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Original research article

Carcass Characteristics, Meat Quality and Eating Quality of Culled Dairy Cows

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ABSTRACT

This study investigated the effect of breed and marbling score on carcass characteristics, meat quality and sensory evaluation of culled dairy cows (HFF), fattening dairy steers (HFM) and crossbred Charolais steers (CHA) with different marbling score (MBS<3 and MBS≥3). Results showed that the CHA group had greater carcass weight and dressing (%) than the HFM and HFF groups. Rib-eyes area of the HFF group was smaller than the others ($p<0.05$). HFF beef with MBS<3 had higher fat content than the others ($p<0.05$) while beef with MBS≥3 of all breeds did not differ in fat content ($p>0.05$). At MBS<3, CHA beef had higher L*and b* values than the others ($p<0.05$), but there was no difference in L* and b* values when MBS≥3. At MBS<3, CHA and HFM groups had higher WBSF than HFF group ($p<0.05$) but at MBS≥3, there was no difference in WBSF among breeds. CHA and HFF beef had notable oleic acid content and MUFA contents ($p<0.05$), while HFM and HFF beef had greater P/S ratio ($p<0.05$). Sensory attributes were not affected by breeds ($p>0.05$). It could be concluded that culled dairy cows had inferior carcass quality compared to Charolais steers and dairy steers. However, the beef of culled dairy cows had no difference in meat color, fat and protein contents in meat, shear force value, or sensory acceptability compared to the others when beef had a marbling score up to score 3. Therefore, culled dairy cows with marbling scores greater than 3 could be an alternative for producing high quality beef.

Keywords: Carcass characteristics; Culled dairy cows; Dairy beef; Marbling score; Meat quality.

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1. Introduction

Beef cattle production increased 2.2% in 2015 due to the high price of live cattle and demand from domestic and neighboring country markets. Thailand mostly imported frozen beef from Australia, New Zealand and India which was valued at USD 66.171 million in 2016 [1]. High quality beef demand has continually increased in Thailand. The quantity of imported beef has gradually increased because of the demand for quality beef demand by Thai consumers [1, 2]. Traditionally, 50,000 dairy cows were annually culled and sent to the beef market. The amount of high quality beef (beef-type) had less than 3% of consumption in Thailand [3]. The old and culled dairy cows were slaughtered without finishing which produced 2,560 tons (1.7%) of dairy beef in the meat industry for use as meat products [4]. Carcass and meat quality of finishing culled dairy cows, such as high marbling score, low shear force and great flavor have been widely accepted by consumers in New Zealand, Ireland, Denmark and France. In France, heifers and culled cows had 75% of beef market share while steers had 25% [5]. Moreover, fattening dairy steers, heifers and culled cows occupied 40% of beef market share in Japan [6]. Several research studies have been done on carcass characteristics and meat quality of dairy beef. Some research focused on fattening culled dairy cows and dairy steers, especially sensory attributes of dairy beef. Therefore, this study aims to compare the carcass characteristics, meat quality and sensory evaluation of culled dairy cows, fattening dairy steers and crossbred Charolais steers.

2. Materials and Methods

Sixty cattle were assigned into 3 groups as follows: 1) twenty crossbred Charolais steers (CHA), 4.20±0.62 years old and 685.85±99.39 kg of slaughter weight; 2) twenty 75% Holstein Friesian crossbred dairy steers (HFM), 4.00±0.56 years old and 652.20 ±49.60 kg of slaughter weight; and 3) twenty 75% Holstein Friesian crossbred dairy cows (HFF), 4.75±0.55 years old and 646.40 ±69.94 kg of slaughter weight. All were culled due to old age, problems related to the udder health and reproductive problems. All cattle were fattened with 70:30 ratio of concentrate to roughage. The 24% CP concentrate was fed at 2.5-3.0 kg/h/d sprayed with molasses. Roughage was pineapple by-products or corn husk ensiled with palm kernel meal and sometimes supplemented with rice straw for 10-12 months (CHA and HFM) and for 4-5 months (HFF) by members of Beef Cluster Cooperative Limited (Maxbeef).

Immediately after slaughter, carcasses were weighed and chilled at 0-4ºC for 7 days. Data were recorded as slaughter weight, warm carcass weight, chilled carcass weight and hide weight. Percentages of warm carcass weight (%), chilled carcass weight (%) and hide weight (%) were calculated. Rib-eye areas were measured after 7 days of aging by using a planimeter at the anterior side of the *longissimus dorsi* muscle (LD) between the 12^{th} and 13^{th} ribs and expressed in square inches [7]. Marbling scores were assessed by visual assessment according to ACFS 6001-2547 [8]. After 7 days of aging, the LD samples were cut into 2.54 cm thick steaks.

All samples were classified into 2 marbling levels: marbling score less than 3 (MBS<3) and more than or equal to 3 (MBS≥3). One hundred grams of LD steaks from the right side of each carcass were vacuum packed individually and stored at -20°C for further analysis.

Meat samples were analyzed for dry matter, crude protein and crude fat [9]. The meat pH was determined by pH meter (Model 191, Knick, Berlin, Germany) at 45 min and 7 days after slaughter [10]. Meat color was measured on an LD interface after being bloomed at 4°C for 1 hr using a Minolta CR-400 colorimeter (Minolta Camera Co. Ltd, Osaka, Japan) and expressed as lightness (L*), redness (a*) and yellowness (b*) [10]. Water-holding capacity (%WHC) was determined [11]. Thawing loss (%) and cooking loss (%) were determined [10]. Samples were cooked on a flat-top grill until they reached an internal temperature of 71°C and Warner-Bratzler shear force (WBSF) was measured by using Instron (Instron Corporation, Buckinghamshire, UK) equipped with a 500-N load cell [2] and expressed as kg/cm^2. For fatty acid analysis, 6 g of raw beef was extracted by using chloroform-methanol (2:1, v/v) [13]. An aliquot of total lipid extract was methylated [14]. Percentage of individual fatty acids per gram of meat was reported.

Sensory evaluation was assessed in terms of eating quality and palatability ratings by semi-trained panelists [15]. Eight trained panelists evaluated attributes and marked their responses on a 9 point scale where 1=dislike extremely and 9=like extremely for appearance, color, flavor, texture and overall acceptability [16].

For the statistical analysis, data were analyzed by ANOVA using GLM procedure of the SPSS package (SPSS, version 22.0, USA) and the least squares mean (LSM) were compared for significance of the difference using Duncan's New Multiple Range Test. Data of carcass characteristics, the model was as followed:

$$Y_{ij} = \mu + B_i + E_{ij}$$

Y_{ij} was the observation of dependent variables (live weight, warm carcass, chilled carcass, hide weight, warm dressing, chilled dressing, hide percentage, REA (cm^2)).

μ was the overall mean,

B_i was the effect of breed, i= 1 2 3 (1=Charolais crossbred steers (CHA), 2=fattening dairy steers (HFM), 3=culled dairy cows (HFF))

E_{ij} is the residual random error associated with the observation.

Data of meat quality, the model was as follows:

$$Y_{ijk} = \mu + B_i + M_j + B_i{*}\, M_j + E_{ijk}$$

Y_{ijk} was the observation of dependent variables (pH-value, color value, WHC (%), thawing loss (%), cooking loss (%), chemical composition (%), WBSF (kg) and fatty acid profile)

μ was the overall mean,

B_i was the effect of breed, i= 1 2 3 (1=Charolais crossbred steers (CHA), 2=fattening dairy steers (HFM) 3=culled dairy cows (HFF))

$B_i{*}\, M_j$ is the interaction of breed and marbling score effects

E_{ijk} was the residual random error associated with the observation

Trained panelists' averaged data for the three samples were analysed by non-parametric test: Independent sample using the SPSS 22.0. The ability of each trained panelist to discriminate between samples was investigated using the Kruskall-Wallis test.

3. Results and Discussion

3.1 Carcass characteristics

The effect of breed had a positive influence on warm carcass weight, chilled carcass weight, hide weight, warm dressing, chilled dressing, hide percentage and rib-eyes area (REA) as shown in Table 1. The CHA group had significantly higher warm and chilled carcass, both in kg and percentage, than the HFM and HFF groups ($p<0.05$). Moreover, the HFM group had greater warm dressing percentage than the HFF group ($p< 0.05$). Holstein steers had lower dressing percentage than beef type steers [17]. Holstein bulls had to utilize more nutrients to build up fat depots [18]. Holstein bulls had a lower capability for protein accretion compared to the Charolais bulls. Hence, the Holstein bulls could not metabolize the nutrients for protein accretion and reroute the ingested energy in internal fat depots. The Charolais breed was characterized by its ability to accrete synthesized substance as meat (accretion type) which was in contrast to dairy breeds (German Holstein), especially in secreting metabolized feed as milk

Table 1. Effects of breed and marbling score on carcass characteristics of culled dairy cows, fattening dairy steers and crossbred Charolais steers**.**

Carcass characteristics	Breed			SEM	P-value
	CHA(n=20)	HFM(n=20)	HFF(n=20)		
Live weight (kg)	685.85	652.20	646.40	11.23	0.306
Warm carcass weight (kg)	406.10^{a}	366.66^{b}	352.41^{b}	7.39	0.007
Chilled carcass weight (kg)	413.35^{a}	375.94^{b}	356.00^{b}	7.45	0.005
Hide weight (kg)	54.10^{a}	48.45^{ab}	43.95^{b}	1.37	0.008
Warm dressing (%)	59.14^{a}	56.29^{b}	54.41^{c}	0.40	0.000
Chilled dressing (%)	57.60^{a}	54.88^{b}	52.88^{c}	0.40	0.000
Hide percentage (%)	7.88^{a}	7.44^{ab}	6.81^{b}	0.16	0.023
REA (cm^2)	85.29^{a}	83.67^{a}	67.27^{b}	1.50	0.000

^{a,b,c} Means values with different superscripts letters within each row denote significantly ($p<0.05$) difference between groups.
Live weight = weight of animals are fasted for 24 hr before weighting; REA (cm^2) = Rib-eye area

(secretion type) [19]. Moreover, hide weight and percentage of CHA were significantly higher than those of the HFF group ($p<0.05$) but did not differ from the HFM group ($p>0.05$). The HFF group had smaller rib-eye area than the CHA and HFM groups ($p<0.05$). There was no difference on carcass characteristics by marbling score and interaction of breed and marbling score ($p>0.05$).

3.2 Chemical composition

Breed had influence on fat and protein contents ($p<0.05$). The HFF group showed higher accumulated fat content than the CHA and HFM groups ($p<0.05$) which agreed with some report confirmed that Holstein bulls had greater intramuscular fat content and marbling score than Charolais bulls [18]. The CHA group had higher protein content than HFF and HFM ($p<0.05$). Beef with MBS≥3 had higher fat content but lower moisture and protein contents. Marbling score affected moisture and fat percentage; beef with higher marbling score had lower moisture content [20]. Moreover, the interaction of breed and marbling score affected all chemical compositions ($p<0.05$) as shown in Fig. 1, 2. For beef with MBS<3, the HFF group had higher fat content than the CHA and HFM groups, while beef with MBS≥3 of all breeds did not differ in fat content. Moreover, beef with MBS≥3 of all breeds had low moisture and protein content but the values were higher in beef with MBS<3.

3.3 pH value, color value, Water Holding Capacity (WHC), thawing loss (%), cooking loss (%)

Breed had an influence on muscle pH_{45}. The HFM group had higher pH_{45} in muscle than the CHA and HFF groups ($p<0.05$). Response to pre-slaughter stress differs depending on animal-related factors such as sex and breed. This could be influenced by differences in glycogen storage and muscle physiology [21]. There was no difference in muscle pH by marbling score and interaction of both effects ($p>0.05$).

Breed and marbling score had an effect on color; the CHA group had greater lightness (L*) than the HFM and HFF groups in both marbling scores. Redness (a*) of the CHA group was greater than that of the HFM and HFF groups. Dairy-type steers (Holstein steers) had higher metmyoglobin content than beef-type steers leading to darker meat (lower L* value) [22]. Moreover, meat color was affected by age and physical activity [23]. Higher levels of myoglobin in muscle caused darker coloration to the meat with advancing age and increasing physical activity. Beef with MBS≥3 had greater L* and b* values than beef with MBS<3 ($p < 0.05$). Differences of meat color were observed between USDA quality grades; L* value was increased as USDA quality grade increased [24]. Moreover, L* value was inversely correlated with a* value because L* value was influenced by fat content or marbling At MBS≥3, a* values were lower than MBS<3 which at MBS≥3 the CHA and HFF groups had higher a* values than HFM group ($p<0.05$). Significant difference in cooking loss (%) between the CHA and HFF groups was found (19.54 vs. 20.58%, respectively). The HFF group had higher thawing loss than the CHA and HFM groups ($p<0.05$).

score while a* value affected the protein content as well. Interaction of breed and marbling score influenced L* a* and b* values ($p<0.05$). At MBS<3, L* and b* values were significantly different among breeds ($p<0.05$), but when MBS increased at score≥3, all breeds had no difference in L* and b* values (Fig.5-7). However, a* values were significantly different among breeds.

Beef with MBS≥3 had higher WHC than beef with MBS<3 (53.21 vs. 43.63%, respectively). Beef with MBS<3 showed higher cooking loss than beef with MBS≥3 (21.80 and 18.45%, respectively) ($p<0.05$). This result agreed with some research which reported that the cooking loss of Japanese black steers was significantly lower in the highest marbling score beef [25].

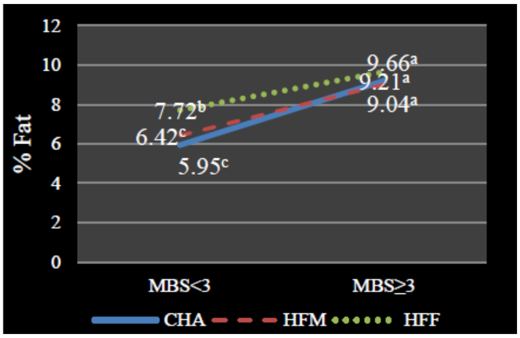

Fig. 1. Interaction of breed and marbling score on fat percentage.

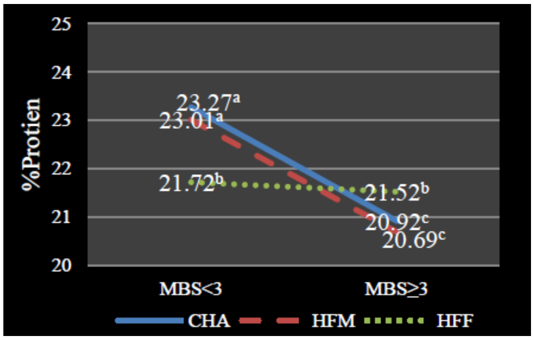

Fig. 2. Interaction of breed and marbling score on protein percentage.

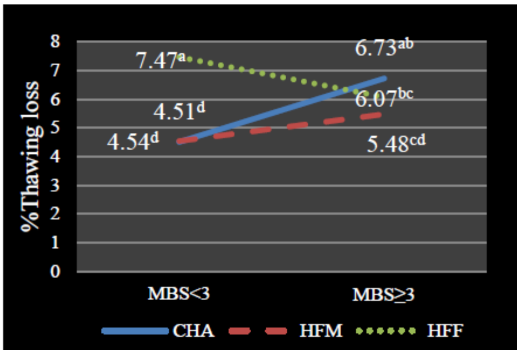

Fig. 3. Interaction of breed and marbling score on %Thawing loss.

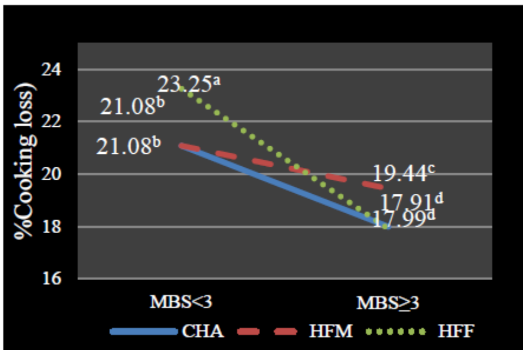

Fig. 4. Interaction of breed and marbling score on %Cooking loss.

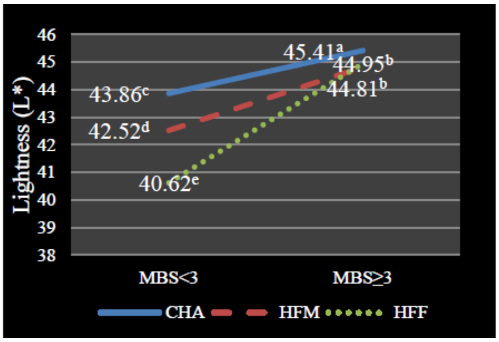

Fig. 5. Interaction of breed and marbling score on lightness (L*).

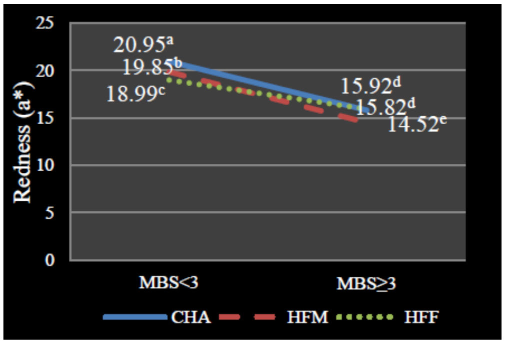

Fig. 6. Interaction of breed and marbling score on redness (a*).

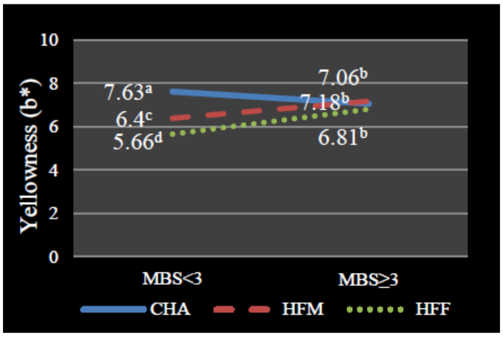

Fig. 7. Interaction of breed and marbling score on yellowness (b*) value.

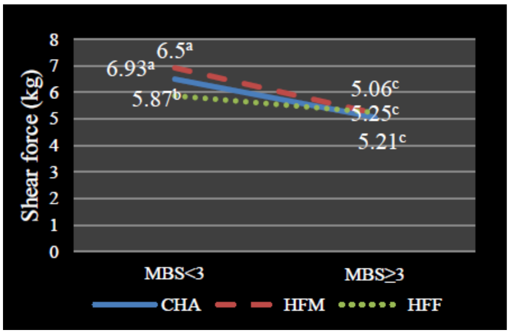

Fig. 8. Interaction of breed and marbling score on shear force value.

The interaction of breed and marbling score had an effect on thawing loss and cooking loss ($p<0.001$). Beef with MBS≥3 showed higher thawing loss and lower cooking loss than beef with MBS<3 as shown in Fig. 3-4. At MBS<3, HFF had higher thawing loss than the CHA and HFM groups. At MBS≥3, the HFM group showed the lowest thawing loss. This was similar to some research which revealed that the highly marbled beef showed less drip loss and cooking loss [26].

3.4 Warner-Bratzler shear force; WBSF

Breed, marbling score and interaction effects influenced WBSF ($p<0.05$). The HFF group had lower WBSF than the HFM group (5.56 and 6.07 kg, respectively) but there was no difference in WBSF between HFF and CHA (5.56 and 5.78 kg, respectively). For marbling score, beef with MBS≥3 had lower WBSF than beef with MBS<3($p<0.05$).Moreover, meat tenderness was affected by breed, gender, age and marbling score [27]. The intramuscular fat was the indicator of meat palatability since it would stimulate the secretion of saliva, causing a juicy feeling in the mouth [28]. Moreover, the interaction of breed and marbling score had an effect on WBSF as shown in Fig. 8. At MBS<3, the CHA and HFM groups had higher WBSF than the HFF group, but at MBS≥3. WBSF was not different among breeds (5.06-5.25 kg).

3.5 Fatty acid profile

Breed, marbling score, and interaction effects influenced fatty acid composition. The CHA and HFF groups had higher C10:0, C12:0, C14:0, C18:1n9c, C18:3n6, C18:3n3 than the HFM group ($p<0.05$), but the HFM group had greater C20:4n6 than the CHA and HFF groups ($p<0.05$). Beef from the CHA and HFF groups were distinguished by a saturate fatty acid (SFA), especially myristic acid (C14:0), palmitic acid (C16:0) and steric acid (C18:0).

Table 2. Meat Quality (pH value, color value, WHC (%), thawing loss (%), cooking loss (%), chemical composition (%) and WBSF (kg) from crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF).

Traits	Breed			SEM	Marbling degree		SEM	P-value		
	CHA (*n*=20)	HFM (*n*=20)	HFF (*n*=20)		MBS<3 (*n*=30)	MBS≥3 (*n*=30)		B	M	B*M
pH-value										
pH_{45min}	6.50^{b}	6.68^{a}	6.54^{b}	0.05	6.61	6.54	0.04	0.035	0.216	0.812
pH_{7day} (ultimate)	5.57	5.61	5.52	0.04	5.589	5.54	0.04	0.400	0.353	0.308
Color value										
Lightness (L*)	44.63^{a}	43.66^{b}	42.79^{c}	0.14	42.33^{b}	45.06^{a}	0.11	0.000	0.000	0.000
Redness (a*)	18.39^{a}	17.19^{b}	17.46^{a}	0.11	19.93^{a}	15.42^{b}	0.09	0.000	0.000	0.000
Yellowness (b*)	7.34^{a}	6.79^{b}	6.23^{c}	0.09	6.56^{b}	7.01^{a}	0.07	0.000	0.000	0.000
Water Holding Capacity (WHC)										
WHC (%)	48.19	50.49	46.57	1.33	43.63^{b}	53.21^{a}	1.08	0.153	0.000	0.145
Thawing loss (%)	5.62^{b}	5.01^{c}	6.77^{a}	0.27	5.51	6.09	0.22	0.002	0.082	0.001
Cooking loss (%)	19.54^{b}	20.26^{ab}	20.58^{a}	0.26	21.80^{a}	18.45^{b}	0.21	0.038	0.000	0.001
Chemical composition (%)										
Moisture	68.71	69.21	68.81	0.17	70.37^{a}	67.46^{b}	0.14	0.097	0.000	0.000
Protein	22.10^{a}	21.85^{b}	21.62^{b}	0.86	22.67^{a}	21.04^{b}	0.07	0.000	0.000	0.000
Fat	7.58^{b}	7.73^{b}	8.69^{a}	0.19	6.70^{b}	9.30^{a}	0.15	0.001	0.000	0.049
Textural parameter										
WBSF (kg)	5.78^{ab}	6.07^{a}	5.56^{b}	0.14	6.44^{a}	5.173^{b}	0.12	0.051	0.000	0.024

[a,b,c] Means with different superscripts are significantly different ($p<0.05$).
WBSF= Warner-Bratzler shear force

Moreover, the CHA and HFF groups also had notable MUFA content especially oleic acid. Oleic acid (C18:1n9c) was the main fatty acid in the intramuscular fat in cattle; it has been positively correlated with beef flavor and overall palatability [29,30]. In the part of PUFA, particularly γ-linolenic acid (C18:3n6), linolenic acid (C18:3n3) was distinguished in the CHA and HFF groups. Both MUFA and PUFA have efficacy to reduce cholesterol levels in the blood. However, the HFM group showed higher arachidonic acid (C20:4n6) than the CHA and HFF groups. Increased arachidonic acid content in adipose tissue has been associated with a higher risk of coronary artery disease [31]. The CHA group had the greatest PUFA-n3 and the HFM group had greater PUFA-n3 than the HFF group ($p<0.05$). The ratio of PUFA: SFA (P/S ratio), MUFA/SFA ratio and n-6/n-3 ratio of CHA were lower than those of the HFM and HFF groups ($p<0.05$). The P/S ratio and n-6/n-3 ratio are main nutritional indices which have implications for cancers and coronary heart disease, particularly the formation of blood clots leading to a heart attack [32,33]. The recommendation is that P/S ratio should be increased to above 0.4. Normally, the P/S ratio of beef was low at around 0.1, except for double-muscled animals which were very lean (<1% intramuscular fat) where P/S ratios were typically 0.5-0.7 [32]. However, this study showed that P/S ratio of all groups were lower (0.03-0.04) than the recommendation of Department of Health [32]. This might be because of old cattle (aged >3 years) in this study which meant age was an important factor affecting fatty acid composition.

Table 3. Fatty acid profiles of crossbred Charolais steers, fattening dairy steers and culled dairy cows with different breed and marbling degree.

Fatty acid profile (mg/g dry sample)	Breed			SEM	Marbling Score		SEM	P-value		
	CHA (*n*=20)	HFM (*n*=20)	HFF (*n*=20)		MBS<3 (*n*=30)	MBS≥3 (*n*=30)		B	M	B*M
SFA										
C10:0 Capric acid	0.08^{a}	0.05^{b}	0.07^{a}	0.006	0.06^{b}	0.07^{a}	0.01	0.006	0.023	0.527
C12:0 Lauric acid	0.20^{a}	0.14^{b}	0.19^{a}	0.012	0.13^{b}	0.22^{a}	0.01	0.012	0.000	0.213
C14:0 Myristic acid	5.29^{a}	3.92^{b}	4.88^{a}	0.196	3.99^{b}	5.40^{a}	0.16	0.001	0.000	0.020
C15:0 Pentadecanoic	0.36	0.34	0.35	0.036	0.31	0.38	0.03	0.905	0.108	0.011
C16:0 Palmitic acid	40.51^{a}	30.10^{b}	31.75^{b}	0.839	29.85^{b}	38.39^{a}	0.69	0.001	0.000	0.226
C18:0 Steric acid	16.35^{a}	10.96^{c}	13.91^{b}	0.702	12.41^{b}	15.06^{a}	0.57	0.001	0.007	0.276
C20:0 Arachidic acid	0.09^{a}	0.06^{b}	0.08^{ab}	0.008	0.05^{b}	0.09^{a}	0.01	0.043	0.001	0.006
MUFA										
C14:1 Myristoleic acid	1.32^{ab}	1.16^{b}	1.59^{a}	0.103	1.40	1.31	0.08	0.031	0.448	0.143
C16:1 Palmitoleic acid	5.93^{ab}	5.11^{b}	6.47^{a}	0.294	5.14^{b}	6.54^{a}	0.24	0.022	0.001	0.286
C17:1 Margaroleic	0.66^{b}	0.55^{b}	0.95^{a}	0.039	0.64^{b}	0.80^{a}	0.03	0.000	0.006	0.000
C18:1n9t Elaidic acid	1.02^{a}	0.78^{b}	1.15^{a}	0.080	0.83^{b}	1.14^{a}	0.07	0.018	0.006	0.074
C18:1n9c Oleic acid	46.54^{a}	36.91^{b}	43.71^{a}	1.411	37.66^{b}	47.11^{a}	1.15	0.001	0.000	0.267
C20:1 Gadoleic	0.14^{a}	0.09^{b}	0.09^{b}	0.008	0.12^{a}	0.10^{b}	0.01	0.004	0.008	0.005
C24:1 Nervonic acid	0.07^{b}	0.09^{ab}	0.10^{a}	0.008	0.10^{a}	0.07^{b}	0.01	0.033	0.007	0.068
PUFA										
C18:2n6t Linolelaidic acid	0.09	0.09	0.10	0.007	0.10	0.10	0.006	0.526	0.564	0.016
C18:2n6c Linoleic acid	1.35	1.09	1.30	0.092	1.13^{b}	1.37^{a}	0.075	0.170	0.038	0.094
C18:3n6 γ-Linolenic acid	0.06^{a}	0.02^{b}	0.05^{a}	0.006	0.04	0.05	0.005	0.002	0.795	0.167
C18:3n3 Linolenic acid	0.23^{a}	0.16^{b}	0.28^{a}	0.018	0.19^{b}	0.26^{a}	0.015	0.002	0.003	0.547
C20:3n6	0.19	0.15	0.16	0.012	0.16	0.18	0.010	0.072	0.222	0.396
C20:3n3	0.40^{a}	0.27^{b}	0.04^{c}	0.015	0.27^{a}	0.21^{b}	0.013	0.000	0.006	0.000
C20:4n6 Arachidonic acid	0.20^{b}	0.44^{a}	0.20^{b}	0.023	0.38^{a}	0.18^{b}	0.019	0.000	0.000	0.001
SFA	62.14^{a}	44.98^{c}	50.54^{b}	1.371	46.26^{b}	58.85^{a}	1.119	0.000	0.000	0.481
MUFA	53.79^{a}	43.18^{b}	51.72^{a}	1.553	44.21^{b}	54.92^{a}	1.268	0.001	0.000	0.227
PUFA	1.85	1.73	1.88	0.085	1.77	1.86	0.069	0.448	0.378	0.088
PUFA-n6	1.90	1.81	1.87	0.083	1.85	1.88	0.068	0.746	0.766	0.069
PUFA-n3	0.64^{a}	0.44^{b}	0.32^{c}	0.022	0.45	0.47	0.018	0.000	0.505	0.000
PUFA/SFA	0.03^{b}	0.04^{a}	0.04^{a}	0.001	0.04^{a}	0.03^{b}	0.001	0.002	0.002	0.741
MUFA/SFA	0.87^{a}	0.97^{a}	1.03^{a}	0.030	0.97	0.94	0.025	0.010	0.374	0.319
n6/n3	3.17^{c}	5.10^{b}	5.89^{a}	0.251	4.71	4.91	0.303	0.000	0.645	0.000

[a,b,c] Means with different superscripts are significantly different ($p<0.05$) between the breeds, marbling and interaction of them.
SFA = sum of C14:0, C16:0, C18:0; MUFA = sum of C14:1, C16:1, C18:1n9c; PUFA = sum of C18:2n6c, C18:3n6, C18:3n3, C20:4n6; n6= Sum of C18:2n6t, C18:2n6c, C18:3n-6, C20:3n-6, C20:4n6; n3= Sum of C18:3n-3, C20:3n

Moreover, the progress of age resulted in the increase of subcutaneous tissue and muscle fat contents while the ratio of P/S fatty acids declined [34]. The n-6/n-3 ratio of the CHA group was greater than those of the HFM and HFF groups ($p<0.001$; 3.169, 5.099, 6.169, respectively). The n-6/n-3 ratio less than 4 was considered to be optimum; however, n-6/n-3 ratio of beef was typically less than 3 [32]. The ratio of n-6/n-3 fatty acids of Holstein-Friesian in this study was similar to some research which reported that the ratio of n-6/n-3 of Holstein-Friesian was 7.085 [35]. Difference of fatty acid composition between breeds arose due to the difference of gene expression or enzymatic activity involved in fatty acid synthesis [36]. Marbling score influenced the fatty acid composition of beef ($p<0.05$). Beef with MBS≥3 had higher C10:0, C12:0, C14:0, C16:0, C18:0, C20:0, C16:1, C17:1, C18: 1n9t, C18:1n9c, C18:2n6c, C18:3n3, SFA and MUFA than beef with MBS<3 ($p<0.05$). Difference in fat content had an influence on fatty acid composition [36]. Specially, oleic acid (C18:1n9c), main fatty acid in the intramuscular fat of cattle and sheep showed positive correlation with cooked beef fat flavor [30]. The content of SFA and MUFA were increased with increasing fatness, leading to a decrease in the relative proportion of PUFA and P/S ratio. In addition, beef with MBS≥3 had lower C20:1, C24:1, C20:3n3, C20:4n6 and P/S ratio than MBS<3 groups ($p<0.05$). The level of fatness has an effect on the meat fatty acid composition, the content of SFA and MUFA fatty acids increase faster with increasing fatness than content of PUFA, resulting in a decrease in P/S ratio [36]. A high fat level of beef was more efficient in increasing P/S ratio.

The P/S ratio of beef with MBS≥3 was lower than that of beef with MBS<3. Furthermore, difference in the intramuscular fat percentage affected the P/S ratio which agreed with research reporting Korean Hanwoo beef (11.29%fat) had lower P/S ratio than Australian Angus beef (5.72%fat) (0.06 and 0.16, respectively) [37]. Beef had normally low P/S ratio compared with pork because of the bio-hydrogenation of unsaturated fatty acids in the rumen [36]. Hence, the P/S ratio of beef could be dropped to a value of 0.05 in fat breeds such as Wagyu breed and could be raised to more than 0.5 in very lean breeds such as double-muscled animals. The interaction of breed and marbling score had an effect on fatty acid composition of C14:0, C15:0, C20:0, C17:1, C20:1, C18:2n6t, C20:3n3, C20:4n6, PUFA-n3 and n6/n3 ($p< 0.05$). C14:0, C15:0, C20:0 were higher content in beef with MBS≥3 of the HFF group. Moreover, C17:1 in beef with MBS≥3 of the HFF group also was higher than the others. However, beef with MBS<3 of the HFM group had distinguished on C20:4n6. Beef with MBS≥3 and MBS<3 of the CHA group and beef with MBS<3 of the HFM group had superior PUFA-n3 and ratio of n-6/n-3 fatty acids.

3.6 Sensory evaluation

The preference scores of all breeds are presented in Table 4-5. The appearance, color, flavor and texture attributes of beef with MBS<3 did not show significant difference ($p>0.05$) among breeds. However, the CHA group tended to show a greater overall acceptability than the others ($p=0.051$). Beef with MBS≥3 had no difference among breeds in appearance, color, flavor, texture and overall acceptability ($p>0.05$). It is generally accepted that high intramuscular fat (IMF) content has a positive influence on the sensory qualities of beef [37]. In addition, increasing the amount of marbling in top loin steaks had a positive impact on the eating quality of beef [38].

Table 4. Sensory evaluation of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with less than marbling score 3 (MBS<3).

Attributes	Score (Mean±SD)			Kruskal–Wallis test (P-values)
	CHA	HFM	HFF	
Appearance	7.29±1.25	6.14±0.69	6.57±1.51	0.138
Color	7.29±1.60	6.14±0.90	6.71±1.60	0.156
Flavor	7.29±1.60	5.43±1.13	6.14±1.35	0.150
Texture	7.57±1.99	7.00±0.58	7.57±1.27	0.319
Overall acceptability	7.79±1.29	6.21±0.70	7.14±0.90	0.051

[abc] Mean value within the same row with different superscripts significantly ($p<0.05$) according to the Kruskal–Wallis test
Score: 1= Dislike extremely, 9 =like extremely

Table 5. Sensory evaluation of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with more than or equal marbling score 3 (MBS≥3)

Attributes	Score (Mean±SD)			Kruskal–Wallis test (P-values)
	CHA	HFM	HFF	
Appearance	7.00±1.15	6.57±0.53	6.71±0.76	0.841
Color	6.71±1.11	7.00±0.82	6.43±1.27	0.716
Flavor	7.57±0.96	7.00±0.82	7.00±1.41	0.529
Texture	6.29±1.80	7.29±0.49	7.29±0.95	0.301
Overall acceptability	6.57±1.72	7.00±0.82	7.57±0.79	0.360

[abc] Mean value within the same row with different superscripts significantly ($p<0.05$) according to the Kruskal–Wallis test
Score: 1= Dislike extremely, 9 =like extremely

4. Conclusion

It could be concluded that culled dairy cows had inferior carcass quality compared to Charolais steers and dairy steers. Dairy cows had lower carcass weight and carcass percentage compared to Chalorais steers, but Holstein steers had greater rib-eye area than Holstein cows. Interestingly, dairy steers had better carcass weight dressing percentage; meanwhile, dairy cows had superior marbling scores. However, beef of culled dairy cows with marbling scores up to score 3 had no difference in meat color, fat and protein contents in meat, shear force value, and sensory acceptability compared to the others Dairy steers even had greater carcass weight and percentage, but they had to be fattened for 10-12 months. However, a shorter fattening period of 4-5 months will be considered for lower cost of production in culled dairy cows. Therefore, culled dairy cows could be an alternative for producing high quality beef, especially with marbling scores more than 3.

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