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Association between dairy meat quality with gender, slaughter age, and marbling score, and relationships among the meat quality traits

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Abstract Gender of dairy cattle did not influence all studied traits (P>0.05). Age at slaughter did not influence the most meat traits, except L* value (P<0.05). Meat from the oldest animals, ≥5 yr old, exhibited significantly lower L* value than the younger animals, 2, and 3 yr old (P<0.05). Marbling score significantly affected traits (P<0.05), except pH, a* and b* color values (P>0.05). The muscle obtained higher marbling scores had more dry matter and ether extracted (intramuscular fat content). Increased marbling score was related to decrease shear force. The lightness of muscle with the highest marbling score had the highest mean L* =52.8. There was strongly positive correlated between %DM and %EE (r= 0.91, P<0.01). The positive relationships between %EE, and L* and b* were found. Shear force was positively correlated with cooking loss (P<0.01), but it was negatively related to L* (P<0.01).

Keywords: Dairy beef, Marbling score, Meat quality, Intramuscular fat content

Introduction

Number of beef cattle in Thailand in the year 2021 was 7.6 million heads. Beef production mostly supplied local consumers, which the product was consumed yearly about 2.89 kilogram (DLD, 2021). However, some beef production was imported. Thus, Thai government plans to increase the amount of cattle via insemination of dairy heifers with beef cattle semen. An others hand, using dairy cattle be used to boost beef production, although, some consumers have a negative image of meat from dairy cattle compared to beef cattle. The production factors, that affect final beef quality are the animal breed, sex, age at slaughter and diet (Serra *et al.*, 2008). The cattle breed influences the growth rate, the amount of muscle tissue and meat quality (Picard *et al.*, 2002). Some studies of different bovine breeds

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have shown that the quality of dairy beef and cattle beef meats did not show differences between breeds (Christensen *et al.*, 2011; Lizaso *et al.*, 2011). Jurie *et al.* (2007) reported that meat tenderness did not differ between dairy bred and beef bred cull cows slaughtered at the same age and fat score, while meat from cull cows showed different tenderness depending on muscle types. The culled dairy cows had inferior carcass quality, compared to Charolais steers and dairy steers, and their beef did not differ in color, fat and protein content, shear force value or sensory acceptability, compared to the others, when beef had a marbling score up 3. Therefore, culled dairy cows with marbling scores greater than 3 could be an alternative for producing high quality beef (Chainam, 2019). Since meat from dairy and beef breeds had little quality difference, so dairy beef had the potential to supply the beef sought by consumers in Thailand. There are three sources of dairy beef: heifers, cull cows and steers, which are slaughtered at different ages. Nevertheless, only limited study had measured the differences of dairy meat quality between gender, age at slaughter, and marbling score. This study measured the differences in meat quality between the minimum 75 % Holstein Friesian dairy steers (male) and culled animals (heifers and cows, female) and also among ages at slaughter and marbling scores. Therefore, meat quality consists of chemical composition, physical and biological properties of beef have to be compared with gender, slaughter age, and marbling score. The objectives were to study the association between dairy meat quality with gender, slaughter age, and marbling score and to study the relationships among the meat quality traits.

Materials and methods

Animals and samples

During 2019-2020, many dairy steers and culled dairy heifers and cows (minimum 75 % Holstein Friesian blood) were raised by the members of Beef Cluster Cooperative Ltd, in Nakhon Pathom and Chiang Mai Province. They had minimum 75 % Holstein Friesian blood. The dairy steers (male) and culled animals (heifers and cows) were raised and intensively fattened, with 14% crude protein concentrate, and were supplied with fresh grass, hay, fermented cassava, pineapple by-products (which varied from farm to farm) for 4 to 6 months, until their live weight reached approximately 500 to 700 kg. They were then transported to the commercial slaughterhouses in Ratchaburi and Chiang Mai Province. They received at libitum of water without feeding for 10 to 12 h before slaughter. Age was assessed by identifying and counting their permanent incisor teeth: the first pair appeared at 1½ to 2 years old, the second pair at 2½ to 3 years, the third pair at 3½ to 4 years old and the fourth pair at 4½ to 5 years (Taylor, 1984). However, for this study the fourth pair is 4½ to ≥ 5 years old.

The animals were stunned with a captive piston pistol and then slaughtered. After removing head, skin, internal organs and hoofs, each carcass was cleaned and then halved. Data from 90 fattened dairy steers and culled dairy heifers or cows were collected as samples. The carcasses were aged approximately 7 days in a 2 to 4 ℃ chill room. At the seventh day, the left side of carcass was cross-sected between the ribs 12 to 13. The longissimus dorsi (LD) muscle was used to assess the five levels marbling score, following the Thai Agricultural Commodity and Food Standard (TACFS) 6001-2004 (ACFS, 2004). Before measuring the color, the LD muscle was allowed to bloom, i.e., exposed to oxygen in the air, for 30 min, after that pH was measured. Then the LD samples, approximately 0.5 kg, were removed, vacuum-packed and stored at −20 °C for further analysis.

After the meat samples were thawed, they were trimmed free of all visible fat, and cut into two, more than 30 mm thick, samples. The first sample was used for cooking loss and Warner-Bratzler shear force analysis. The second sample was ground and used for analysis of dry matter, ash, and fat content of muscle, determined following AOAC (2005) methods.

Measurement of meat quality

Color

The L*, a* and b* in the CIELAB color space were measured on the left side of ribe eye area with a Chroma Meter (CR-400, Minolta Co., Ltd., Suita-shi, Osaka, Japan) in triplicate.

pH

The pH was measured in duplicate directly using a pH meter equipped with a spear tip glass electrode (Model SG2 - ELK Seven Go™, Mettler Toledo International Inc., China).

Cooking loss and shear force

For cooking loss and shear force measurement, two slices of approximately 30 mm thick, from LD, were weighed, placed in a high density polyethylene bag, heat sealed and then cooked in a water bath set at 80 ℃ for 30 min or until the internal sample temperature reached 70 ℃. After cooking, samples were cooled with running tap water to room temperature. Then the cooked sample were weighed again. Ten $10\times20\times10$ mm^3 cuts, in each cooking loss sample, were removed from across the slice parallel to the muscle fiber. Each cut was sheared once, perpendicular to the muscle fiber, using a Warner-Bratzler shear head attached to a single column Texture Analyzer Machine (Model EZSX, Shimadzu, Japan), equipped with a 50 kg load cell, using a 50 mm/min crosshead speed. The cooking loss was calculated from the difference between before and after cooking mass divided by sample mass before cooking and reported as a percentage.

Statistical analysis

Meat quality traits measured were chemical composition; percent dry matter, crude ash and ether extract as intramuscular fat content, cooking loss and shear force value, pH, and color (L*, a*, b*). Distributions of the studied traits data were reported as mean, standard deviation, minimum and maximum. General linear model was used to analyze the influence of gender, age at slaughter, marbling score, and slaughter weight on the studied traits, as shown in the following statistic model.

$$Y_{ijk} = \mu + G_i + A_j + MS_k + \beta\left(SWT_{ijk} - \overline{SWT}\right) + \varepsilon_{ijk}$$

where the Y_{ijk} were studied traits, μ was overall mean, G_i was a fixed effect of gender i (i=1, 2), A_j was fixed effect of age j (j= 2, 3, 4, ≥5 yr. old), MS_k was a fixed effect of marbling score (k= 1, 2, 3, 4, 5), β was regression coefficient of the studied traits to the slaughter weight, SWT_{ijk} was the slaughter weight of the animal k in each gender group i and in each age group j, $\overline{SWT}$ was mean of slaughter weight, and e_{ijk} was a random effect of the observation Y_{ijk}.

Pdiff option was used to compare differences of the least squares means (LSM). Pearson product-moment correlations were calculated for the relationship between the marbling score and the meat quality traits (SAS, 1999).

Results

Data distribution

Result showed the data distribution of the meat quality traits from dairy beef. The ether extract or intramuscular fat content, as fresh basis, in *longissimus dorsi* muscle ranged between 1.0 to 27.2 %, with the average of 7.3%. Meat tenderness, as a Warner-Bratzler shear force, ranged between 2.4 to 9.8 kgF, with the mean 4.8 kgF. Mean color was L* = 40.7, a* = 22.5, and b* = 11.3 (Table 1).

Factors affecting meat quality traits

The factors of gender, age at slaughter and marbling score affecting the meat quality traits are shown in Table 2. Gender of the dairy cattle did not affect all the studied traits ($P<0.05$). Age at slaughter had not influenced the meat quality traits (P>0.05), except the L* value (P<0.05). While the marbling scores significantly affected almost of the studied traits (P<0.05), except pH and both a*, and b* color values (P>0.05).

Table 1. Meat quality traits

Traits	n	Mean	S.D.[3/]	Minimum	Maximum
Dry matter (%)[1/]	90	33.44	4.10	24.43	45.85
Crude ash (%)[1/]	90	1.03	0.18	0.64	1.56
Ether extract (%)[1/2/]	90	7.31	5.58	0.95	27.16
Shear force (kgF)	88	4.79	1.53	2.35	9.76
Cooking loss (%)	88	22.41	4.95	12.45	35.36
pH	87	5.54	0.37	4.44	6.33
L*	84	40.70	4.07	32.06	51.61
a*	85	22.53	2.61	16.04	28.78
b*	85	11.33	2.10	6.60	15.61

[1/]: As fresh basis, [2/]: Intramuscular fat content, [3/]: Standard Deviation

Table 2. P-values of the factors influenced the traits studied

Studied traits	Adjusted			
	Gender	Age	MS	R^2
Dry matter (%)	.565	.898	.000	0.582
Crude ash (%)	.058	.103	.010	0.280
Ether extract (%)	.811	.615	.000	0.680
Shear force (kgF)	.347	.329	.000	0.291
Cooking loss (%)	.116	.678	.019	0.173
pH	.652	.827	.163	0.103
L*	.457	.012	.000	0.487
a*	.093	.096	.386	0.161
b*	.333	.118	.230	0.269

[1]: Slaughter weight as covariable

The effect of gender

Least squares mean (LSM) and standard error (SE) of each trait in each gender is shown in Table 3. Although gender of animal did not influence the meat quality traits (P>0.05), percentage of crude ash from female meat trended to be higher than those from male meat, 1.05 and 0.96 percent, respectively. Likewise, the a* value mean of the female meat trended to be higher than those of male (23.7 and 22.5, respectively).

Table 3. Gender influenced the studied traits (LSM±SE)

Trait	Gender	
	Female (n1=55)	**Male (n2=35)**
Dry matter (%)	36.90±0.89	36.43±0.84
Crude ash (%)	1.05±0.05	0.96±0.05
Ether extract (%)	11.70±1.06	11.47±1.00
Shear force (kgF)[1/]	4.00±0.43	3.62±0.42
Cooking loss (%)[1/]	21.84±1.49	19.63±1.46
pH[2/]	5.74±0.12	5.69±0.11
L*[3/]	44.17±0.98	43.50±0.93
a*[4/]	23.71±0.80	22.46±0.76
b*[4/]	11.56±0.60	12.11±0.57

[1/] n1=54, n2=34; [2/] n1=50, n2=37; [3/] n1=48, n2=36; [4/] n1=49, n2=36

The effect of slaughter age

Muscle from the youngest animal, 2 yr old had higher the lightness value (L*) than that of the oldest animal, ≥5 yr old ($P<0.05$), but did not differ from the 3 and the 4 yr old animals, as shown in Table 4.

Table 4. Age at slaughter effecting to the studied traits (LSM±SE)

Studied traits	Age (yrs.)			
	2 (n1=3)	**3 (n2=12)**	**4 (n3=18)**	**≥5 (n4=57)**
Dry matter (%)	36.58±1.79	36.76±1.06	36.97±0.87	36.35±0.69
Crude ash (%)	1.14±0.10	1.02±0.06	0.94±0.05	0.91±0.04
Ether extract (%)	10.21±2.12	11.38±1.26	12.10±1.04	12.63±0.82
Shear force (kgF)[1]	4.00±0.86	3.98±0.53	3.28±0.44	3.99±0.34
Cooking loss (%)[1]	21.55±3.02	20.73±1.84	21.10±1.52	19.54±1.18
pH[2]	5.77±0.24	5.71±0.14	5.73±0.12	5.64±0.09
L*[3]	46.61±1.96[a]	44.49±1.16[a]	42.86±1.03[ab]	41.37±0.76[b]
a*[4]	24.93±1.61	23.70±0.95	21.82±0.82	21.90±0.62
b*[4]	12.58±1.21	12.64±0.72	10.89±0.62	11.24±0.47

[1]: n1 to n4 were 3, 11, 17, and 57; [2]: n1 to n4 were 3, 12, 16, and 56; [3]: n1 to n4 were 3, 12, 14, and 55; [4]: n1 to n4 were 3, 12, 15, and 55, respectively.
[ab]: The different letter in the same row is significantly different in statistic ($P<0.05$).

The effect of marbling score

The *Longissimus dorsi* muscle, that the highest marbling score (MS) level 5 had significantly higher % dry matter, and % ether extract (intramuscular fat content) than those obtained from MS level 1, 2, 3, and 4

(Table 5). In contrast, the muscle obtained from MS level 1 and 2 had significantly higher % crude ash than those of the MS level 5 but did not differ from those obtained from MS level 3 and 4. The muscle with MS level 3, 4 and MS 5 had lower shear force trait than those with MS level 1 and MS 2. The highest % cooking loss was found in the muscle obtained from MS level 1 with the average of 25.96 %. The highest L* value was detected in the LD obtained from MS level 5, with the average of 52.76 %, while the lowest L* value was observed in the muscle obtained from MS level 1 (39.48).

Table 5. Marbling score influenced the studied traits (LSM±SE)

Studied	**Marbling score**				
traits	**1 (n1=13)**	**2 (n2=50)**	**3 (n=23)**	**4 (n4=2)**	**5 (n5=2)**
DM (%)	29.74±0.98^{d}	32.34±0.55^{c}	36.68±0.73^{b}	39.30±2.11^{b}	45.27±2.06a^{a}
CA (%)	1.15±0.06^{a}	1.11±0.03^{a}	1.01±0.04^{ab}	0.93±0.12^{ab}	0.82±0.12^{b}
EE (%)	1.47±1.16^{d}	4.67±0.65^{c}	11.26±0.87^{b}	16.10±2.51^{b}	24.41±2.45^{a}
SF (kgF)[1]	5.56±0.47^{a}	5.00±0.27^{a}	3.87±0.37^{b}	2.59±1.03^{b}	2.04±1.00^{b}
CL (%)[1]	25.96±1.66^{a}	22.84±0.94^{b}	22.04±1.30^{bc}	15.64±3.61^{c}	17.18±3.51^{bc}
pH[2]	5.58±0.13	5.52±0.07	5.67±0.10	6.16±0.28	5.63±0.27
L*[3]	39.48±1.08^{c}	41.59±0.63^{b}	45.00±0.87^{b}	40.33±2.33^{bc}	52.76±2.28^{a}
a*[4]	23.80±0.88	22.91±0.51	24.14±0.71	21.97±1.91	22.62±1.87
b*[4]	11.53±0.67	11.53±0.38	12.68±0.53	10.79±1.44	12.65±1.40

DM: Dry matter, CA: Crude ash, EE: Ether extract, SF: Shear force value, CF: Cooking loss;
abcd: The different letter in the same row is significantly different in statistic (P<0.05).
[1]: n1 to n5 were 13, 51, 20, 2, and 2; [2]: n1 to n5 were 13, 50, 20, 2, and 2; [3]: n1 to n5 were 13, 49, 18, 2, and 2; [4]: n1 to n5 were 13, 50, 18, 2, and 2, respectively.

The relationship among meat quality traits

It presented the correlation coefficients of the meat quality characteristics. There was strongly positive correlated between %DM and %EE (intramuscular fat content) with the correlation coefficient (r) of 0.91 (P<0.01) (Table 6). The positive relationships between %EE, and L* (P<0.01) with r = 0.43, and b*(P<0.05) with r = 0.28, were found. The shear force value (SF) had positively correlated with the %Ash and %CL (P<0.01), but it had negative relationship with the %DM, %EE, L* value (P<0.01). This result showed that there was no correlated between pH value and all the traits studied (P>0.05). The L* value had positively related to the a* and b* with the coefficients of 0.25 and 0.29, respectively (P<0.05 for a* and P<0.01 for b*), while there was positive correlated between the a* and b*values (P<0.01).

Table 6. Correlation coefficients of marbling score and the meat quality traits

Traits	**%DM**	**%Ash**	**%EE**	**SF**	**%CL**	**pH**	**L***	**a***	**b***
MS[4/]	0.75**	-0.38**	0.79**	-0.49**	-0.32**	-0.01^{ns}[3/]	0.55**	-0.00^{ns}	0.20^{ns}
%DM[5/]	1	-0.36**	0.91**	-0.48**	-0.25*[2/]	0.12^{ns}	0.39**	0.02^{ns}	0.30**
%Ash		1	-0.42**	0.32**	0.41**	0.09^{ns}	-0.02^{ns}	0.06^{ns}	-0.44**
%EE[6/]			1	-0.44**	-0.25*	0.17^{ns}	0.43**	0.04^{ns}	0.28*
SF[7/]				1	0.41**	-0.08^{ns}	-0.30**	-0.09^{ns}	-0.06^{ns}
%CL[8/]					1	-0.01^{ns}	-0.25*	-0.04^{ns}	-0.34**
pH						1	0.12^{ns}	0.17^{ns}	-0.13^{ns}
L*							1	0.25*	0.29**
a*								1	0.45**

[1/] P<0.01, [2/] P<0.05, [3/]Nonsignificant difference, [4/] Marbling score, [5/] % Dry matter, [6/] %Ether extract or intramuscular fat content, [7/] Shear force value, [8/] %Cooking loss

Discussion

Both intrinsic and extrinsic factors influenced beef characteristics. Gender of cattle (an intrinsic factor) is an ante mortem factor and impacts beef quality. Many previous studies reported that steers and heifers of beef type produced better meat quality traits than bull (Frickh *et al.,* 2003; Velik *et al.,* 2008), while meat from heifers was more tender than steer (Bass *et al.,* 2010). Zhang *et al.* (2010), who studied in Qinchuan cattle, beef type, reported that males (both intact and castrated) had higher % ash content and % cooking loss than females. Węglarz (2010) found the significant effect of cattle category (bull, steer, heifer, and cows) to the pH, L*, a*, and b*. The researcher reported that the brightest red meat (L*) was obtained from heifers and the darkest from cows, and the highest values of a* and b* were found in bulls. In contrast to our study, we found that there was not significant difference between dairy females and males meat quality. This may be because of the mentioned studies investigated in draft breed cattle (Qinchaun) and crossbreds beef cattle. Karnjanasirm *et al.* (2019) studied the meat quality in Holstein Friesian steers in Thailand, reported the average of % cooking loss and of the a* value was 35.77 and 14.50, respectively, compared to our results from males that the average of % cooking loss was 16 % lower, and the average of redness value was 7.8 higher than those reported. This indicated that extrinsic factors, especially feeding management influenced the studied traits.

Meat color (lightness, L* and redness, a*) is controlled by concentration and chemical stage of myoglobin pigment in the meat surface, which generally differing in muscle, species, and animal age (Warner, 2014). Sukjai *et al.* (2012) found that there was no significant difference in the meat traits from the cull dairy cows slaughtered at different age, similarly to our results, which slaughtered age did not affect most of the traits studied, except the L* value (P<0.05). Meat from younger animals (2 and 3 yr old) was significantly brighter (46.6 and 44.5) than that from the ≥5 yr old animals (41.4), but it did not differ from 4 yr old animal (42.9). The reason is the young animal have less muscle myoglobin (Warner, 2014).

Slaughter age influenced dairy beef quality was also found by Pateiro *et al.* (2012) who reported that the average of %ash, % cooking loss, and index of red color (a*) from Holstein-Friesian cull cows with 5 yr old were 2.07, 22.51, and 20.56, respectively, which were similar results of females in our study, 1.06, 22.02, and 23.90, respectively.

Marbling score is an important criterion for setting carcass price couple with carcass weight. The higher marbling scores, the more extra money which the farmers can benefit. Results showed that the MS highly significantly influenced almost of the studied traits (P<0.01), except pH, the a* and b* color values (P>0.05). When assessing meat, the marbling score, and the L* value in the CIE Lab space were expected to be strongly correlated (r=0.55) because L* measures 'lightness' or white color and would be increased by the presence of large amounts of white fat visible in a sample. Warner-Bratzler shear force of the longissimus muscle which obtained from MS level 5 and 4 were lower than those which obtained from MS level 1 and MS 2. These indicated marbling score had significantly impacted tenderness of the dairy beef. The similar result also was found in the relationship study, the higher marbling score, the lower shear force value (r= -0.49, P<0.01). Percentage of dry matter, % ether extract (% intramuscular fat content) and the L* increased with the increasing of marbling, while % crude ash, Warner-Bratzler shear force value, and % cooking loss decreased with the marbling score increasing. Our results agreed with Kim and Lee (2003) and Li *et al.* (2006) who studied in the beef cattle. It is interested that the L* color value of the muscle obtained from MS level 5 was the highest with the average of 52.53. The reason might be the highest intramuscular fat content, reflected the meat color to be brighter.

Although the factors of gender, age at slaughter, and marbling score in our study, had significantly affected some meat quality, however, the adjusted R-squared (Adjusted Coefficient of Determination) of the models were varied from 0.103 to 0.680. The Adjusted R-squared was a measure of "goodness of fit" for the models (Panik, 2012). It represented the proportion of variation in dependent variable (Y) that can be explained by linear influence of factor (X). The Adj. R-squared of % dry matter and % ether extract traits were moderate (0.582 and 0.680, respectively), while the Adj. R-squared of the pH, a*, and b* were quite low level (0.103, 0.161, and

0.269, respectively). It means that the traits of pH, a*, and b*, especially the pH was not explained by the studied factors. Therefore, other independent variables should be added into those statistic models.

Besides the studied intrinsic factors (gender, age at slaughter and marbling score), the breeds or crossbreed, genetic aspect, and weight at slaughter and the extrinsic factors such as management, diet, physical and chemical characteristic of diet, pre-and post-slaughter conditions, which influenced meat quality from ruminant (Guerrero *et al.*, 2013) should be considered.

In summary, marbling score was the most important factor, more important than gender and slaughter age: it significantly affected chemical composition, tenderness, and the lightness of dairy beef, whereas it did not affect pH after aging, redness, and yellowness of meat.

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