per 50 kg body weight or through drenching with Albendazol at a dosage of 1 mL per 10 kg body weight. Vaccination against hemorrhagic septicemia was administered once a year, deep into the muscle, using a dosage of 1 mL. Additionally, vaccination against foot and mouth diseases type A and O (bivalent) was administered subcutaneously every 4–6 mth, with a dosage of 2 ml. Both vaccines were sourced from the Department of Livestock Development of Thailand. When the cattle were fed longer than 12 mth from the recording date and had a body weight of more than 600 kg, farmers sold them to the PYK. However, the recommendation for finishing weight could be changed depending on market demand and supply ability of cooperatives.

Carcass and cuts

The fattened (finished) cattle were transported carefully from farms to the PYK to prevent stress. Fattened cattle were fasted before slaughter (but allowed access to water for 6–12 hr) to ensure the digestive tract was empty and to reduce the risk of contamination during processing. At the slaughter date, the live cattle were weighed, stunned, hanged with the hind legs up, bled, the head, testes, feet, lower legs, hide, and internal organs were removed and the remaining carcass was split in half down the backbone, the two halves were weighed and then hung on a rail for cooling. The temperature of the hot carcasses (halves) was reduced to 3°C within 24 hr in the clean room, after which, all halves were continuously chilled for 7 d. The carcasses were transported from the Sakhon Nakhon province to Bangkok (630 km) and continuously chilled until completing 14 d before selling either in the form of a half carcass, quarter carcass or as retail cuts to customers. All slaughter processes of the PYK had been agreed upon with the National Bureau of Agricultural Commodity and Food Standards (2007). On average, the fattened Charolais crossbreds had a pre-slaughter weight of 566.75 ± 75.95 kg, a hot carcass weight of 313.48 ± 45.34 kg, a dressing percentage of 55.28 ± 2. 27% and a marbling score of 3.01 ± 0.12.

Chilled half carcasses were cut into quarters between the 10th and 11th rib in the PYK system. The quarters were evaluated for marbling (five scores), weighed and kept continuously chilled at 3°C until cutting for sale to customers. The chilled quarters (forequarters and hindquarters) were cut using the Thai French cutting system (Osothong, 2015) by the well-trained and experienced butchers of the PYK. All processes were done in a clean and temperature-controlled room. All cuts were separated from the quarters. After cutting, every cut was weighed and recorded. Eight cuts from the forequarters (Brisket, Chuck, Fore Shank, Paleron, Rib Set, Ribeye, Short Ribs and Silver Shank) and nine cuts from the hindquarters (Bavette, Bottom Round, Knuckle, Sirloin, Striploin, T-bone, Tenderloin, Top Round and Tritip) were chosen based on available information and customer demands.

Data preparation

The data gathered from individual animals were separated into many sections for business security, including those gathered before and after cutting the carcasses (halves, quarters). Unfortunately, it was not possible to link all animal information together, so only the carcass code (individual cattle), cutting date, code names of the cuts, weight of the cuts, initial carcass code and destination code were available for this investigation. The data recorded in the workbooks were extracted and stored electronically in a worksheet. All available data were prepared as an input file for data manipulation and analyses. Data outliers from each of the 17 cuts (8 cuts from forequarters and 9 cuts from hindquarters) were identified and discarded. Numbers of records ranged from 4,388 for the Silver Shank to 12,971 for the Fore Shank.

Statistical analyses

Carcasses cut on the same date were assumed to be managed alike and under the same environmental conditions (contemporary group). Unfortunately, carcass data could not be linked to information on animal performance and raising conditions before slaughter. Thus, a single-trait mixed linear model was utilized that considered cutting date as a fixed effect, with individual animal and residual as random effects. Phenotypic variances (V_p), animal variances (V_a) and residual variances (V_e) for each of the cuts were estimated using restricted maximum likelihood. The animal variance for each cut was assumed to contain the additive genetic variance for that trait. Thus, heritabilities for all cuts were computed as V_a-to-V_p ratios. Pearson product-moment correlations were estimated between the cuts of forequarters, hindquarters and halves. Hypotheses were tested using 95% confidence intervals ($\alpha = 0.05$). Computations were carried out using the MIXED procedure of the SAS software (SAS Institute, Inc., 2016).

Results and discussion

The unique characteristics of each beef cut could result in a wide range of variation in quality, ultimately influencing the preferences and purchasing decisions of customers (Mottin et al., 2019; Liu et al., 2022). Understanding these differences is critical for meeting the diverse needs and expectations of consumers in today's dynamic market. The mean, standard deviation and coefficient of variation (CV) of the beef cut parameters are shown in Table 1. Among all considered beef cuts, Rib Set (8.53 ± 1.54 kg) was the heaviest cut, while Silver Shank (0.56 ± 0.08 kg) was the lightest cut of the forequarters. Conversely, T-bone (10.93 ± 1.80 kg) was the heaviest and Bavette (0.69 ± 0.14 kg) was the lightest cut of the hindquarters. However, the CV ranged from 0.14 (Silver Shank) to 0.30 (Ribeye), with both being in the forequarters.

The beef cuts in the forequarters had a larger range in CV (0.14–0.30) than for the hindquarters (0.15–0.23), perhaps because the forequarters comprised multiple muscles used more frequently for weight-bearing activities, such as standing and walking. The proportion of beef muscle in the forequarters and hindquarters of steers is approximately 52% and 48%, respectively (Moon et al., 2015). The relative market value of these two regions is influenced by consumer preferences and is determined by the sensory attributes and physicochemical properties of the muscle types (Johnson et al., 1988). Despite the potential value of the forequarters, which includes primal Chuck and Rib, as well as rough Brisket, Plate, and Shank, its market demand has been limited due to variations in yield and palatability. In particular, the palatability of the neck and brisket muscles has been identified as a contributing factor to this market disparity (Johnson et al., 1988; Moon et al., 2015).

Customer-preferred cuts (Rib Set, Ribeye, Brisket, Sirloin, Striploin and Tenderloin) had higher CV values than the other cuts (Bottom Round and Top Round (as shown in Table 1. Large variation in the beef cuts subject to high demand could be a problem for beef production and businesses. To fulfill the need for beef cuts in high demand, additional cattle would need to be slaughtered, with the consequent accumulation of unsold cuts in low demand. These low-demand cuts would require special marketing strategies to help sell them as soon as possible. To improve the consistency of the preferred high-quality beef cuts, suitable genetic selection, feeding programs and management practices are needed (Khy et al., 2000; Tatum et al., 2000; Clinquart et al., 2022).

Between 64 and 74 fattened cattle (from 28 to 64 farms) were slaughtered on each of the 104 slaughter dates. The average live weight at each slaughter date was in the range 532.78–626.39 kg. Thus, the large variation among beef cuts could be partly explained by the variation among slaughter weights due to significant slaughter date effects ($p < 0.05$).

Table 1 Mean, standard deviation and coefficient of variation of beef cuts from forequarters and hindquarters of fattened Charolais crossbreds raised under Thai tropical conditions

Beef cut	Number of records	Mean ± SD (kg)	Coefficient of variation
Forequarters			
Brisket	5,835	7.45 ± 1.84	0.25
Chuck	5,930	6.18 ± 1.47	0.24
Fore Shank	12,971	2.15 ± 0.39	0.18
Paleron	5,680	2.18 ± 0.40	0.18
Ribeye	3,750	5.29 ± 1.58	0.30
Rib Set	5,824	8.53 ± 1.54	0.18
Short Ribs	5,818	4.12 ± 0.80	0.19
Silver Shank	4,388	0.56 ± 0.08	0.14
Hindquarters			
Bavette	7,114	0.69 ± 0.14	0.21
Bottom Round	7,862	7.51 ± 1.31	0.17
Knuckle	7,638	5.24 ± 0.81	0.15
Sirloin	7,969	5.26 ± 1.00	0.19
Striploin	8,850	4.74 ± 1.08	0.23
T-bone	8,070	10.93 ± 1.80	0.16
Tenderloin	7,969	2.08 ± 0.48	0.23
Top Round	8,110	8.49 ± 1.45	0.17
Tritip	7,409	1.17 ± 0.24	0.20

Table 2 shows the values for the phenotypic variance (V_p), animal variance (V_a) and variance ratio (V_a/V_p) for each of the beef cuts. Unfortunately, none of the animals in the current study could be linked to their pedigree information. Consequently, they were assumed to be unrelated. The V_p ranged from 0.007 kg^2 (Silver Shank) to 3.454 kg^2 (Brisket) for forequarter cuts and from 0.064 kg^2 (Sirloin Tip) to 3.293 kg^2 (T-bone) for hindquarter cuts. Similarly, the V_a ranged from 0.006 kg^2 (Silver Shank) to 3.015 kg^2 (Brisket) for forequarter cuts and from 0.059 kg^2 (Sirloin tip) to 3.083 kg^2 (T-bone) for hindquarter cuts. Lastly, the variance ratios (V_a / V_p) ranged from 0.75 (Fore Shank) to 0.95 (Ribeye and Rib Set) for forequarter cuts and from 0.87 (Sirloin) to 0.96 (Tenderloin) for hindquarter cuts. These high values indicated a strong similarity between phenotypic and animal variation, suggesting that environmental variation was minimal for these traits.

Table 2 Variance components and variance ratios for beef cuts

Beef cut	Variance component (kg^2)		Variance ratio
	Animal variance (V_a)	Phenotypic variance (V_p)	(V_a / V_p)
Forequarters			
Brisket	3.015	3.454	0.87
Chuck	1.907	2.201	0.87
Fore Shank	0.126	0.168	0.75
Paleron	0.153	0.173	0.89
Ribeye	2.878	3.032	0.95
Rib Set	2.171	2.368	0.95
Short Ribs	0.581	0.663	0.88
Silver Shank	0.006	0.007	0.90
Hindquarters			
Bavette	0.193	0.212	0.91
Bottom Round	1.598	1.806	0.88
Knuckle	0.609	0.687	0.89
Sirloin	0.929	1.065	0.87
Striploin	1.193	1.276	0.93
T-bone	3.083	3.293	0.94
Tenderloin	2.559	2.665	0.96
Top Round	1.971	2.224	0.89
Tritip	0.059	0.064	0.91

Beef cattle raised for fattening in Thailand are typically the result of crossbreeding between either a purebred or a crossbred sire and a local crossbred cow. Considering differences in additive and non-additive genetic effects among these crossbred animals, even if producers raised them following the same guidelines, animals could perform differently. Thus, to increase consistency, cattle with desirable cut traits should be selected for breeding. Providing appropriate nutrition to fattening crossbred cattle consistently may help ensure they develop at a similar rate, which may lead to more consistent weights of cuts. Proper management practices, such as regular weighing and monitoring of the animals, may help identify outliers and allow for adjustments to promote more consistent growth. Furthermore, sorting carcasses based on weight and size during processing could help ensure that similar cuts are grouped together.

Pearson correlation coefficients between forequarter cuts are shown in Table 3, while those between hindquarter cuts are presented in Table 4. All forequarter cuts were positively correlated (Table 3), except for the correlation between Chuck and Fore Shank (-0.69; $p < 0.01$), and between Ribeye and Rib Set (0.06; $p > 0.05$). However, it should be noticed that Ribeye had a correlation coefficient of less than 0.50 with the other cuts, whereas other cuts had correlation coefficients ranging from 0.46 (Brisket and Silver Shank; $p < 0.01$) to 0.77 (Fore Shank and Paleron; $p < 0.01$). All hindquarter cuts had highly significant positive correlations with each other ($p < 0.01$), as shown in Table 4, except for that between Striploin and T-bone (0.02; $p > 0.05$). The correlation ranged from 0.02 (Striploin and T-bone) to 0.86 (Bottom Round and Top Round, and Knuckle and Top Round; $p < 0.01$). Sirloin had correlations higher than 0.50 with other cuts (0.52 to 0.81; $p < 0.01$), except with Striploin (0.40; $p < 0.01$). T-bone had high correlations with other cuts (0.69 to 0.80), except with Striploin (0.02; $p > 0.05$) and Tenderloin (0.32; $p < 0.01$). Striploin had low (0.02, with T-bone) to medium (0.52, with Tenderloin) correlations with other traits. Conversely, Tenderloin had medium correlations ($p < 0.01$) with other traits, ranging from 0.32 (with T-bone) to 0.52 (with Sirloin and with Striploin).

Table 3 Correlation coefficients between forequarter cuts

Beef cut	BK	CH	FS	PL	RE	RS	SR	SS
Brisket (BK)	1.00	0.65**	0.56**	0.58**	0.19**	0.71**	0.67**	0.46**
Chuck (CH)		1.00	-0.69**	0.71**	0.20**	0.76**	0.72**	0.59**
Fore Shank (FS)			1.00	0.77**	0.25**	0.56**	0.63**	0.70**
Paleron (PL)				1.00	0.40**	0.70**	0.66**	0.69**
Ribeye (RE)					1.00	0.06^{ns}	0.20**	0.17**
Rib Set (RS)						1.00	0.73**	0.53**
Short Rib (SR)							1.00	0.56**
Silver Shank (SS)								1.00

^{ns} = not significant; ** = highly significant ($p < 0.01$).

Table 4 Correlation coefficients between hindquarter cuts

Beef cut	BV	BT	KN	SL	ST	TB	TL	TR	TT
Bavette (BV)	1.00	0.67**	0.64**	0.69**	0.42**	0.69**	0.41**	0.70**	0.66**
Bottom Round (BT)		1.00	0.85**	0.79**	0.35**	0.79**	0.47**	0.86**	0.68**
Knuckle (KN)			1.00	0.78**	0.39**	0.74**	0.46**	0.86**	0.62**
Sirloin (SL)				1.00	0.40**	0.80**	0.52**	0.81**	0.73**
Striploin (ST)					1.00	0.02ns	0.52**	0.42**	0.50**
T-bone (TB)						1.00	0.32**	0.78**	0.72**
Tenderloin (TL)							1.00	0.47**	0.39**
Top Round (TR)								1.00	0.68**
Tritip (TT)									1.00

ns = not significant; ** = highly significant ($p < 0.01$).

Hindquarter cuts seemed to be more highly correlated than forequarter cuts, indicating that the weight of one hindquarter cut would be more likely a good indicator of the weight of another hindquarter cut, while this would be less likely for forequarter cuts. This difference in correlation could have been because the hindquarters contain larger, more uniform muscles than the forequarters, which have a more complex muscle structure and a wider range of muscle sizes and shapes (Moon et al., 2015). Correlations between forequarter cuts could be influenced by factors such as breed, age, sex and feeding management. Generally, muscles within the same anatomical region tend to have higher correlations between their sensory and technological properties than those from different regions (Listrat et al., 2016). Thus, properties of muscles close to each other, within either the forequarters or the hindquarters, would likely have higher correlations due to similar usage and proximity.

Most forequarter cuts had non-significant correlations with hindquarter cuts (Table 5), perhaps because they came from different muscle groups and were used differently by the animal. The forequarters comprise muscles more involved in weight-bearing activities, such as standing and walking, while the hindquarters contain muscles for locomotion, such as running and jumping. These different patterns of muscle use lead to differences in muscle structure and composition, which can affect the size and quality of the cuts (Listrat et al., 2016). Genetics, nutrition and management practices could also influence the size and quality of beef cuts in both the forequarters and hindquarters.

Positive and highly significant correlations were found between Paleron (forequarter cut) and all cuts of the hindquarters (0.28 to 0.94), Barvette and Fore Shank (0.94), T-bone and Silver Shank (0.21) and Tritip and Silver Shank (0.01). These positive and highly significant correlations could be attributed to the fact that some muscles or muscle groups were used more or less frequently than others, which could have affected their size and weight (Listrat et al., 2016). For example, the Paleron muscle is a weight-bearing muscle located in the shoulder area, which could contribute to its larger size and weight compared to other muscles in the forequarters. Additionally, some cuts from the hindquarters, such as the Fore Shank and Silver Shank, may have similar characteristics or be derived from similar muscle groups as other cuts, which could explain the strong correlations between them.

Table 5 Correlation coefficients between forequarter and hindquarter cuts

Beef cut	BK	CH	FS	PL	RE	RS	SR	SS
BV	-0.10ns	0.03ns	0.94**	0.94**	-0.09ns	0.03ns	0.45ns	0.00ns
BT	-0.19ns	-0.37ns	-0.04ns	0.79**	-0.05ns	-0.02ns	0.01na	0.06ns
KN	-0.47*	-0.42ns	-0.22ns	0.82**	-0.02ns	-0.03ns	-0.12ns	-0.31ns
ST	-0.10ns	0.01ns	0.06ns	0.74**	-0.03ns	0.08ns	-0.21ns	-0.18ns
SL	0.10ns	0.20ns	-0.13ns	0.28**	0.19ns	-0.01ns	-0.00ns	-0.22ns
TB	0.03ns	0.11ns	0.17ns	0.68**	0.14ns	0.11ns	0.05ns	0.21**
TL	-0.00ns	0.00ns	-0.07ns	0.39**	0.03ns	0.03ns	0.00ns	-0.17ns
TR	-0.05ns	-0.17ns	0.39ns	0.80**	-0.03ns	0.01ns	-0.31ns	0.26ns
TT	-0.69**	-0.20ns	0.00ns	0.62**	-0.07ns	0.10ns	0.15ns	0.01**

BK = Brisket; CH = Chuck; FS = Fore Shank; PL = Paleron; RE = Ribeye; RS = Rib Set; SR = Short Rib; SS = Silver Shank; BV = Bavette; BT = Bottom Round; KN =Knuckle; ST = Sirloin Tip; SL = Striploin; TB = T-bone; TL = Tenderloin; TR = Top round; TT = Tritip.

ns = not significant; * = significant ($p < 0.05$); ** = highly significant ($p < 0.01$).

A significant negative correlation was found between Knuckle and Brisket (-0.47; $p < 0.05$) and between Tritip and Brisket (-0.69; $p < 0.01$). These significant negative correlations could have been due to the Brisket muscle being a large and heavily used muscle in the front of the animal, which may contain more connective tissue and have a different physiological makeup compared to the Knuckle and Tritip muscles in the hindquarters (Listrat et al., 2016). This could have resulted in differences in growth rates and muscle development between these regions, leading to a negative correlation. However, differences in genetic makeup, nutrition and management practices between animals could also contribute to the observed correlation. Thus, further research would be necessary to fully understand the underlying factors contributing to the observed relationship.

The mean weight of beef cuts obtained from the Charolais crossbred cattle in the current study fell within the ranges of values reported in the literature for other fattened cattle (Lee et al., 2013; Seo et al., 2021). However, high variation in the weight of beef cuts of the fattened Charolais crossbreds could affect business competition, especially in the beef industry, where consistency and uniformity are important factors in meeting consumer demand (Liu et al., 2022). Inconsistent beef cuts can lead to difficulties in processing and packaging, as well as potential differences in meat quality and taste. These outcomes could negatively impact the reputation and competitiveness of businesses in the beef industry, particularly those that rely on consistent production and quality to maintain consumer trust and loyalty. Some reductions in the variation in the weight of beef cuts in fattened Charolais crossbreds could be achieved by several management practices, including: 1) choosing animals with desirable traits for growth and carcass quality; (2) providing adequate and balanced nutrition to the animals throughout their lives; (3) ensuring that the animals are free from diseases and are properly vaccinated to prevent health-related problems; (4) proper handling and transportation of the animals to minimize stress; and (5) uniformity in the processing of the animals at the abattoir.

A cooperative having smallholders could manage their fattening strategy to get the desired consistency of beef cuts from Charolais crossbreds by implementing several strategies. These could include a standard feeding program that includes proper nutrition, feed quality and quantity to ensure uniformity of cattle growth and development (Khy et al., 2000; Clinquart et al., 2022), with strict enforcement. A consistent and sufficient water supply to maintain the health and productivity of the cattle should be provided. Carcass traits generally have medium-to-high heritability (Utrera and Van Vleck, 2004). Thus, the cooperative could use selective breeding and proper genetic management to improve the genetic quality of their Charolais crossbreds. This could include selecting the best-performing animals and culling those not meeting the desired standards. In addition, the cooperative could consider introducing new genetic material to improve the genetic diversity of their herd. A standardized and consistent management system should be implemented to ensure that all aspects of the cattle production process are properly controlled and monitored. This could include regular health checks, appropriate handling and transportation and timely veterinary care. A quality control system should be established to ensure consistency and uniformity of the beef products. This could include using standardized methods for weighing and grading beef cuts and implementing strict quality control measures throughout the production process. By implementing these strategies, the cooperative could improve not just the consistency (reducing variation) of the weight of the beef cuts from their Charolais crossbreds but also their marketability, profitability and competitiveness in the beef industry.

Implications

This investigation has provided information that could help smallholders and cooperatives to plan their production and marketing strategies more effectively. They can identify the most profitable cuts and focus on producing those with consistent weights to meet consumer demands, which helps increase profitability and competitiveness in the market. Furthermore, this research has provided information for further research and development in the beef industry. By identifying the factors contributing to the variation in the weights of beef cuts, researchers can develop new strategies and technologies to improve the consistency and quality of beef production in the future.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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