CARCASS CHARACTERISTICS, MEAT QUALITY AND EATING QUALITY OF CULLED DAIRY COWS

JARUNAN CHAINAM

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN ANIMAL SCIENCE
GRADUATE SCHOOL, MAEJO UNIVERSITY
2019

CARCASS CHARACTERISTICS, MEAT QUALITY AND
EATING QUALITY OF CULLED DAIRY COWS

JARUNAN CHAINAM

THIS DISSERTATION HAS BEEN APPROVED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
IN ANIMAL SCIENCE

APPROVED BY

Advisory Committee

Chair ..... Yanin Opat.
(Associate Professor Dr. Yanin Opatpatanakit)
20 / Feb / 2019

Committee ..... Siriporn K
(Associate Professor Dr. Siriporn Kiratikarnkul)
20 / Feb / 2019

Committee ..... Rong-Shinn Lin
(Professor Dr. Rong-Shinn Lin)
20 / Feb / 2019

Committee ..... Kiatbenjakul P.
(Dr. Patthamawadi Kiatbenjakul)
20 / Feb / 2019

Program Chair, Doctor of Philosophy in
Program Animal Science ..... Yanin Opat.
(Associate Professor Dr. Yanin Opatpatanakit)
20 / Feb / 2019

CERTIFIED BY GRADUATE SCHOOL ..... K Meng
(Associate Professor Dr. Kriangsak Mengamphan)
Dean of Graduate School
25 / Feb / 2019

ชื่อเรื่อง ลักษณะซาก คุณภาพเนื้อ และคุณภาพการบริโภคของโคนมคัดทิ้งขุน

ชื่อผู้แต่ง นางสาวจารุนันท์ ไชยนาม

ชื่อปริญญา ปรัชญาดุษฎีบัณฑิต สาขาวิชาสัตวศาสตร์

อาจารย์ที่ปรึกษาหลัก รองศาสตราจารย์ ดร.ญาณิน โอภาสพัฒนกิจ

บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อศึกษาผลของระบบการขุนโค และเพศต่อลักษณะซากของโคนม และศึกษาเปรียบเทียบลักษณะซาก คุณภาพเนื้อ และการประเมินทางประสาทสัมผัสของโคนมคัดทิ้งกับโคนมเพศผู้ขุน และโคขุนลูกผสมสายพันธุ์ชาโรเลส์ การศึกษาครั้งนี้แบ่งออกเป็น 2 การทดลอง การทดลองที่ 1 ศึกษาศักยภาพของโคนมคัดทิ้ง โดยศึกษาข้อมูลซากโค จำนวน 307 ตัว ผลการศึกษาพบว่าเกษตรกรส่วนใหญ่รับซื้อแม่โคนมจากพ่อค้าคนกลาง ซึ่งไม่มีประวัติของพ่อและแม่ จึงทำให้ไม่ทราบข้อมูลระดับสายเลือดของแม่โค อย่างไรก็ตามพบว่า ส่วนใหญ่โคนมคัดทิ้งมีระดับสายเลือดโฮลสไตน์ฟรีเซี่ยน 87.5% โดยสาเหตุของการคัดทิ้งส่วนใหญ่คือ ปัญหาการสืบพันธุ์ เช่น การผสมไม่ติด ปริมาณผลผลิตน้ำนมต่ำ และปัญหาโรคเต้านมอักเสบ ทั้งนี้โคนมคัดทิ้งถูกนำไปขุน 4-5 เดือน จนได้น้ำหนัก 450-600 กิโลกรัม ด้วยสูตรอาหารสำหรับโครีดนม โดยมีสัดส่วนอาหารข้นและอาหารหยาบเท่ากับ 70:30 ซึ่งอาหารข้นมีระดับโปรตีน 24% จำนวน 2.5-3.0 กิโลกรัมต่อตัวต่อวัน และแหล่งอาหารหยาบ ได้แก่ ผลพลอยได้จากสับปะรดหรือข้าวโพด และอาจเสริมด้วยกากปาล์ม ผลการศึกษาพบว่าลักษณะซากของโคนมคัดทิ้งมีอายุเฉลี่ย 4.58±0.73 ปี, คะแนนโครงร่างเฉลี่ย 3.52±0.61 และคะแนนไขมันแทรกเฉลี่ย 2.72±0.83 น้ำหนักมีชีวิตของโคนมคัดทิ้งเฉลี่ยเท่ากับ 581.11±66.73 กิโลกรัม ซึ่งค่าเฉลี่ยน้ำหนักซากอุ่น น้ำหนักซากเย็น และน้ำหนักหนัง เท่ากับ 313.70±38.91, 312.22±38.29 และ 36.94±6.29 กิโลกรัม ตามลำดับ เปอร์เซ็นต์ซากอุ่นและเปอร์เซ็นต์ซากเย็นเท่ากับ 53.99 และ 52.64% ตามลำดับ

นอกจากนี้ยังศึกษาผลของน้ำหนักเข้าฆ่าและเพศต่อลักษณะซากของโคนม โดยใช้ข้อมูลในปี 2557-2559 จำนวน 520 ตัว โดยเป็นโคนมคัดทิ้งจำนวน 412 ตัว (อายุมากกว่า 4 ปี และน้ำหนักเข้าฆ่าเฉลี่ย 580.85±3.76 กิโลกรัม) ถูกนำมาเลี้ยงขุนด้วยอาหารข้นและอาหารหยาบเป็นระยะเวลา 4-5 เดือน และโคนมเพศผู้ขุนจำนวน 108 ตัว (อายุมากกว่า 2 ปี และน้ำหนักเข้าฆ่าเฉลี่ย 584.45±7.33 กิโลกรัม) ถูกเลี้ยงขุนเป็นระยะเวลา 10-12 เดือน ผลการศึกษาพบว่าน้ำหนักเข้าฆ่าของโคนมคัดทิ้งไม่มีผลต่อเปอร์เซ็นต์ซากอุ่นและเปอร์เซ็นต์ซากเย็น ($p>0.05$) แต่มีอิทธิพลต่อน้ำหนักซากอุ่น น้ำหนักซากเย็น

น้ำหนักหนัง เปอร์เซ็นต์น้ำหนักหนัง น้ำหนักเสี้ยวหน้า และน้ำหนักเสี้ยวหลัง ($p<0.05$) นอกจากนี้ น้ำหนักมีชีวิตของโคนมคัดทิ้ง พบว่า มีความสัมพันธ์เชิงบวกกับน้ำหนักซากอุ่นและซากเย็น ($r=0.954$ และ 0.936, $p<0.001$) ตามลำดับ น้ำหนักเข้าฆ่าของโคนมเพศผู้ขุนที่มากกว่า 650 กิโลกรัม พบว่า มีคะแนนไขมันแทรกสูงกว่าทั้งสองกลุ่ม (2.05, 1.33 และ 1.68; $p<0.001$) ตามลำดับ อย่างไรก็ตาม น้ำหนักซากอุ่น น้ำหนักซากเย็น เปอร์เซ็นต์ซากอุ่น และเปอร์เซ็นต์ซากเย็นของโคนมเพศผู้ขุนมีค่าสูงกว่ากลุ่มโคนมคัดทิ้ง ($p<0.05$) แต่พบว่า คะแนนไขมันแทรกของโคนมคัดทิ้งมีคะแนนสูงกว่ากลุ่มโคนมเพศผู้สูง (1.85 vs 1.59; $p<0.01$)

การทดลองที่ 2 ศึกษาลักษณะซาก คุณภาพเนื้อ และการทดสอบทางประสาทสัมผัสของแม่โคนมคัดทิ้ง (HFF) และโคนมเพศผู้ขุน (HFM) เปรียบเทียบกับโคขุนลูกผสมสายพันธุ์ชาโรเลส์ (CHA) โคนมเพศผู้ตอนหรือแม่โคนมคัดทิ้ง จำนวนกลุ่มละ 20 ตัว โดยมีระดับคะแนนไขมันแทรกแตกต่างกัน 2 ระดับ (MBS<3 และ MBS≥3) พบว่าอิทธิพลของสายพันธุ์มีผลเชิงบวกต่อลักษณะซาก กลุ่ม CHA มีน้ำหนักซากและเปอร์เซ็นต์ซากสูง อย่างไรก็ตาม กลุ่ม HFF มีพื้นที่หน้าตัดเนื้อสันน้อยที่สุด ในกลุ่ม MBS≥3 พบว่าค่าความสว่าง (L*) และ ค่าสีเหลือง (b*) ไม่มีความแตกต่างระหว่างสายพันธุ์ อย่างไรก็ตาม กลุ่ม CHA และ HFF พบว่ามีค่าสีแดง (a*) สูงกว่ากลุ่ม HFM ส่วนในกลุ่ม MBS<3 พบว่า ค่าการสูญเสียระหว่างการรักษา (%thawing loss) ของ HFF มีค่าสูงกว่ากลุ่มอื่น ในทางตรงกันข้าม ค่าการสูญเสียระหว่างการรักษาของ CHA และ HFM มีเปอร์เซ็นต์สูงขึ้นเมื่อระดับไขมันแทรกสูงขึ้น ส่วนเปอร์เซ็นต์การสูญเสียหลังทำสุก (%cooking loss) มีค่าลดลงเมื่อคะแนนไขมันแทรกสูงขึ้น ขณะที่ปริมาณความชื้นโปรตีน และค่าแรงตัดผ่านมีค่าลดลง เมื่อมีระดับไขมันแทรกมากกว่า 3 นอกจากนี้พบว่าค่าแรงตัดผ่านไม่มีความแตกต่างกันระหว่างกลุ่มทดลองที่มีระดับไขมันแทรกมากกว่า 3 การให้คะแนนไขมันแทรกด้วยการประเมินเทคนิคการประมวลผลด้วยภาพ (IMG1) มีความสัมพันธ์เชิงบวกกับการประเมินด้วยสายตามนุษย์ (VIS) ($r=0.708$, $p<0.01$)) นอกจากนี้ การประเมินคะแนนไขมันแทรกด้วยสายตามนุษย์ (VIS) และเปอร์เซ็นต์ไขมัน พบว่ามีความสัมพันธ์เชิงบวกด้วยเช่นกัน ($r=0.675$, $p<0.01$) กลุ่มเนื้อโคสุกของ CHA และ HFF มีปริมาณกรดไขมัน SFA และ MUFA ลดลง เมื่อเทียบกับกลุ่มเนื้อโคดิบ ตัวอย่างเนื้อโคสุกของ HFM มีปริมาณ C18:1n9c (โอเลอิก), SFA, MUFA, PUFA-n3 และ n6/n3 ratio สูงที่สุด โดยเนื้อโคสุกของ HFM และ HFF มีปริมาณโอเลอิกสูงกว่ากลุ่มตัวอย่าง CHA ในขณะที่กรดโอเลอิกไม่มีความแตกต่างกันระหว่างเนื้อโคที่มีระดับไขมันแทรกที่ต่างกัน ($p>0.05$) จากการทดสอบลักษณะทางประสาทสัมผัส ไม่พบความแตกต่างกันในลักษณะทางประสาทสัมผัสระหว่างสายพันธุ์ ยกเว้นลักษณะการยอมรับโดยรวม โดยในกลุ่ม MBS<3 ด้านกลิ่นเนื้อพบว่า HFM มีความเข้มข้นของกลิ่นคล้ายนม และรสมันเลี่ยนสูงกว่ากลุ่มอื่น ส่วนกลุ่ม CHA และ HFM มีรสชาติอูมามิสูง โดยกลุ่ม MBS≥3 พบว่า มีกลิ่นเนื้อ (beefy) กลิ่นคล้ายนม (milky) และยังพบว่ารสอูมามิ ความหวาน และความมันเลี่ยน มีคะแนนสูงขึ้น นอกจากนี้การทดสอบกลิ่นสารระเหยในเนื้อพบว่า กลุ่ม HFM ที่มี MBS≥3 มี

ปริมาณสาร 2,3-butanedione (buttery) สูงในตัวอย่างเนื้อโคดิบและ methyl-pyrazine (nutty, brown, musty, roasted), butyrolactone (milky, creamy, peach-like) ในตัวอย่างเนื้อโคสุกมากกว่ากลุ่มที่มี MBS<3 ($p<0.05$) ขณะที่กลุ่ม CHA ที่มี MBS≥3 พบปริมาณสาร methyl-butanal (pungent, sweet, roasty), methyl-pyrazine, 2,6-dimethyl pyrazine (roasted, nutty) สูงกว่ากลุ่มที่มี MBS<3 โดยคะแนนไขมันแทรกที่สูงขึ้นมีผลทำให้กลุ่ม HFF มี butyrolactone (milky, creamy) สูงขึ้น

จากการศึกษาครั้งนี้ สรุปได้ว่าโคนมที่คัดทิ้งมีคุณภาพซากด้อยกว่า เมื่อเทียบกับโคขุนลูกผสมสายพันธุ์ชาโรเลส์ และโคนมเพศผู้ขุน อย่างไรก็ตามคุณภาพเนื้อของโคนมคัดทิ้งไม่มีความแตกต่างจากอีกสองกลุ่มในด้านสีเนื้อ เปอร์เซ็นต์ไขมัน เปอร์เซ็นต์โปรตีน ค่าแรงตัดผ่าน ลักษณะทางประสาทสัมผัส เมื่อเนื้อโคนมคัดทิ้งมีระดับไขมันแทรกมากกว่า 3 นอกจากนี้ปริมาณกรดไขมันโอเลอิก ไขมันอิ่มตัว ไขมันไม่อิ่มตัวเชิงเดี่ยว โอเมก้า 3 และสัดส่วนของ n6/n3 มีค่าสูงในเนื้อโคสุกของโคนมเพศผู้ เนื้อโคนมสุกมีปริมาณกรดไขมันโอเลอิกสูงกว่าเนื้อโคขุน โดยเนื้อโคนมเพศผู้มีกลิ่นคล้ายนม กลิ่นเค็ม และรสชาติอูมามิและรสมันเลี่ยนที่ดีกว่า แต่มีค่าความแน่นของเนื้อสูงกว่ากลุ่มเนื้อโคขุนและโคนมคัดทิ้ง กลุ่มเนื้อโคนมมีความโดดเด่นของกลิ่นสาร butyrolactone ซึ่งมีลักษณะของกลิ่นคล้ายนม กลิ่นครีมนม โดยกลิ่นสาร butyrolactone เข้มข้นขึ้นเมื่อเนื้อโคมีระดับไขมันแทรกมากกว่า 3

คำสำคัญ: เนื้อโคนม, โคนมคัดทิ้ง, ลักษณะของซาก, คุณภาพของเนื้อ, คะแนนไขมันแทรก, ลักษณะทางประสาทสัมผัส, องค์ประกอบของสารละเลย, รสชาติเนื้อโค

Title	CARCASS CHARACTERISTICS, MEAT QUALITY AND EATING QUALITY OF CULLED DAIRY COWS
Author	Miss Jarunan Chainam
Degree	Doctor of Philosophy in Program Animal Science
Advisory Committee Chairperson	Associate Professor Dr. Yanin Opatpatanakit

ABSTRACT

This study was aimed to investigate the effects of fattening systems and sex on carcass characteristics of dairy cattle and to compare carcass characteristics, meat quality and sensory evaluation of culled dairy cows with fattening dairy steers and crossbred Charolais steers. The study was divided into 2 experiments. Experiment 1 undertook to study potential of culled dairy cows from 307 carcasses. The general information including fattening systems and carcass data of culled dairy cow were defined. The survey showed that most farmers bought cows from middlemen who had no records of sire and dam leading to lack of information about pedigree or proportion of breed inheritance. However, the highest proportion being more than 87.5% Holstein Friesian inheritance in culled cows was defined. The reasons for culling were reproductive problems such as infertility, low production, old cow and udder or mastitis problems. It was found that culled cows were fattened for 4-5 months to gain more body weight or until 450-600 kg of slaughter weight. Diets were the same as milking cows' diet consisting of 70:30 ratio of concentrate to roughage. The 24% crude protein concentrate was fed at 2.5-3.0 kg/h/d. Roughage was pineapple or corn by-products and sometimes supplemented with palm meal. For carcass characteristics, culled dairy cows had average age of 4.58±0.73 years, BCS of 3.52±0.61 and marbling score of 2.72±0.83. Average live weight was 581.11±66.73 kg which average weights of warm carcass, chilled carcass and hide were 313.70±38.91, 312.22±38.29 and 36.94±6.29 kg, respectively. Percentage of the warm and chilled carcass weight were 53.99 and 52.64%. Effects of slaughter weight and sex on carcass characteristics of dairy cattle showed that data of 520 records during 2014-2016 included 412 culled dairy

cows (>4 years old and 580.85±3.76 kg of slaughter weight) fattened with concentrate and roughage for 4-5 months and 108 fattening dairy steers (>2 years old and 584.45±7.33 kg of slaughter weight) fattened for 10-12 months. The results showed that the slaughter weight of culled dairy cow did not affect percentages of warm and chilled carcasses but had influence on warm carcass weight, chilled carcass weight, hide weight, hide weight percentage, fore quarter and hind quarter ($p<0.05$). There was no effect of slaughter weight on percentages of warm and chilled carcasses ($p>0.05$). Live weight of culled dairy cow was positively correlated with warm and chilled carcass weights ($r= 0.954$ and 0.936, $p<0.001$). The slaughter weight of dairy steer over 650 kg had a better marbling score than other groups (2.05 vs 1.33 and 1.68; $p<0.001$). Warm and chilled carcass weights of dairy steer were heavier than those of culled dairy cow ($p<0.05$). Warm and chilled dressing percentages of dairy steer were also higher than those of culled dairy cow ($p<0.05$). The marbling scores of dairy cow were higher than those of dairy steer (1.85 vs 1.59; $p<0.01$).

In Experiment 2, carcass characteristics, meat quality and sensory evaluation of culled dairy cows (HFF) compared to crossbred Charolais steers (CHA) and dairy steers (HFM) was investigated. Each of 20 steers or cows with different marbling score (MBS<3 and MBS≥3) were studied. Effect of breed had positive influence on carcass characteristics. CHA group had higher carcass weight and dressing (%) whereas HFF group had the smallest rib-eyes area. At MBS≥3, L*and b* values were not different among breeds, however, CHA and HFF groups had higher a* values than HFM group. At MBS<3, thawing loss of HFF group was higher than those of other groups whereas thawing loss of CHA and HFM groups increased at MBS≥3. However, cooking losses decreased as marbling score increased. As marbling score increased, contents of moisture and protein in beef and shear force value decreased whereas fat content in beef increased ($p<0.01$). Moreover, there was no difference in shear force value (5.06-5.21 kg) among breeds with MBS≥3. Marbling score grading by image processing technique assessment (IMG1) positive correlated with human visual appraisal (VIS) ($r=0.708$, $p<0.01$). Moreover, the marbling score of VIS positively correlated with fat percentage ($r=0.675$, $p<0.01$). Grilled CHA and HFF beefs had lower SFA and MUFA compared to raw beef. Grilled HFM beef had the greatest C18:1n9c (oleic acid), SFA,

MUFA, PUFA-n3 and n6/n3 ratio. Grilled HFM and HFF beefs had greater oleic acid than CHA, but there was no difference in oleic acid between marbling scores ($p>0.05$). There was no difference in sensory attributes by breeds except overall acceptability of beef with MBS<3. HFM beef had a higher intensity milky flavor and oily taste than others. CHA and HFM beefs had more detectable umami taste. Beef with MBS≥3 had high beefy and milky flavor and also great umami, sweetness and oily taste. HFM beef with MBS≥3 had great 2,3-butanedione (buttery) in raw beef, and methyl-pyrazine (Nutty, brown, musty, roasted), butyrolactone (milky, creamy, peach-like) in grilled beef than those with MBS<3 ($p<0.05$). CHA beef with MBS≥3 had higher 2-methyl-butanal (pungent, sweet, roasty), methyl-pyrazine, 2,6-dimethyl pyrazine (roasted, nutty) than those with MBS<3. At high marbling score, HFF and HFM beefs had great butyrolactone (milky, creamy).

It could be concluded that culled dairy cow has inferior carcass quality compared to Charolais steer and dairy steer. However, beef of culled dairy cow had no difference in meat color, fat and protein contents in meat, shear force value, sensory attributes compared to the others when beef had marbling score up to score 3. Moreover, higher C18:1n9c (oleic acid), SFA, MUFA, PUFA-n3 and n6/n3 ratio was noted in grilled beef from dairy steer. Grilled beef from dairy cattle had greater oleic acid than Charolais steer. Beef from dairy steer had superior milky/salty flavor and umami/oily taste but had higher denseness compared to beefs from Charolais steer and culled dairy cow. Dairy beef was predominant on butyrolactone as a milky, creamy flavor while higher butyrolactone was found in beef with marbling score higher than 3.

Keywords: dairy beef, culled dairy cows, carcass characteristics, meat quality, marbling score, sensory attributes, volatile compounds, beef flavor

ACKNOWLEDGEMENT

I would like to thanks to my supervisor, Dr. Yanin Opatpatanakit, Associate Professor, Faculty of Animal Science and Technology, Maejo University, Chiang Mai, for his suggestions, support, and inspiration throughout my dissertation. I also gratefully acknowledge to co-advisors: Dr. Rong-Shinn Lin, Professor, Department of Biotechnology and Animal Science, National Ilan University, Ilan, Taiwan, Dr. Siriporn Kiratikrankul, Associate Professor, Faculty of Economics, Maejo University, Chiang Mai and Dr. Patthamawadi Kiatbenjakul, Lecturer, School of Food Technology, Institute of Agricultural Technology, Suranaree University of Technology, Nakhon Ratchasima for their kindness and encouragement to carry out my project work. I want to thank all our faculty members, office staff of Faculty of Animal Science and Technology, Maejo University and School of Food Technology, Suranaree University of Technology for their co-operation. I extend my gratefulness to Dr. Jirawat Yongsawatdigul, Associate Professor and to all staffs of School of Food Technology, Suranaree University of Technology for their assistance and laboratory supports. I wish to thank all my lab mates and research scholarship from Faculty of Animal Science and Technology, Maejo University for their support.

I would like to respect and honest to my beloved, my elder sister (Mrs. Srila Chainam) for funding the education, my family members and friend for their love, support and incessant inspiration that always has been the fighting power for me.

JARUNAN CHAINAM

February 2019

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

TABLE OF APPENDIX

FIGURE OF APPENDIX

CHAPTER 1
INTRODUCTION

Rationale

Currently, demand for high quality beef consumption has been increased in Thailand. However, the number of fattening steers has not been enough to meet market requirement due to lack of beef cattle for feedlot (Sethakul, 2016). Thailand had mostly imported frozen beef from Australia and New Zealand which had been valued of 74,112 US$. These lead to higher prices of live cattle and beef in the last 2-3 years (Office of Agriculture Economics, 2016a). A quantity of imported beef gradually increased which was reflected to the quality beef demand of Thai consumers (Office of Agricultural Economics, 2016b; Bunmee et al., 2018). Consumers desire tenderness and flavor attribute which are mainly influenced by *Bos Taurus* breed and feeding management for an increase in intramuscular fat. Study on beef market share in France, heifers and culled cows occupied 75% of beef market share while steers were 25% (Jurie et al., 2007). Fattening dairy steers, heifers and culled cows occupied 40% of beef market share in Japan (Suzuki, 2015). Moreover, most of the beef meat sold in Denmark originated from dairy cow (Vestergaard et al., 2007). Traditionally, dairy cows in Thailand were annually culled 50,000 cows and launched to the beef market. The amount of high quality beef (beef-type) had been less than 3% of market share in Thailand (Setthakul et al., 2012). The old and culled dairy cows were slaughtered without feeding which were produced 2,560 tons (1.7%) of dairy beef in meat industry such as meat products (Lertwittayanuruk, 2007). Several researches had been widely studied on carcass and meat quality of dairy beef. Carcass and meat quality of finishing culled dairy cows as high marbling score, low shear force and great flavor have been widely accepted by consumers in New Zealand, Ireland, Denmark and France (Dransfield et al., 2003; Keane et al., 2003; Jurie et al., 2007; Vestergaard et al., 2007). Finishing culled dairy cows for two or four months had enhanced body condition, carcass characteristics, marbling score and meat palatability (Vestergaard et al., 2007).

Moreover, Sethakul and lengnoodum (2012) reported that culled dairy cow fattened for 12 months had marbling score of 3.5-4.0. However, dark color of meat and smaller rib-eye area were appeared as disadvantages against high quality beef. Moreover, increasing of marbling score had a positive effect on tenderness, juiciness, flavor, and overall palatability (Corbin et al., 2015). Armbruster et al. (1983) showed that roasted rib of Holstein beef had better flavor. However, several research works had been widely studied on carcass characteristics and meat quality of dairy beef. Some research has been studied on fattening culled dairy cows and dairy steers especially sensory attributes of dairy beef. Therefore, this study aimed to compare carcass characteristics, meat quality, sensory evaluation as well as beef flavor (volatile compounds) of culled dairy cows, fattening dairy steers and crossbred Charolais steers. Furthurmore, it will be more_market opportunity of dairy beef production for farmers in order to generate more income. Additionally, consumers will have new choices for premium beef instead of imported beef as well.

Hypothesis

1. Carcass characteristics and meat qualities of culled dairy cows and fattening dairy steers will be similar with high quality beef and it could be replaced the beef in the market.

2. Chemical and physical properties of culled dairy cow and fattening dairy steers will be similar with high quality beef, especially fat percentage, color value (L*a*b*) and shear force value.

3. Sensory evaluation of culled dairy cow and fattening dairy steers, are similar to those of high quality beef.

4. Volatile compound of culled dairy cow and fattening dairy steers, are similar to those of high quality beef or a unique flavor.

Objectives of research

1. To compare the carcass characteristics and meat qualities of culled dairy cows, fattening dairy steers with crossbred Charolais steers.

2. To study the sensory evaluation beef from crossbred Charolais steers, culled dairy cows and fattening dairy steers by semi-trained panelists.

3. To study the volatile compounds of crossbred Charolais steers, culled dairy cows and fattening dairy steers by gas chromatography-mass spectrometry (GC-MS).

Expected knowledge from the dissertation

1. To know preliminary information of culled dairy cows as: %HF blood proportion, age, body condition score (BCS), farm management (feeding and raising condition), fattening period and carcass characteristic of culled dairy cows.

2. To know carcass characteristic of culled dairy cows, fattening dairy steers and crossbred Charolais steers as: live weight, carcass weight, dressing percentage, rib eye area (REA) and marbling score.

3. To determine meat qualities of culled dairy cows, fattening dairy steers and crossbred Charolais steers as: pH value, color value, water holding capacity (%), thawing loss (%), cooking loss (%), Warner-Bratzler shear force (WBSF), texture profile (TPA), proximate composition (moisture, protein, fat) and fatty acid profile.

4. To study the influence of the marbling score on meat quality of crossbred Charolais steers, culled dairy cows and fattening dairy steers.

5. To determine the correlation of marbling score grading by visual and by image technique assessments.

6. To evaluate sensory attributes of culled dairy cows, fattening dairy steers and crossbred Charolais steers by trained panelists.

7. To evaluate volatile compound of culled dairy cows, fattening dairy steers and crossbred Charolais steers by gas chromatography-mass spectrometry (GC-MS).

CHAPTER 2

REVIEW OF LITERATURE

Thailand, there had been imported high quality frozen beef from abroad. Mostly, they were imported from Australia, New Zealand, USA and Argentina's which in 2011 have import permit 12,104.1 tons of frozen beef (Department of Livestock Development, 2012). Lertwittayanuruk (2007) had been reported that 1.4 percentage of Europe crossbred has to produce quality beef and another 1.1 percent of beef had imported from foreign countries that was demand for consumption in domestic. This suggests that the ability to produce beef did not according with increased market demand. However, the number of dairy cows and culled dairy cows were not fattening that can yield 2,560 tons of beef or 1.7 percent of the beef industry in the country. A number of successful fattening beef enterprises in Thailand had been started to supply high quality beef. All enterprises used similar basic principles with monitored finishing of crossbred bulls or steers on farm and controlled slaughtering and marketing. However, Thailand still imports a huge amount of frozen beef. Thailand imported high quality frozen beef from different countries each year. Mainly, it imported from Australia, New Zealand, USA and India which had allowed import of frozen beef. In 2016, import of beef and beef product had 11,040 tons of volume with the value of 2,316.00 million baht when compare with the import of beef and beef product in 2015 which has 10,314.90 tons of volume with the value of 2,206.63 million baht which increase 7.03 and 4.96 percentage, respectively due to still demand beef quality successively (Office of Agricultural Economics, 2017) The main reasons are the lack of beef quality, especially of prime cuts such as T-bone, strip loin, tenderloin, sirloin and rib eye and the lack of knowledge in carcass and meat quality. In 2011, dairy cull beef of Thailand are entering to the market average 50,000 per year (Sethakul et al., 2012). The beef quality frozen that is European breed (*Bos Taurus* cattle), has been accepted by consumers due to the European crossbred have a good quality, especially marbling score and tenderness has better than Indian crossbred (*Bos indicus*) (Koch et al., 1982; Wheel et al., 1996). However, consumer acceptance for Thai beef is low. Many

researches have been reported that cattle of Europe crossbred *(Bos Taurus)* has a meat quality greater than India crossbred (*Bos indicus*). However, fattening are also commonly used in European breed such as Charolais crossbred, Limousine crossbred and must be over 50 percentage of European breed. However, Dairy farming in Thailand found that a dairy have more than 87.5 percent European blood, mainly Holstein Friesian crossbred (Harintranon, 2001). Therefore, the development of meat quality from culled dairy cows will be able to enhance the beef quality. There are opportunities to expand the market share of beef quality as well as in foreign countries where the fattening cull dairy cows for beef production. The research was studied on carcass and meat quality of dairy cattle fattening in foreign country (Dransfield et al., 2003; Keane et al., 2003; Vestergaard et al., 2007). In 2012, it have been reported that body condition of dairy cattle rather fat prior to culling have a carcass and meat quality similar with finished beef which it can be improved carcass and meat quality of finished cull dairy cow and widely accepted by consumers. However, dairy beef are also cheaper than Charolais beef that is very popular to consumers in the roasted and grilled (Sukjai, 2012).

For livestock, culling was the process of removing animals from a group based on specific criteria. Culling usually implied the killing of the removed animals. Criteria for culling livestock and animal production could be based on population or production. In a domestic or farming situation, the culling process involves selection and the selling of surplus stock. Dairy cows might continue to be economically productive for much lactation. In most cases, 10 lactations were possible. The chances of problems arising which might lead to a cow being culled were high; however, the average herd life of US Holstein was less than 3 lactations. Over 90% of all cows were culled for 4 main reasons: Infertility-failure to conceive and reduced milk production, mastitis-persistent and potentially fatal mammary gland infection, lameness-persistent foot infection or leg problems causing infertility and loss of production, production some cows fail to produce milk at economic levels to cover their feed costs. Milk production below 12 to 15 liters per day was not economically viable. Cow longevity was strongly correlates with production levels. Lower production cows have live longer than high production cows, but less profit. Their meat was rather low quality and value

so it was generally used for meat processing. Increased numbers of cull cows were being presented for slaughter due to gradual decline in dairy cow (especially, Holstein–Friesian) fertility (Evans et al., 2004; Minchin et al., 2007). In Ireland, 2001 and 2005, it has been reported that an average of 342,000 cows was slaughtered each year between September and December. The large proportion of cows slaughtered in November, suggests that many unfit (low body weight and condition score). Dairy cows were presented for slaughter at the end of lactation without finishing prior to slaughter, this coincides with peak supplies of prime cattle and a period when factory prices tend to be reduced due to the inrush of such cattle at that time. Thus, strategies to improve the carcass value of cull dairy cows and allow a more even distribution of slaughtering could extensively increase farm return (Minchin et al., 2009). In 2007, cull cows comprised 21% of all cattle slaughtered in Ireland (Minchin et al., 2007; DAF, 2006). Moreover, study on beef market share in France, there were 75% from fattening dairy cows and heifers and 25% from fattening dairy steers (Jurie et al., 2007). In Japan, there were 40% of beef market share from fattening dairy steers, heifers and culled cows (Suzuki, 2015). In Danish dairy production, the exchange percentage was around 34–38% per year and the average dairy cow has around 2 lactations before slaughter (Therkildsen et al., 2011). Therefore, there was a general interest in improving the meat quality of slaughter cows, in order to improve the value of the meat from the dairy cattle when removed from the herd, and thus increase the total output of the dairy production.

In addition, there were fattening cull dairy cows to improve the quality of meat was widely accepted by consumers in the dairy industry, such as Denmark and Ireland, in particular the eating quality such as increases marbling score, to improve color and flavor including tenderness and juiciness of culled dairy beef (Vestergaard et al., 2007). Thonney et al. (1991) had been revealed that rib eye steaks from Holstein steers cannot be distinguished visually from steaks from Simmental x Angus beef steers and that steaks from Holstein steers were at least as palatable as steaks from Simmental x Angus steers. However, roughage a source was one important factor for carcass and meat quality. Cull dairy cows fed with different roughage sources had been increased percentage fat (Phujeang, 2009). There were great marbling scores, carcass weight when

fed with high energy concentrate with hay (Pfhul et al., 2007). The cattle through finishing and aging process found increased overall of meat quality and fat content (Intramuscular fat), enhanced meat tenderness and decreased shear force value.

Factors affect carcass quality

The economic interest of finishing cull cows has been studied primarily in beef breeds (Malterre, 1986; Cranwell et al., 1996; Franco et al., 2009). Cull dairy cows and suckler herds were of considerable economic importance to the producer and beef food chain, however, the producer was faced with a number of challenges to maximize the value of cull cows to their business. Clearly the value of the cull cow, as with all beef production systems, was highly sensitive to specific market conditions, but maximizing returns from dairy cull cows was also sensitive to the costs associated with feeding to achieve slaughter at the correct weight and body condition. In assessing whether to put an animal into a finishing regime, the producer must consider whether the costs associated with finishing were likely to be justified by the extra returns realistically available for better quality stock.

However, from the past to present time, there are several researches that to study carcass characteristic of cull dairy cow. Steven and Cassie (2005) have been reported that one-fifth of the United States cow herd was made up of dairy cows and 15 to 20% of fed beef steers are Holstein. Therefore, it was important to understand the comparative value of Holstein and beef type breeds for beef production. Garrett (1971) found Holstein steers had lower dressing percentage than beef type steers. Steven and Cassie (2005) showed that Holstein steers had a lower dressing percentage (59.1 vs. 61.9%; $p<0.003$) than beef steers but similar carcass weight. Holsteins also had a smaller rib eye area (12.0 vs. 10.8 in^2; $p<0.002$) than beef steers. Kidney, heart and pelvic fat, marbling and USDA calculated yield grades were similar among the two steer types.

Compared with forage-fed cows, feeding a high-energy diet to cull cows was thought to improved carcass composition (Matulis et al., 1987), increase intramuscular fat deposition (Price and Berg, 1981), and improve steak palatability (Miller et al., 1987).

Schnell et al. (1997) have been revealed that carcass weights and dressing percentage increased through 28 d of feeding and lean firmness increased through 42 d of feeding. Adjusted preliminary yield grades and final yield grades increased with feeding. Fat color became whiter but marbling was not affected by feeding. Weights of fat-free lean, fat, and bone and percentages of fat in soft tissues of cow carcasses was increased by 28 d on feed. Overall steak tenderness was higher for cows fed 56 d than for cows fed 0 or 14 d. Vestergaard et al. (2007) showed that finishing feeding of dried-off dairy cows for either 2 or 4 months resulted in larger muscles, increased fatness, improved overall carcass quality. All carcass quality characteristics were improved by the finishing feeding. The total carcass composition showed an improved carcass yield, markedly reduced bone and increased fat trim proportion. Franco et al. (2009) have been reported that all carcass quality characteristics were improved with a finishing period. The effect of finishing time is more illustrative when the conformation, fatness score and carcass yield are considered. An important and significant difference was found in carcass yield in cows from finishing 30 days against no finishing (49.43 vs. 39.54). The result could be of importance for the live animal market price which is consistent with Pritchard and Burg (1993) reported that finishing feeding was increased dressing percentage, rib eye area, and rib fat thickness. Longer feeding periods progressively increased the number of high quality carcasses produced. Therefore, the finishing of cull cows in the dairy herds could be an import activity to raise the cattle farm. The productive life of these cows was about five years. Over 50% were culled for various reasons, none of which prevents them from being used for butchering. Finishing these animals increases their weight and improves their condition score and fatty state of carcass (Malterre, 1986; Cranwell et al., 1996) with a subsequent rise in price. Higher this value could be very significant for fatty cows when they were sold in the market. Therefore, this situation could be give rise to an important increase in the price per kilogram of meat carcass.

Factors affect meat quality

Traditionally, the term "meat quality" covers natural properties of meat for the suitability of the meat for eating, further processing and storage including retail display. The major attribute of interest are safety, nutritional value, flavor, texture, water-holding capacity, color, lipid content, lipid composition, oxidative stability and uniformity (Andersen et al., 2005). Moreover, meat quality refers to the compositional quality and the palatability of meat. The major parameters considering in the assessment of meat quality are appearance, juiciness, tenderness and flavor. In addition, the most important quality trait of meat for purchase decision by customers is color. The customer's point of view, freshness of meat is related to bright red for red meats. Fresh beef is expected to have a reddish color. Thus, dark red or purple color of beef is considered as less fresh (Chen et al., 2010). Meat should have a desirable color that is uniform throughout the entire cut. The color was related to the level of protein pigment, myoglobin, present in the muscle. Meat should also have marbling (intramuscular fat) throughout the cut, which effect on juiciness, tenderness, and flavor of the meat. Juiciness of meat can be determined by Water-holding capacity, was defined as the ability of meat to retain water during application of external forces, such as cutting, heating, grinding or pressing (Lawrie and Ledward., 2006). Meats from dairy cows were often recognized as very tough meat, which comes from older animals. In the beginning of the lactation, protein degradation in muscle tissue will be high in order to release amino acids for milk production, whereas later in the lactation where the absorbed nutrients the milk production and protein degradation in the muscle tissue are minimized because of low protein degradation which express as tough characteristic. Shemeis et al. (1994) had been revealed that the Danish cull cow with advanced in age, the color of carcass, lean and fat, tended to become darker yellow and the *longissimus dorsi* has a greater area with cover-fat thickness. Meat quality appeared to be independent of age but regards with its color, which related with traits and its content of dry matter and intramuscular fat. However, the meat showed an increase in shear force value with age. Independent of age, the classification of cows according to their body condition score (is a technique used a numeric score

for assessing the energy reserves of livestock. It uses a scale from 1, very thin to 5, very fat) prior to slaughter revealed significant differences in the quality of carcass and meat. The better conformation score of carcass, the higher score of fatness and larger *longissimus dorsi* area with cover-fat thickness. However, the slaughtered cows mainly are dairy cattle breed with different Holstein Friesians blood share. A high HF blood share (up to 50%) of culled dairy cows considerably influences beef quality in cattle production in Poland. Beef cows are defined as red meat, which has higher costs compared to pink meat from young slaughter cattle in some countries (Weglarz, 2010). However, factors affecting the palatability of beef are tenderness, juiciness, and flavor. Among these three, tenderness is the driving factor in economic terms and also the favorable attribute for consumers when eating a steak in the restaurants or home. Robbins et al., (2003) reported that customers were willing to pay a premium beef top loin steaks because of higher tenderness. Boleman et al., (1997) reported that tenderness could determine using the Warner-Braztler (WB) plade. Schnell et al. (1997) reported that fattening cull cow with fed a high-concentrate diet for 0, 14, 28, 42 or 56 day, Warner-Bratzler shear force values did not differ until 56-d feeding period (3.94, 5.17, 4.33, 3.85 and 4.07 kg, respectively). Recently, USDA has agreed WBSF standards for tenderness certification, WBSF value of 43.25 N (4.4 kg) or lower as "Certified Tender" and of 38.25 N (3.9 kg) and lower as "Certified Very Tender" (ASTM, 2011). Moreover, tenderness is the most appreciated attribute by the consumer and is affected by ageing. Boakye (1993) reported that ageing is chilling process after the post-mortem which is low temperature should under 0°C to retard bacterial growth and slow down the action of the endogenous enzymes for improve meat quality. Moreover, tenderness is normally depends on myofibrillar and connective tissues (Lepetit et al., 1986). Both muscle structures are affected by different mechanisms after the slaughter. The post-mortem tenderization process (over 7 days) is the effect of numerous enzymes activity as protease degrading the myofibrillar and connective tissue (RoncaleÂs et al., 1995; Monsón et al., 2005; Marino et al., 2013), although the connective tissue, is main inhibit factor of meat tenderness which could be degrade through ageing process (Nishimura et al., 1998). Color meat was one of the most important factors in physical appearance which was an indicator meat quality and

freshness of the consumers. In meat, myoglobin was the main pigment-containing compound. The proportion of reduced and oxygenated myoglobin provides a subjective idea of freshness while oxidized myoglobin, metmyoglobin with a grey-brown color, was undesirable (Renerre, 1990). However, several factors are affected to color of meat. The level of myoglobin within a muscle was influenced by species, muscle function, and age. Different ages had affected the meat color such as brownish pink color (12 day of age), bright, cherry color (3 years of animal age) and red to dark red color (>10 years of animal age) (Kerry et al., 2002). When myoglobin content was increased, the color intensity of the meat was increased from white or pink to very dark red (Karry et al., 2002). Vestergaard et al. (2007) has been reported that a finishing period of two months is very beneficial, due to the increases of meat fatness, luminosity (L*) and overall carcass quality. Furthermore, 14 ageing days were sufficient to improved tenderness. Both the visual marbling and intramuscular fat (%) showed higher in finishing 2 months (2.9, 3.7%) and 4 month (3.7, 5.5%) of cows than without finishing, respectively. Vestergaard et al. (2007) the shear force value of 0, 2, 4 month finishing feeding tended ($p<0.06$) to be reduced (5.93, 5.68, 5.13). Therefore, the shear force value was low and indicated an overall good tenderness in these cows. Franco et al. (2009) have been reported that the cows with finishing for 2 months had 29% more IMF than those of no finishing (8.52% vs. 6.02%) and the percentage of intramuscular fat content (IMF) was increased by the finishing treatment (finishing for 1 and 2 months). On the other hand, moisture content decreased with a longer finishing period, which corresponded to Varela (2002), who reported that the increase in IMF content in the meat means a decrease in moisture content. Franco et al. (2009) Water holding capacity (WHC), in term of cooking loss (CL) was higher no finishing group than finishing for 2 months group (28.37% vs 25.47%), respectively whereas moisture content was higher in no finishing group than finishing for 2 months group (72.57% vs 70.32), respectively. There is an inverse relationship between moisture content and % cooking loss. An inverse relationship was observed between WHC and IMF content, IMF was higher in finishing for 2 months group than in no finishing group due to cow had a feed for a longer duration of finishing. As a result, the body accumulates more energy for fat synthesis in muscle and as a reserve energy source (Minchin et al., 2009),

whereas CL was higher in no finishing group than finishing for 2 months group. In term of shear force value, significant differences in maximum shear force at day 1 of ageing between no finishing group and finishing for 2 months group were 10.62 vs. 8.00 ($p<0.05$), respectively. Although, it was significant differ on 7 and 35 days ($p<0.05$).

Generally, longer duration (1-2 months) of finishing group and ageing time (7-35 days) improves shear force values of meat. Franco et al. (2009) reported that cows from finishing for 2 months group had lower shear force, which was undoubtedly related to a higher percentage of fat than in no finishing group, which indicated that IMF provided a higher degree of tenderness to the muscle. It was generally accepted that an increased level of the intramuscular fat (IMF) had a positive influence on the sensory qualities (Kim and Lee, 2003; Corbin et al., 2015). On the other hand, Schnell et al. (1997) worked with cull beef cows with identical finishing feeding on 28-56 days had improve overall tenderness and shear force values comparable with cows slaughtered immediately after purchase due to longer duration on finishing feeding showed high fat content accumulation.

Shear force and collagen content of the *longissimus muscle* are indicators of tenderness, which was one of the most important components of meat quality. As mentioned, the cooking loss and shear value were influenced by the type of meat, trim time, temperature, pH, sarcomere length, and the method of cooking (Lawrie, 1998; Jaturasitha, 2007). Furthermore, they were related to the rate of postmortem degradation of the myofibrils, which regarding to biochemical proteolysis (Maltin et al., 2001).

Scollan (2003) reported that fat in meat provides essential fatty acids and vitamins A, D, E, and K (the fat-soluble vitamins) to the consumer and plays a critical role in the sensory perception of juiciness, flavor and texture. Intramuscular fat consisted of saturated fatty acids (approximately 47% of SFA), monounsaturated fatty acids (42% of MUFA) and PUFA (4% of total fatty acids). Beef was considered to increase a risk toward human disease as it has a high proportion of saturated fatty acids. From total SFA, 30% represented as stearic acid (C18:0), which was effected on plasma cholesterol in humans. The Department of Health has recommended a reduction in the intake of saturated fat and an increase in the intake of unsaturated fatty acids, in

particular the omega-3 polyunsaturated fatty acids (n-3 PUFA) that were known to be beneficial to human health (Scollan, 2003). At the same time, the recommended ration of polyunsaturated fatty acid (PUFA) to saturated fatty acid (PUFA: SFA ratio) should be increased to above 0.4. The PUFA: SFA ratio for beef was typically low at around 0.1, except for double-muscled animals which were very lean (<1% intramuscular fat) where PUFA: SFA ratios were typically 0.5-0.7. Consumption of saturated fatty acids (SFA) was associated with increased serum a low-density-lipoprotein cholesterol concentration that was a risk factor for coronary heart disease. Monounsaturated fatty acids (MUFA) and some polyunsaturated fatty acids (PUFA) are anti-thrombogenic (Scollan, 2003). Ruminant fat has a higher SFA and a lower PUFA: SFA ratio than non-ruminant fat, due to hydrogenation of dietary unsaturated fatty acids in the rumen. Therefore, the increasing of the PUFA: SFA ratio in intramuscular fat would improve the healthiness of beef from a consumer's viewpoint (French et al. 2000). More recently, nutritionists had focused on the type of PUFA and the balance in the diet between n-3 PUFA formed from α-linolenic acid (18:3) and n-6 PUFA formed from linoleic acid (18:2). The recommended ratio of n-6:n-3 (usually expressed as the ratio of essential fatty acids C18:2n-6 (linoleic acid) : C18:3n-3 (linolenic acid), should be less than 4 which was considered optimum for reducing risk of cancer and coronary heart disease. In addition, the n-6: n-3 ratio for beef was beneficially low, typically less than 3 (Scollan, 2003). The fat percentage and fatty acid composition were influenced by different factors including breed, gender, slaughter weight and feeding (Zembayashi et al., 1995; Holló, et al., 2001). However, genetic and nutritional factors were considered to contribute the most to differences in fatty acid composition (Scollan et al., 2006). Differences in the fatty acid composition between genetics occurred due to a different gene expression or enzyme activity involved in fatty acid synthesis (De Smet et al., 2004). Among non-nutritional factors, age was an important factor affecting fatty acid composition. When the age progresses, the content of subcutaneous tissue and muscle fat increased, while the ratio of polyunsaturated (PUFA) and saturated (SFA) fatty acids declined (Warren *et al.,* 2008). Therefore, consumers often have the perception that the meat of older cattle tends to be fattier and therefore had negative effects on human health (Kelava et al., 2013).

The fatty acid composition of cattle fat affected the nutritional value of meat in various aspects of meat quality, including flavor and shelf-life. Increasing the ratio of polyunsaturated and saturated fatty acid (PUFA: SFA) was favorable (Demirel et al., 2006). Moreover, fatty acids were also involved in several technological aspects of meat quality since they have very different melting point and variation in fatty acid composition had an important effect on firmness or softness of the fat in meat (Wood et al., 2003). The fatty acids composition of ruminant meat might be influenced by the fatty acid composition of feed and the fatty acids composition of ruminant meats is different from that of non-ruminants. The ratio of PUFA: SFA was lower because the rumen hydrogenates unsaturated fat from the diet. On the other hand, dietary unsaturated did not change in pig metabolism. Loin steaks and chops, the P: S ratio in muscle was 0.58, 0.11, 0.15 pork, beef and lamb, respectively (Enser et al., 1998).

Feeding affected on fatty acids in beef. In feeding trials with beef animals, providing a grass diet in comparison with concentrates diet based on barley, molasses, soya, grass diet increased the proportions of n-3 PUFA (C18:3n-3, C20:5n-3, C22:5n-3 and C22:6n-3) and also reduced the proportion of saturated C16:0. (Scollan, 2003) due to the presence of alpha-linolenic acid (C18:3n3) in grass which was the precursor for the omega-3 pathway. Therefore, grass-fed beef was a good source of n-3 PUFA (omega-3) (Daley et al., 2010; Wood et al., 2003). Grass-finished beef was higher linolenic (C18:3 n-3), eiconsapentaenoic acid (EPA) (C20:5 n-3), and DPA (C22:5 n-3) than grain-finished beef (Realini et al., 2004; Descalzo et al., 2005; Nuernberg et al., 2005; Alfaia et al., 2007; Garcia et al., 2008; Leheska et al., 2008). In terms of saturated fatty acids, beef from grass-finished animal possessed greater percentage of stearic acid (C18:0) than beef from grain-finished animals (Realini et al., 2004; Nuernberg et al., 2005; Alfaia et al., 2007; Garcia et al., 2008; Leheska et al., 2008). Some reports showed that beef from grass-finished cattle decreased in content of palmitic acid (C16:0) (Realini et al., 2004; Nuernberg et al., 2005; Alfaia et al., 2007) however, others reports found that beef from grass finished cattle was no different in C16:0 content (Descalzo et al., 2005; Garcia et al., 2008; Leheska et al., 2008). Pasture or hay feeding strongly decreases SCD gene expression (Chung et al., 2007; Duckett et al., 2009), resulted in a depression in MUFA as well as an elevation in SFA in beef. Pasture or hay feeding also

caused a depression in marbling scores (Lunt et al., 2005) which corresponded to Smith et al. (2009) reported that when cattle graze pastures or hay fed, their beef consistently showed a higher concentrations of n-3 FAs which, omega 3 fatty acid was a precursor in the synthesis trans10, cis-12 conjugated linoleic acid (C18:2) isomer which was an inhibitor of Stearoyl-CoA desaturase, resulted in much less MUFA, and contains less marbling score which corresponding to Descalzo et al. (2005); Alfaia et al. (2007); Garcia et al. (2008); Leheska et al. (2008) reported that the greatest difference in fatty acid profile between forage and grain-finished cattle occurred in the amount of unsaturated fatty acids. The total content of monounsaturated fatty acids (MUFA) was lower in grass-finished beef compared with grain finished beef. However, the amount of linoleic acid (C18:2 n-6) was similar between grass and grain-finished beef (Descalzo et al., 2005; Nuernberg et al., 2005; Alfaia et al., 2007; Garcia et al., 2008; Leheska et al., 2008).

Beef from grain-finished cattle contained high levels of palmitic acid (C16:0) (20-26%), stearic acid (C18:0) (12-24%), and oleic acid (18:1n-9) (35- 40%). Fat comprised of 43 to 46% saturated fatty acids and contained only 5 to 7% polyunsaturated fatty acids. The concentration of oleic acid (18:1n-9) in adipose tissue reflected the average concentration of oleic acid in the diet (St. John et al., 1987), but in ruminant species such as beef cattle, oleic acid (18:1n-9) was largely hydrogenated to stearic acid by ruminal microorganisms (Ekeren et al., 1992). However, in animal tissues are consisted with 3 types of fatty desaturases as Δ5, Δ6, and Δ9 desaturase. Of these, only the Δ9 desaturase acts upon saturated fatty acids (SFA) to convert them to their respective monounsaturated fatty acids (MUFA).The most abundant fatty acid in beef was oleic acid (18:1n-9) produced by the Δ9 desaturation of stearic acid (C18:0). The Δ9 desaturase, which was encoded by the Stearoyl-CoA desaturase (SCD) gene, also converts trans-vaccenic acid (TVA; C18:1 t11) to its corresponding conjugated linoleic acid (CLA: C18:2) isomer, cis-9, trans-11 CLA (Smith et al. 2009).

Beef fat from Wagyu cattle showed a different fatty acid profile than other breed. In comparison of fatty acid profile of Wagyu cattle and Angus cattle, subcutaneous and intramuscular fats from Wagyu cattle showed higher percentages of C16:1 and C18:1 fatty acids but less C16:0 and C18:0 fatty acids than fat from Angus cattle (May et al., 1993). A similar study was revealed that subcutaneous fat from

Japanese Black cattle had a higher percentage of C18:1, C16:1 and lower percentage of C18:0, C16:0, and total SFA than those of Holstein (Zembayashi et al., 1995). Based on the findings of Dryden and Marchello (1970) and Westerling et al. (1979) the high content of C18:1 and low content of C18:0 from Wagyu cattle could indicate a superior flavor than beef from other cattle breeds. Smith et al. (2009) reported that the fatty acid primarily responsible for soft fat in Japanese (Wagyu) and Korean (Hanwoo) cattle was oleic acid (18:1n-9). The concentration of oleic acid also was positively correlated with overall palatability of beef, so any dietary or production factor that enhances the conversion of stearic acid to oleic acid increased fat softness. Smith *et al.* (2009) reported that wide variation in the amount of intramuscular lipid (i.e., marbling) and fatty acid composition of beef from grain-fed cattle has been observed in the U.S., Japan, and Korea which found that monounsaturated fatty acids accumulated in adipose tissue in cattle fed high-concentrate, finishing diets. This coincides with an increase in SCD gene expression, which was exaggerated in Korean Hanwoo and Japanese Black cattle. These cattle not only had a greater genetic tendency to produce more MUFA, but also were fed for longer periods of time. Intramuscular lipid accumulates; there was a concomitant elevation in the concentration of oleic acid, which indicated a significant correlation between amount of intramuscular lipid and the concentration of MUFA in beef. However, this relationship was significant when finishing from long-fed cattle which were increased in intramuscular lipid in beef and resulted of marbling adipocyte hypertrophy.

Therefore, different of source diet was affected with fatty acid in beef. High-concentrate diets stimulate the activity of adipose tissue stearoyl-CoA desaturase (SCD), which was responsible for the conversion of saturated fatty acids (SFA) to their Δ9 desaturated counterparts. Also, grain feeding causes a depression in ruminal pH, which decreases those populations of ruminal microorganisms responsible for the isomerization and hydrogenation of polyunsaturated fatty acids (PUFA). The net result of elevated SCD activity in marbling adipose tissue and depressed ruminal isomerization/hydrogenation of dietary PUFA was a large increased in MUFA in beef over time. Conversely, pasture diets depresses both the accumulation of marbling and

SCD activity, so that even though pasture feeding increased the relative concentration of PUFA in beef, it also increased SFA at the expense of MUFA (Smith et al. 2009).

Factors affect eating quality or sensory evaluation

Sensory attributes of beef were very important from consumer's point of view, mainly regarding to its tenderness and flavor (Corbin et al., 2015). Sensory attributes, appearance, odor, flavor, taste, and texture, were frequently used to evaluate food quality by sensory panelists. Descriptive sensory analysis was an analytical sensory evaluation method involving the discrimination and description of sensory attributes of products by trained panelists (Murray et al., 2001). Trained panelists were screened and trained to assess specific characteristics based on the results of discrimination and description sessions. Trained panelists should be capable of identification and quantification with rating scale for the assessment, result could provide information correlated with instrumental analysis (Lyon & Lyon, 2001; Murray et al., 2001). The perception of a variety of sensory traits including color, tenderness, juiciness, and flavor of beef were the critical factors for consumers' buying decision, which also indicated meat quality as well as healthiness (Verbeke & Viaene, 1999).

Marbling is the amount and distribution of intramuscular fat within the rib-eye visual. Evaluations of marbling were related to differences in eating quality of beef. Beef cuts with high levels of marbling were more likely to be tender, juicy and flavorful than cuts with low levels of marbling (Tatum, 2007). Therefore, marbling was the most important factor in valuing beef carcasses by both industry and consumers. Consumers used marbling as a basis for estimating eating quality and nutritional value of beef steaks. Eating quality was commonly defined as a combination of tenderness, juiciness, and flavor. An increase in USDA quality grade had been shown to increase flavor, tenderness, and overall palatability (Smith et al., 1987). Tatum (2007) USDA quality grades were used to reflect differences in expected eating quality among slaughter cattle and their carcasses. There were eight USDA Quality Grades for beef: Prime, Commercial, Choice, Utility, Select, Cutter, Standard and Canner. Eating quality generally was most desirable for "Prime beef" and least desirable for "Canner beef".

The quality grade of a beef carcass was determined by evaluating carcass indicators of physiological maturity and marbling. Maturity, the age of a beef animal had a direct effect on tenderness of the meat it produces. As cattle mature, their meat became progressively tougher. Evaluations of carcass maturity were used in determining USDA Quality Grades. There were five maturity groupings, designated as A through E. Approximate ages corresponding to each maturity classification are: A = 9 to 30 months, B = 30 to 42 months, C= 42 to 72 months, D= 72 to 96 months and E = more than 96 months. A general rule, the Prime, Choice, Select and Standard grades were restricted to beef from young cattle (A or B maturity). Likewise, the Commercial, Utility, Cutter and Canner grades normally were comprised of carcasses produced by cattle of advanced maturity (C, D and E maturity). Ten marbling scores were used to determine USDA quality grades for beef, ten of which were shown in Figure 1. A maturity and marbling were determined. These two factors were combined to determine USDA Quality Grade.

Increased marbling level had a positive effect on beef tenderness, juiciness, flavor and overall palatability. Consumer sensory panel ratings for tenderness, juiciness, flavor and overall liking of beef strip loin typically increased with increased fat level (Corbin et al., 2015). Especially, tenderness had been cited as the most important factor affecting beef palatability (Huffman et al., 1996), and consumer were willing to pay more for tender beef products. Schnell et al. (1997) report that fattening cull cow with fed a high-concentrate diet for 0, 14, 28, 42 or 56 days, steak of cows fed 56 d increased in tenderness attribute more than from cows fed 0 or 14 d. In general, sensory tenderness was increased without requiring excessive trimming of fat by feeding cull beef and dairy cows with high-concentrate diet periods up to 56 d.

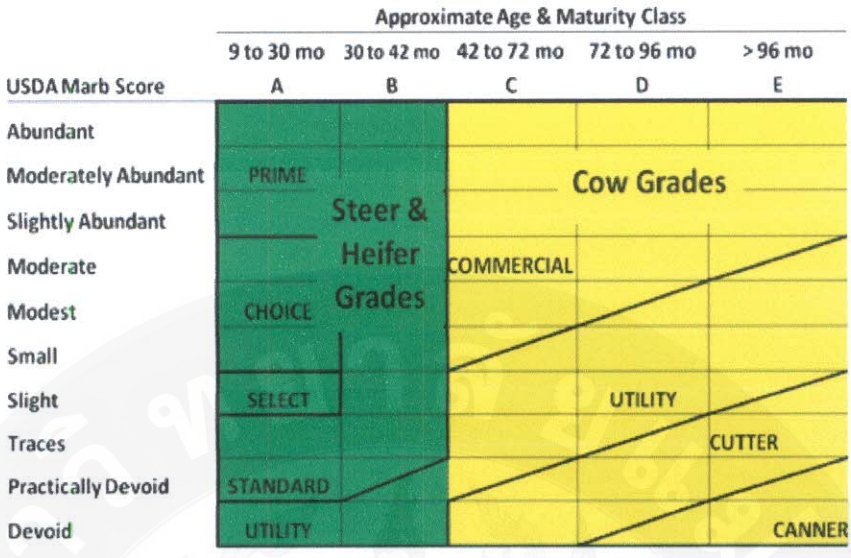


Figure 1 Marbling and maturity relationships to determine USDA quality grades

Source: Woerner (2010)

However, flavor and juiciness are attributes that also contributed to the eating quality of beef. Many factors can influence these attributes, but marbling level was currently used as a visual indicator of palatability in the beef quality grading system (USDA, 1997). Increased marbling resulted in higher quality grades. Several studies had been shown that increased marbling levels increase consumer acceptance of fresh beef steaks (Killinger et al., 2004). However, when tenderness reaches an acceptable level, flavor became the next most important driver of beef eating satisfaction (Corbin et al., 2015). Moreover, overall acceptability was more highly correlated with flavor than tenderness or juiciness, regardless of tenderness variation (O'Quinn et al., 2012). Flavor had been identified as the single most important factor in determining consumer acceptability when meat was prepared at home. Beef flavor was a combination of taste and odor. While taste was generally detected on the tongue as sweet, sour, salty, bitter or other taste sensations such as "umami", odor or aroma was detected in the nose and plays a large role in flavor perception (Legakoa et al., 2015). Increase of intramuscular fat was expected to increase flavor desirability by consumer

Factors affect volatile compound on eating quality

Volatile measurement, the measurement of volatile aroma compounds was relatively straightforward and reliable. Most research on volatile compounds utilized headspace analyses, which the cooked beef usually the same sample that was used for human sensory evaluation was put into an enclosed container and the space above the beef was sampled with a solid phase micro extraction (SPME) fiber. This SPME fiber was then desorbed into a gas chromatograph/mass spectrometer (GC/MS) (Figure 1), which may or may not be equipped with an olfactory or smell port where a panelist can smell the volatile compounds as they exit the GC. The benefit of measuring the beef samples in this manner was that the volatile compounds could be measured on the exact samples that a trained or consumer sensory panel were using and then volatile aroma compounds could be correlated to consumer like and dislike (Kerth & Miller, 2013). A beef quality survey reported that tenderness, flavor and juiciness were the most important factors influencing consumer's eating satisfaction of beef. Moreover, flavor was the one of most important characteristic of meat quality perceived by the consumer and influenced consumer's meat purchasing habits (Ma et al., 2013).

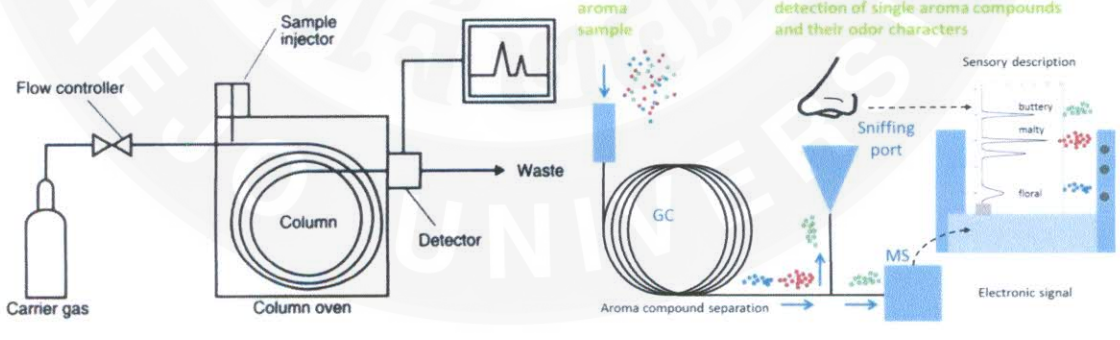


Figure 2 Diagram of a gas chromatograph/mass spectrometer (GC/MS)

Source: Kerth & Miller (2013)

Flavor, was detected by humans in a complex system of sensory tissues located on the tongue and in the mouth, sinus and nasal cavities. Basic tastes were detected by gustatory sensory cells, aromas by the olfactory bulb, and somato sensory perception by trigeminal nerves. All three senses combine to determine the overall flavor. Meat flavor was resulted from the basic tastes combination as sweet, sour, bitter, salt and umami which derived from water-soluble compounds in beef such as sugars, sugar phosphates, sugar nucleotides, free amino acids and peptides. Five basic tastes are identified by the taste buds found mainly on the tongue (Carden & Baird, 2000; Brewer, 2006). Volatile flavor compounds are identified by olfactory neurons and were responsible for the aromatic sensation perceived by the brain (Meilgaard et al., 2007). Humans were capable to identify and discriminated over thousands of different flavor compounds (Carden and Baird, 2000). More than 1000 volatiles contributed to the flavor of cooked meat have been identified. In uncooked beef was weakly-flavored, salty, metallic, blood-like taste with slightly, however it constituted a rich source of compounds being precursors of volatile compounds. (Ma et al., 2013; Soncin et al., 2007).

Factors affecting changes in volatile compounds was breed, sex, age and diet through the slaughter process, meat storage process, type of muscle, cooking method (e.g. grilling, roasting) as well as degree of doneness (e.g. rare, medium, well-done) (Warris, 2000) which was corresponding with Machiels et al. (2003) revealed that overall flavor profile of cooked meat depends on the species, the breed, diet, the cooking method and some other parameters such as the meat processing. Moreover, the main role in meat flavor development was temperature, duration and type of the heat treatment applied. A number of reactions proceed during heat treatments that result in the formation of hundreds of volatiles responsible for the species-specific meat flavor. Meat was exposed to various thermal processes, including: roasting, frying, grilling and cooking. High temperatures induced the formation of numerous amounts of heterocyclic compounds. Hence, many pyrazine, pyridines, pyrroles and thiazoles were identified in roasted and fried meat, but not in meat broth (Shi and Ho., 1994). The roasting of meat enhances oxidation process compared to other methods of heat treatment due to prolonged meat exposure to high temperatures (Domínguez et al., 2014). A strong correlation exists between heating temperature, concentration of free amino acids,

carnosine, IMP, pyrazines and hexanol and the intensity of taste of roasted, burnt and cooked beef (Lorenzen et al., 2005). The flavor of cooked beef was developed during heating which was presented various volatile compounds. The major precursors of meat flavor were either lipids or water-soluble components. The main reactions that important to the development of the flavor of meat during the heating process were the oxidation and degradation of lipids, the interaction of lipid-degraded products through the Maillard reaction (browning reaction) and thiamine degradation (Machiels et al., 2003). The Maillard reaction was interactions of reducing sugars (e.g. ribose, glucose) and free amino compounds (e.g. amino acids, peptides), which was stimulated by heating process. Thousands of volatile compounds are generated and created from thermal processing which was occurred by heat-induced reactions that produced to several chemical group such as hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, esters, lactones, furans, pyrrans, pyrroles, pyrazines, pyridines, phenols, thiophenes, thiazoles, thiazolines, oxazoles, and other nitrogen or sulfuric compounds (Kosowska et al., 2017).

Factors affecting changes in volatile compounds

Breed of cattle effects on beef flavor, several researches had been confirmed that the palatability of meat had significantly affected by the breed. Nitrogen- and sulfur compounds, free amino acids, alcohols, aldehydes and ketones in the flavor volatiles differed among beef from different breeds of cattle (Brewer, 2006). Additionally, beef from Holstien cattle had been shown to have a more desirable flavor profile than beef from Angus cattle (O'Quinn, 2012). The fact that beef from the Friesian breed showed stronger fatty flavor and aftertaste were related to their different fatty acid composition of the intramuscular fat, predominantly caused by genetic control of animal lipid metabolism (Larick et al., 1989) and also related to changes in the level of volatile compounds originating in intramuscular lipids degradation and sulphurous compounds, among them octane and 2,2,4,6,6-pentamethylheptane characterize Friesian beef (Gorraiz et al., 2002). Flavor differences of the both breeds had caused by the different volatile compound which was occurred by intramuscular

lipid oxidation products, such as aldehydes, aliphatic and alicyclic hydrocarbons, and noncyclic sulfur compounds, and dimethylsulfide, resulting from the Maillard reaction. The flavor of a meat species was a mixture of volatile compounds representing various flavor notes. In cooked meet, apart from typically meaty flavor notes, like 2-metyl-3-furantiol or bis-(2-methyl-3-furan) disulfide, there also occur compounds characterized by green, mushroom-like, sweet, and earth-like odors, however taken all together they reflect a typical character of a food product (Cerny, 2012). Meat from different species had diffrent sensitivity to lipid oxidation because the different species contain various proportions of unsaturated fatty acids; for example, chicken contains a higher percentage of unsaturated fatty acids and therefore has a faster rate of lipid oxidation than pork. Because pork contains more unsaturated fatty acids than beef, pork was more sensitive to lipid oxidation compared to beef. Therefore, the development of lipid oxidation varies due to the specie. Beef produced from cattle of Wagyu breed was more flavored than the meat obtained from dairy breeds. In addition, it contained more volatiles and higher concentrations of volatile acids, lactones and aldehydes compared to the meat of dairy breeds characterized by the high content of aldehydes and alcohols (Sato et al., 1995). Among these, breed and diet were importance factors as different chemical compositions of the meat, especially fat content and fatty composition (Machiels et al., 2004). Phospholipids, which were located in the cell membranes, are sensitive to oxidation in meat due to their more unsaturated fatty acids compared to other lipids. Lean meat contains a high percentage of phospholipids that makes it sensitive to oxidation. Therefore, phospholipids act as the major contributors to oxidative rancidity in lean meat. However, lipid oxidation is also influenced by the degree of unsaturation of the fatty acids in the phospholipid and triglyceride fractions. Fats and fatty acids play a significant role in imparting a specific flavor to particular meat species. The main fraction of lipids responsible for the formation of specific volatiles included phospholipids (Soncin et al., 2007), and to a lesser extent triacylglycerols (Meinert et al., 2007). This specificity was due to differences in fatty acid profiles in various species of animals. The fatty acids contained in phospholipids were more unsaturated compared to the acids occurring in triacylglycerols. Phospholipids contain relatively high amounts of linolenic and

arachidic acids, that are subject to auto-oxidation processes which result in the formation of: 2,4-decadienal, 2-nonenal, 1-octen-3-one, 2,4-nonadienal (Perez-Alvarez et al., 2010). The most intensive compound being a product of arachidic acid oxidation is *trans*-4,5-epoxy-(E)-2-decenal, which is followed by 1-octen-3-one, 2,4-decadienal, 2,4,7-tridecatrienal and hexanal (Blank et al., 2001). The oxidized lipids enter into reactions with Maillard reaction products, which results in the synthesis of many important compounds like pyrazines, thiazoles and thiols. Thiamine was an important vitamin that naturally occurs in meat. Thermal degradation of thiamine resulted in the formation of transient and final volatile compounds which affected odor development in meat products, like thiazoles, thiophenes and furans. Volatiles were formed that are characterized by the following flavor notes: meaty (2-methyl-3-furanthiol, bis (2-methyl-3-furyl) disulfide, 3-thiophenethiol, 2-firmyl-5-methyl thiophene, 2-methyl-3-(methyldithio) furan), earth-like (4,5-dimetylthiazole), burnt (2-acethylthiophene) and green (2-methyl-4,5-dihydro-3(2H)-thiophenone) (Ba et al., 2012). Lipids were primarily answerable for desirable and undesirable flavors and aromas in meat. However, lipid oxidation in most cases deteriorated the quality of meat and caused unacceptable flavor for consumers. Lipids could be oxidized by enzymatic and non-enzymatic reactions and there were many mechanisms to explain these complex reactions in meat. Autoxidation was a continuous free-radical chain reaction and is the most important mechanism of lipid oxidation in meat. There were many factors associated with lipid oxidation in meat; for example, heat and light; catalysts; oxygen content and types of oxygen; phospholipids; unsaturated fatty acids; condition of pre-slaughter; processes that destroy muscle membranes; and pH. Mottram (1998) reported that the lipid-derived volatiles are the compounds mainly answerable for explaining the differences between the volatile profiles of meat species and were the main contributors to the species-specific flavor.

Therefore, the fatty acid composition of muscle lipids had important for meat flavor, due to lipid degradation products, especially aldehydes, which generated intensely during cooling condition. However, Legakoa et al. (2015) reported that increase of intramuscular fat rarely increased volatile flavor compounds. Feeding with concentrate diet, fish oil ingredient was increased the fatty acid content of n-3 PUFA,

EPA, and DHA however, it produced the highest oxidative lipid changes in meat, and this corresponded with generally negative comments on odor and flavor from a taste panelists (Scollan, 2003). However, the total proportion of n-3 fatty acids was higher in grass-finished beef compared with grain-finished beef (Nuernberg et al., 2005; Alfaia et al., 2007; Garcia et al., 2008; Leheska et al., 2008). Therefore, the higher proportion of PUFA in grass finished beef, leaded to more susceptible to lipid oxidation, and also change the flavor profile of grass-finished beef observed by sensory panelists (Dryden and Marchello, 1970; Westerling and Hedrick., 1979; Melton et al., 1982; Garmyn et al., 2011). Differences in fatty acid profile of beef caused by different feeding regimes or by cattle breed-types contributed to different flavor of beef. Therefore, the unique fatty acid profile could either provide positive or negative effects on beef flavor.

Sex/gender factor indicated the beef from bulls had a stronger liver-like and bloody odor and flavor, while beef from heifers had stronger characteristic which was indicated that beef from heifers flavor had more desirable flavor than beef from bulls. It might be associated to the genetic control of animal development, sex hormones and their influence the intramuscular fat composition, which all would determine different profiles of volatile compounds (Sink 1979). It was widely accepted that meat flavor improves with aging up to an optimum, and then it degrades, getting rancid after long storage periods (Touraille & Girard 1985).

Effect of diet on beef flavor, animals' diet had a great impact on the palatability of the produced meat and, consequently, on the volatile compounds formed (Wood et al., 2008). Cattle feeding with cereal grain increased carcass weight and intramuscular fat content compared to the feeding with green forage. Beef originating from animals administered green forage was characterized by a higher content of linolenic acid and by lower contents of oleic and linoleic acids than the beef produced from animals administered feed concentrates, which eventually affected also the volatiles formed (Elmore et al., 2004). Various muscles dissected from the same animal differ in their palatability. Generally, the muscles with a higher kinetic activity display stronger flavor compared to the less active muscles (Castellini et al., 2008). Diets had affected to sensory attribute, which is mainly divided to 2 kinds, high-energy (grain) diets and low-energy (forage or grass) diets. However, Melton (1990) revealed that high-energy grain

diets produced a more acceptable and positive strong flavor in red meats than low-energy diets. Grain feeding generally increased carcass weight and intramuscular fat content compared with forage feeding. More than 40% of the variation on beef flavors was influenced by diet (Bruce et al., 2005). Elmore et al. (2004) reported that in concentrates-fed beef were higher levels of linoleic acids (C18:2n6) and oleic acids (C18:1n9) than forage-fed beef. However, levels of α-linolenic acids (C18:3n3) were higher in the silage-fed beef. Grain diets containing fish by-products, raw soybeans or canola oil and meal can cause undesirable flavors in beef (Melton, 1990) due to increasing of unsaturated fatty acids had an affected to increase oxidation during storage. Grosch (1987) reported that the volatile compounds on the concentrates diet, 1-octen-3-ol, cis-2-octen-l-ol, 1-hexanol, pentanal, hexanal, heptanal, octanal, 2-pentylfuran and pentyl formate were originated from oxidation products of linoleic acids (C18:2n6). Volatile compounds on the silage diet, 1-penten-3-ol and cis-2-penten-1-ol were also originated from oxidation products of α-linolenic acids (C18:3n3). Elmore et al. (2004) reported that 1-Octen-3-ol, Hexanal, 2-Pentylfuran, Trimethylamine, *cis*- and trans- 2-octene and 4,5-Dimethyl2-pentyl-3-oxazoline were higher in the steaks from the concentrates-fed cattle, while 1-Phytene was showed higher levels in the beef from grass-fed cattle.

The post-slaughter ripening of meat affected its tenderness as well as develops its flavor profile. The compounds released post-mortem like: sugars, amino acids, peptides, organic acids and products of adenine nucleotide degradation, affect the development of the final flavor of meat (Liu et al., 2012). Non-ageing beef had a weak, bland aroma, whereas the ageing process increases and intensifies its flavor. The ageing for up to 14 days increased the greasy taste and the positively evaluated notes like: beef-like, broth-like, sweet, caramel, but also the negatively perceived ones likes: cardboard-like, bitter and sour (Bruce et al., 2005). Aroma-active volatiles were then form mainly as a result of lipid oxidation processes, e.g.: nonanal, 2,3-octanedione, pentanal, 3-hydroxy-2-butanone, 2-pentyl furan, 1-octen-3-ol, butanoic acid, pentanal and hexanoic acid (Stetzer et al., 2008).

Aging improved tenderness (Gruber et al., 2006), but the questions still remained concerning the effects of aging on flavor (Mottram, 1998). The extension of aging was changed the aroma and flavor precursors of beef flavor, so aging was affected on flavor and the sensory characteristics of the cooked product. Aging altered precursors of beef flavor and leaded to the change in sensory characteristics. Unaged beef had a weak, bland odor while aged beef had a strong, savory, roasted odor. Aging up to 14 days increased fatty flavor and positive flavor notes such as "beefy", "brothy", "sweet" and "browned caramel", however, some negative attributes might be occurred such as "painty", "cardboard", "bitter" and "sour" (Spanier et al., 1997; Gorraiz et al., 2002; Bruce et al., 2005). On the other hand, Brewer (2006); Stetzer et al. (2006) reported that positive flavor compounds decrease with aging (Pentanal and 3-hydroxy-2-butanone) and negative compounds increase (nonanal, butanoic acid and 1-octene-3-ol increase). Aging increased carbonyls derived lipid oxidation, some of which might contribute noticeable off-flavors. Aging for more than 21 days might decrease flavor identity and aging for 35 days might increase metallic flavor (Yancey et al., 2005). Changes in umami taste also occurred during aging. Glutamic acid content increased twice during the first 7 days of aging from 9 mg/100g at 4 days to 21 mg/100g at 7 days (Bauer, 1983).

Marketing opportunity of dairy cattle

Thailand is a country of native beef cattle resource farming. The beef cattle population in Thailand in 2017 was currently about 4.9 million head (Office of Agricultural Economics, 2015). About 1.0 million head of beef cattle were slaughtered annually. Beef cattle in Thailand could be classified into three groups according to their genetic types (Bunmee et al., 2018). The first group was Thai native cattle which make up 61% (2,813,223 head) of the population. The second most numerous groups were Brahman and Brahman crossbreeds (35% of the population). The third major group was fattening beef cattle (158,222). Beef produced in Thailand had exclusively been for domestic consumption. Only 1% of Thailand's beef cattle were for the premium market which was based on marbling score, 40% are sold into modern

markets that consider muscling of cattle, and the remainder enter traditional markets, beef market in Thailand were divided into 3 type. The first group was traditional beef market. This market was produced from The Thai native and Brahman cross-bred and normally provides cattle for household consumption and other low value markets which lack meat quality specifications. Numerous cattle were sold without finishing. Culled and old cows were also sold in these markets. The market share for these market chains was about 50%. The price of cattle depends on age, conformation, and stage of animal within the production system. Buyers were usually wholesalers or slaughterhouse owners who slaughter cattle for retailers. Occasionally, culled or old cows were fattened for 3 to 4 months using agricultural by-products to increase body muscle and fat percentages. It could be add-value for culled or old cows and also increased market opportunity of them. The second one, mid-value beef was produced from Brahman and some *Bos taurus* cross-breeds. The market share for mid-value beef was 49%. Cattle are traded from the stocker system producers to the slaughterhouse via a marketing group or cooperative community chain. The mid-value carcasses were sold in fresh markets, supermarkets and restaurants, and were priced according to consumer demand and product quality. The price for beef had risen by over 100% from 2007 to 2015 as a result of strong growth in demand. The increase in price reflected increase in domestic beef consumption (Bunmee et al., 2012). The third was premium beef market, consumers in major urban centers were leading premium meat's growing demand. It had been shown that consumers would pay a premium for guaranteed tender beef products (Shackelford et al., 2007) and for that reason high quality tender beef was goal for producers of beef to increase profitability. High quality beef with high intramuscular content was produced in fattening farms and sold in supermarkets. The carcass was chilled and aged for 2 weeks to improve tenderness. The market share for this high quality beef had been only 1% of the market in Thailand. Cattle from the stocker system were fed for 8 to 12 month a high energy diet with low fibre content.

In many countries had been focus on the dairy beef production which also had the beef production from dairy steer and culled dairy cows. Jurie et al., (2007) reported that beef market share in France, there were 75% from fattening dairy cows and heifers

and 25% from fattening dairy steers. In Japan, there were 40% of beef market share from fattening dairy steers, heifers and culled cows (Suzuki, 2015). In Danish dairy production, the exchange percentage was around 34–38% per year and the average dairy cow has around 2 lactations before slaughter (Therkildsen et al., 2011). Most of the beef meat sold in Denmark originates from dairy cow (Vestergaard et al., 2007). In 2007, cull cows comprised 21% of all cattle slaughtered in Ireland (Minchin et al., 2007; DAF, 2006).

Beef consumption in Thailand is about 170 thousand tones per year. Beef was an important source of nutrients including essential amino acids, protein and B vitamins and therefore should remain as a healthy choice of meat of Thai consumers (Mann, 2003). Therefore, dairy cow was an interesting choice because of Holstein Friesian cattle was a *Bos Taurus* cattle. They have more than 87.5% of Europe blood and good genetic potential. Dairy cows showed high quality meat. Dairy beef was similar with high grade quality of cattle beef, especially in terms of marbling score (Vestergaard et al., 2007; Poojang et al., 2009). In addition, there were fattening cull dairy cows to improve the quality of meat was widely accepted by consumers in the dairy industry, such as Denmark and Ireland, in particular the eating quality such as to increase degree of marbling score, to improve color and flavor including to increases tenderness and juiciness of culled dairy beef (Vestergaard et al., 2007).

Figure 3 Conceptual framework

CHAPTER 3

MATERIAL AND METHODS

This experiment was divided in to two parts.

1. Experiment 1 Potential of culled dairy cow

1.1 Study on fattening systems and carcass characteristics of culled dairy cows

Three hundred and seven culled dairy cows were slaughtered at Ibrorheem slaughterhouse by halal method. The carcass data were collected and chilled at 0-4 °C. The carcasses were dry aged for 7 days and recorded for chilled carcass weight. The carcass was ribbed between the 12^{th} and 13^{th} rib to expose rib-eye for marbling score evaluation. The *longissimus dorsi* muscle (LD) sample was cut into 2.54 cm thick steak. The general information of culled dairy cow were collected from dairy farm including the proportion of Holstein Friesian inheritance, age, body of condition score (BCS), farm management, feeding and fattening period etc.

1.2 Effects of gender and slaughter weight on carcass characteristics of dairy cattle

Five hundred and twenty records were collected for carcass quality. Four hundred and twelve culled dairy cows aged more than 4 years old and had averaged slaughter weight of 580.85±3.76 kg. They were fattened with concentrate and roughage for 4-5 months (Table 1 Proximate composition of pineapple by-product, corn by-product, oil palm meal and concentrate). One hundred and eight fattening dairy steers aged more than 2 years old and had averaged slaughter weight of 584.45±7.33 kg which were fattened for 10-12 months. All cows and steers were at least 75% Holstein Friesian crossbred and were fattened by members of Beef Cluster Cooperative Limited (Maxbeef) during 2014-2016. Immediately after slaughter, carcasses were weighed and chilled at 0-4 °C for 7 days. Carcass data were also recorded.

2. Experiment 2 Study on carcass characteristics, meat quality and sensory evaluation of culled dairy cows compared to crossbred Charolais steers and dairy steers

There were sixty beef carcasses from 3 groups of cattle used for meat quality assessment.

The first group consisted of 20 culled dairy cows with at least 75.00 % crossbred Holstein Friesian fed with pineapple by-products and supplemented with concentrate for 4-5 months.

The second group consisted of 20 dairy fattening steers, with at least 75.00 % crossbred Holstein Friesian fed with pineapple by-products and supplemented with concentrate for 10-12 months.

The third group consisted of 20 Charolais crossbred steers fed with pineapple by-products and supplemented with concentrate for 10-12 months.

Carcasses were chilled at 0-4 °C for 7 days. The *longissimus dorsi* muscle (LD) sample was cut into 2.54 cm thick steak. All Samples was classified into 2 marbling grades as marbling score less than 3 (n=10) and marbling score higher than 3 (n=10). A steak was vacuums packed individually and stored at -20°C. All steaks were determined for physico-chemical properties, sensory evaluation and identification of volatile compounds.

Carcass characteristic measurements

Prior to slaughter culled dairy cows were subjectively evaluated the body condition score (1=emaciated 2=thin 3=average 4=heavy and 5=fat, respectively) by an experienced person based on Elanco Animal Health (Anon, 1994). The animals were slaughtered and dressed according to commercial practices after chilling at 0-4°C for 7 d.

Live weight, carcass weight, hot carcass weight, cold carcass weight, dressing percentage were recorded.

Carcass was divided into 2 quarters, the forequarter and hindquarter, between the 12^{th} and 13^{th} ribs. The forequarter was the chuck, rib, shortplate, brisket and foreshank. The hindquarter was consisted to the short loin, sirloin, tenderloin, flank

and round. Forequarter and hindquarter were determined according to the method of Sung et al. (2015); Ćirić et al. (2017).

Rib eye area was measured by using planimeter at the anterior side of the *longissimus dorsi* muscle (LD) between the 12th and 13th ribs. The value was expressed in square inches (Bunmee et al., 2011).

1. Marbling score assessment

Marbling score was evaluated by visual assessment (VIS) on a cross-section of the *longissimus dorsi* muscle (LD) at the 12th to 13th rib interface, according to ACFS 6001-2547 (ACFS, 2004). The 5 point regime, was scored as 1 to 5 correspond to traces, slight, small, moderate and abundant, respectively. The detail was shown in Figure 4.

Image processing technique (IMG) was assessed by MATLAB 7.0 software on Windows XP, Microsoft Visual Studio 9.0 (Figure 5), which had been developed as tools to measure and evaluate qualitative data from digital photos. Assessment of marbling score was used the tool for determination of intramuscular fat with image processing techniques from digital photos of *longissimus dorsi* muscle at the 12th to 13th rib. The procedures and interpretation of the image sensor in a digital camera was as a numeric value that used to calculate the percentage of marbling (Jirasuwannakul, 2011). This study, image processing technique (IMG) was assessed by using criterion of marble grading from Thai-French which had the closest rating score to ACFS standard reference which was defined class level: TF-G1.0 to TF-G5.0 (Marbling fat=0-30%).

Meat quality measurement

1. Proximate analysis

One hundred grams of *longissimus dorsi* muscle (LD) from right side of each carcass was packed in vacuum packaging and stored at -20 °C. Uncooked steaks were trimmed, removed visible fat and ground through a plate with 4.5 mm holes using a food mincer. Dry matter, crude protein and crude fat were determined according to

the procedures of the Association of Official Analytical Chemists (AOAC, 1996). All samples were analyzed in duplicate.

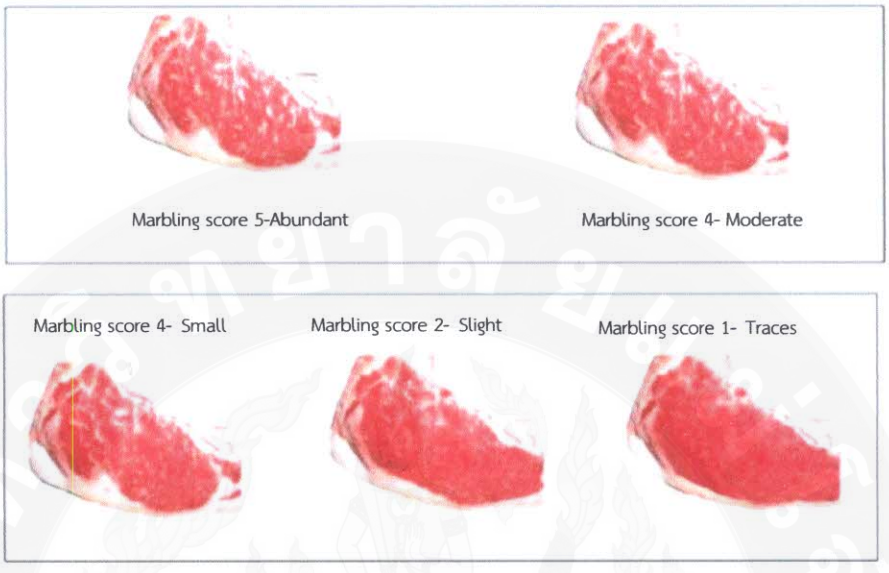


Figure 4 Visual assessments

Source: ACFS (2004)

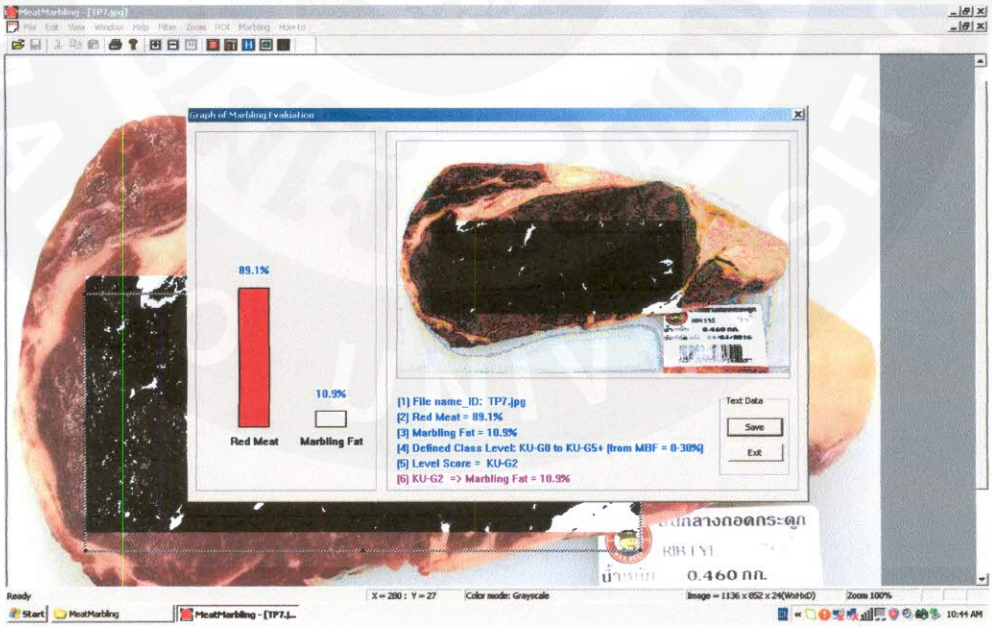


Figure 5 Image technique assessments

Source: Jirasuwannakul (2011)

2. pH measurement

The pH of the *longissimus dorsi* muscle (LD) was determined by pH meter (Model 191, Knick, Berlin, Germany) at 45 min after slaughter which the electrode was inserted into the LD between the 12^{th} and 13^{th} rib about 5 cm depth. The pH meter was calibrated with 4.0 and 7.0 buffer solutions before and after uses each carcass (Lambertz et al., 2014).

3. Color measurement

Meat color was measured on 2.54-cm thickness slices of *longissimus dorsi* muscle (LD) at the 12^{th} to 13^{th} rib interface after being bloomed at 4°C for 1 h using a Minolta CR-300 colorimeter (Minolta Camera Co. Ltd, Osaka, Japan), which were calibrated against a white calibration plate. Lightness (L*), redness (a*), and yellowness (b*) of the meat were determined (Labmertz et al., 2014).

4. Water holding capacity

The Water-holding capacity (WHC) was measured in three methods: Water holding capacity (%), thawing loss (%) and grilling loss (%).

Water-holding capacity (%) was determined according to the method of Ryoichi et al. (1993). Two grams of the mince sample was wrapped on a filter paper (Whatman No.4 Ltd. Kent, UK), subsequently placed into a centrifuge tube and centrifuge (CR 20B2, Hitachi Koki Co., Ltd. Fukuoka, Japan) at 6,710×g for 10 min. The released water absorbed into the filter paper was weighed and calculated as a percentage of the initial moisture of meat. Expressed as the percent of the original weight lost after centrifugation

$$\text{Expressible moisture (\%)} = \frac{\text{(weight before centrifuge - weight after centrifuge)}}{\text{weight before centrifuge}} \times 100$$

$$\text{Water-holding capacity (\%)} = \frac{\text{(\% moisture - \% expressible moisture)}}{\text{\% moisture}} \times 100$$

Thawing loss (%) was analyzed followed by the method of Labmertz et al. (2014) to assess thawing loss of a 2.5-cm slice of *longissimus dorsi* muscle (LD) in vacuum sealed polyethylene bag and frozen at -20°C for 1 month. Samples were thawed at 4°C for 24 h. Thawing loss was calculated from the difference of initial and final weight.

$$\text{Thawing loss (\%)} = \frac{\text{(weight before thaw - weight after thaw)}}{\text{weight before thaw}} \times 100$$

Grilling loss (%) was analyzed followed by the method of Lambertz et al. (2014) for determining grilling loss, 2.5 cm slices of *longissimus dorsi* muscle (LD) was grilled in a convection oven (model 720, Mara, Taipei, Taiwan) at 150°C until reaching an internal temperature of 71°C and weight after 5 min of cooling. Grilling was calculated from the difference of initial and final weight.

$$\text{Grilling loss (\%)} = \frac{\text{(weight before grill - weight after grill)}}{\text{weight before thaw}} \times 100$$

5. Warner-Bratzler shear force (WBSF) measurement

According to Cooke et al. (2004), cooked samples were cooked to an internal temperature of 71°C, on electric grill (Model Imarflex IF-809, Thailand). Uniform sized pieces (1.3 × 1.3 × 2.5 cm) from the middle portion of each piece are used as the test samples according to Choat et al. (2014). Shear force was analyzed by Warner Bratzler shear force (WBSF) flat blade, distance 30 mm, pre-test speed 2 mm/s, test speed 4 mm/s and post-test 8 mm/s. (Instron Corporation, Bucking hamshire, UK) equipped with a 500-N load cell WBSF values was calculated from peak force values and sample cross-sectional area (cm^2) and expressed in kg.

6. Texture profile analysis (TPA) measurement

Texture profile analysis (TPA) was performed using the procedure described by Bourne (1978). The textural characteristics of beef will be determined by TA-XT2 (Texture Technology Corporation, Scarsdale, NY). A cooked beef sample was thawed overnight at 4°C. Uniform sized pieces (1.3 × 1.3 × 2.5 cm) from the middle portion of each piece are used as the test samples according to Choat et al. (2014). The test sample was placed on a platform fixture and compressed to 80% of the original height at a crosshead speed of 1.2 mm/s through 2 cycle sequences at a pre-test speed of 1 mm/s, a post-test speed of 10 mm/s, and a distance of 13 mm using a 25 kg load cell and a compression platen cylinder probe 6 mm (P6). The TPA parameters computed are as follows:

1. Hardness (kg): resistance at maximum compression of first bite to deform the sample
2. Springiness or elasticity (mm): distance that the sample recovered its height between the first and second compressions
3. Cohesiveness: positive force ratio of the second compression area to the first compression area (A2/A1)
4. Gumminess (kg): multiply of hardness and cohesiveness (Bourne, 1978; Klettner, 1993; Yetim et al., 2006).

7. Fatty acid profile

Fatty acid analysis was analyzed according to the fat extraction and methylation and saponification method of Folch et al. (1957); Metcalfe et al. (1966). Adding 36 ml chloroform-methanol (2:1) into 6 grams of raw and cooked beef samples contained in centrifuge tube and then homogenize for 2 minutes, and leave them 30 minute. Before pouring them into separatory funnel was filtrated with filter paper No. 4, then, added 12 ml of chloroform, 12 ml of deionize water and 2 ml of 0.58% NaCl, mixed the solution together, leaved it overnight for phase separation, The chloroform solution phase in 50 ml centrifuge tube was added with Na_2SO_4 and shake to make the solution clear and filtrate with filter paper No. 4, then collected

the solvent layer in the flask 125 ml and flush with N_2 and the residue was weighted for calculated the fat sample, which stored at -20°C and cover with aluminum foil.

1.5 ml of 0.5N NaOH/MeOH will be added into 25 mg of the fat sample. The sample was contained into screw capped test tube and flushed it with N_2. Heating samples at 85°C for 30 second, mixed together and cooled at room temperature. The samples were added 3 ml of 14% BF in methanol, 1 ml of C17 internal standard (2.0 mg/ml in Hexane) and flushed with N_2. Then, the samples were heated at 85°C for 30 minutes again, mixed together and cooled at room temperature. One ml of isooctane was added, mixed sample together. Five ml of saturated NaCl solution was added and closed the cap and then shake and leaved it for phase separation layer. Finally, 1 ml isooctane was added into the vial for injected 1 µl of sample into the gas chromatography (Hewlett Packard, HP 6890 series GC system). All samples were analyzed in duplicate

Conditions of analysis by GC are as follows. Column was used SP-2560 100 m x 0.25 ID x 0.20u m film. Oven was programmed 140°C 5 min to 240°C at 4 °C/min hold 15 min. Detector was used Flame Ionisation Detector (FID) at 260°C and injector was programmed split 100:1 at 250°C.

Sensory evaluation

Sensory evaluation was analyzed according to the method of Choat et al. (2006). Beef sample was removed from the 12^{th}-13^{th} rib eye of the *longissimus dorsi* muscle (LD). Sensory evaluation was assessed in term of eating quality and palatability ratings by semi-trained panelists. After post-mortem, *Longissimus dorsi* muscle (LD) from each carcass was aged for 7 d before used in sensory evaluation. Individual steaks were thawed and cooked using a belt grill (model TBG-60, Magikitch'n, Quakertown, PA) until an internal temperature reach 70°C. A final internal temperature was monitored using a handheld thermometer (model HH21, Omega Engineering Inc., Stamford, CT). After cooking, connective tissue was trimmed and then cut into cubes of approximately 1.3 × 1.3 × 2.5 cm and labeled with 3-digit blinding codes before serve. Sensory evaluation was assessed in term of eating quality and palatability ratings by

semi-trained panelists according to the method of Choat et al. (2006). The panelists were evaluated attributes and marked their responses on a 9 point scale (AMSA, 1995) where 1=dislike extremely and 9=like extremely for appearance, color, flavor texture and overall acceptability. Moreover, descriptive sensory evaluations were conducted using a modification of the Chumngoen and Tan (2015) method. In this study, eight panelists (4 males and 4 females) with the age of 22 to 30-y old who were previously screened and selected to participate in a training course. Each session was spend time for 3 h, and focused on the sensory characteristics of beef. The training panelists were learned to identify the sensory attributes required for describing the texture, flavor and taste of beef. References and scales were also developed during the training sessions. The panelists were evaluated the intensity of attributes and marked their responses on a 15-point scale, structured rating scales (AMSA, 1995) where 1= low and 15= high for texture flavor and taste attributes. For the appearance of cooked samples, meat color (1=light, 15=dark) was determined at the samples' cut surfaces. Panelists were cleaned pallet with drinking water and unsalted crackers between each sample. Six sessions was conducted and panelists evaluated 2-3 samples per session. Samples were identified with random numeric codes. Samples were served to the panelists where samples were warmed for around 5 min. Panelists were rate attributes for texture (juiciness, denseness, cohesiveness, fibrousness), flavor (beefy/brothy, browned /grilled, milky/fat-like, salty), taste (umami, sweet, oily) and meat color.

Volatile compound evaluation

Extraction of raw and cooked beef volatile compounds: Volatile extraction by the headspace solid phase micro-extraction method (HS–SPME) was carried out according to the modified method of Ma et al., (2013). Grilling protocols are the same as those previously describe. The cooked sample was immediately cooled in an ice bath to prevent further aroma development. After cooling, beef samples were be minced by a food mincer. Two grams of mince raw and cooked beef samples was placed in a 15 ml headspace vials fitted with a PTFE/silicone septum and crimp cap.

Thirty microliters of an internal standard (Cycholohexanol) and 10 microliters of 7.2% BHA were placed in the headspace vials.

Gas chromatography/mass spectrometry (GC-MS): Gas chromatography /mass spectrometry GC/MS analyses were performed on an Agilent 7890A gas chromatograph. Separation of compounds was performed by using DB-WAX column (polar), 60 mx 250 µm i.d. x 0.25 µm film thickness (Agilent J & W Scientific, Model No. 122-7062, Folcom, USA). The headspace vials and their contents was loaded by a PAL Sampler for a 10 min of incubation time at 40 °C in the Pre Inc Agitator 500 rotation per minute followed by 30 min of extraction time where volatile compounds in raw and cooked samples was using a DVB/CAR/PDMS SPME fiber. At the end of extraction, the fiber was immediately inserted into the GC injector (250°C) to allow the absorbed volatile compounds and transferred to the analytical column for the analysis of volatile compounds. The SPME DVB/CAR/PDMS fiber was desorbed at 250°C at the injection port for 5 min with a split ratio of 5:1 and split flow of 4 mL/min. Before each sample analysis, the fibers were exposed to the injection port for 1 min to remove any volatile contaminants. Helium was used as a carrier gas at a constant flow rate of 0.8 mL/min, pressure mode at 12.244 psi and average linear velocity of 22.839 cm/sec. It was operated in splitless mode. Chromatographic conditions was as follows: the oven was programmed to 32 °C for 10 min holding time, increased to 40 °C at 3 °C/min hold for 15 min, then at 3 °C/min to 160 °C and then it was raised at 4 °C/min to 250 °C and hold for 5 min thus total running time was 90.167 min.

Peak determination and peak area integration was performed with Mass Hunter Quan (Agilent, Version B.04.00). Peak identification was carried out by comparison of the volatile sample mass spectra with spectra in the NIST Mass Spectrometry Data Center or NIST web book (http://webbook.nist.gov/chemistry/). To confirm the identity of volatile compounds, the retention index (RI) was calculated for each volatile compound using the retention times of a homologous series of C6-C18 n-alkanes and comparing the RI with compounds analyzed under similar condition in previous literature. The approximate quantities of the volatiles were estimated by comparison of their peak areas with the Cychlohexanol internal standard using a response factor of 1.

Statistical analyses

For the statistical analysis from Experiment 1, Pearson's correlation was used to determine relationships of age, body condition score, marbling score, slaughter weight, warm carcass weight, chilled carcass weight, hide weight, percentage of warm carcass weight, Percentage of chilled carcass weight and percentage of hide weight using SPSS package (SPSS 22.0, Chicago, IL, USA). A significance level of 5% was adopted ($P<0.05$).

Data were analyzed by an analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the SPSS package (SPSS, version 22.0, USA) and the least squares mean (LSM) were compared. All statistical of LSM were performed for a significance level $p<0.05$. The model used was:

$$Y_{ij}k = \mu + W_i + E_{ijk}$$

Y_{ijk} is the observation of dependent variables (slaughter weight, warm carcass weight, chilled carcass weight, hide weight, percentage of warm carcass weight, percentage of chilled carcass weight, percentage of hide weight, marbling score, age, fore quarter and hide quarter).

μ was the overall mean.

W_i was the effect of slaughter weight, i= 1 2 3 (1=450-549 kg 2=550-649 kg 3=>650 kg).

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

Y_{ijk} was the observation of dependent variables.

$$Y_{ij}k = \mu + G_i + E_{ijk}$$

Y_{ijk} was the observation of dependent variables (slaughter weight, warm carcass weight, chilled carcass weight, hide weight, percentage of warm carcass weight, percentage of chilled carcass weight, percentage of hide weight, marbling score, fore quarter and hide quarter).

μ was the overall mean.

G_i was the effect of gender, j= 1 2 (1= cows 2= steers)

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

Y_{ijk} was the observation of dependent variables.

Pearson's correlation was used to determine relationships of marbling score, slaughter weight, carcass weight, warm carcass weight, chilled carcass weight, dressing percentage, fore quarter and hide quarter on fattening dairy steer and culled dairy cow using SPSS package (SPSS 22.0, Chicago, IL, USA). A significance level of 5% was adopted ($p<0.05$).

In Experiment 2, data of carcass characteristics, meat quality, sensory evaluation and volatile compounds were analyzed according to 3 * 2 factorial arrangements in Completely Randomized Design (CRD) by General Linear Model (GLM) of SPSS package (SPSS 22.0, Chicago, IL, USA). The model included the main fixed effects of breed and marbling score and their interaction. Duncan's new multiple range test (DMRT) was used to compare differences among means ($p<0.05$).

$$Yijk = \mu + Bi + MSj + Bi^* MSj + Eijk$$

Yijk was the observation of dependent variables (slaughter weight, warm carcass weight, chilled carcass weight, dressing percentage, rib eye area and marbling score, pH value, color value, water holding capacity (WHC), thawing loss, grilling loss, chemical analysis, texture profile analysis (TPA) and Warner Bratzler Shear force (WBSF), fatty acid profile, sensory evaluation and volatile compounds).

μ was the overall mean.

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

MSj was the effect of marbling score, j = 1 2 (1=MS< 3, 2= MS≥ 3)

Bi* MSj was the interaction of breed and marbling score effects

Eijk was the residual random error associated with the observation

Pearson's correlation was used to determine relationships of pH value, chemical analysis, marbling score, Warner Bratzler Shear force (WBSF), rib eye area (REA), texture profile analysis (TPA), color value, water holding capacity (WHC), thawing loss and grilling loss using SPSS package (SPSS 22.0, Chicago, IL, USA). Moreover, Pearson's correlation was also used to determine relationships of human visual appraisals (VIS) and image processing technique (IMG) assessments. A significance level of 5% was adopted ($p<0.05$).

CHAPTER 4

RESULTS AND DISCUSSION

Experiment 1 Potential of culled dairy cow

1.1 Study on fattening systems and carcass characteristics of culled dairy cows

From 307 records of culled dairy cows, these cows were fattened by members of Beef Cluster Cooperative whose farms located in Nakhon Pathom, Ratchaburi and Prachaup Khiri Khan. The results showed that there were 2 types of farms as both dairy and beef fattening farms and dairy fattening farms only. Most of farmers bought cows from middlemen who had no records of sire and dam leading to lack of information about pedigree or proportion of breed inheritance. However, it was found that there was mostly proportion of more than 87.5% Holstein Friesian inheritance in culled cows. The reasons for culling were reproductive problems such as infertility, low production, old cow and udder or mastitis problems. Moreover, there were reasons associated with financial problems and high production cost in terms of management and medical care.

From the survey, it was found that 60.26% of 307 culled dairy cows were from mainly 4 dairy farms as Worasin farm (29.64%), Wanut farm (23.13%), Tongpoon farm (5.86%) and Sureeyun farm (1.63%). Culled cows were fattened for 4-5 months to gain more body weight or until 450-600 kg of slaughter weight. During fattening, these cows were still milked in order to earn income for feeding cost. Diets were the same as milking cows' diet consisted of 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. The culled dairy cows were fed with concentrate and roughage for 4-5 months then sent to slaughterhouse. Moreover, some of the dairy farms also bought dairy steer and fattening for 10-12 months to produce dairy beef for beef market.

Figure 6 Feeds and feeding A. Pineapple by-product B. Oil palm meal C. Concentrate D. Fattening house

Table 1 Proximate composition of pineapple by-product, corn by-product, oil palm meal and concentrate

Items	Dry matter (%)	Ash (%)	Protein (%)	Crude Fiber (%)	Crude fat (%)	Energy (cal/g)
Pineapple by-product	94.08	2.40	5.19	11.79	1.43	4,068
Corn by-product	92.77	3.40	8.39	26.33	2.73	4,185
Oil palm meal	95.66	3.33	30.84	14.43	9.52	4,985
Concentrate	89.42	7.20	23.45	9.53	5.08	3,921

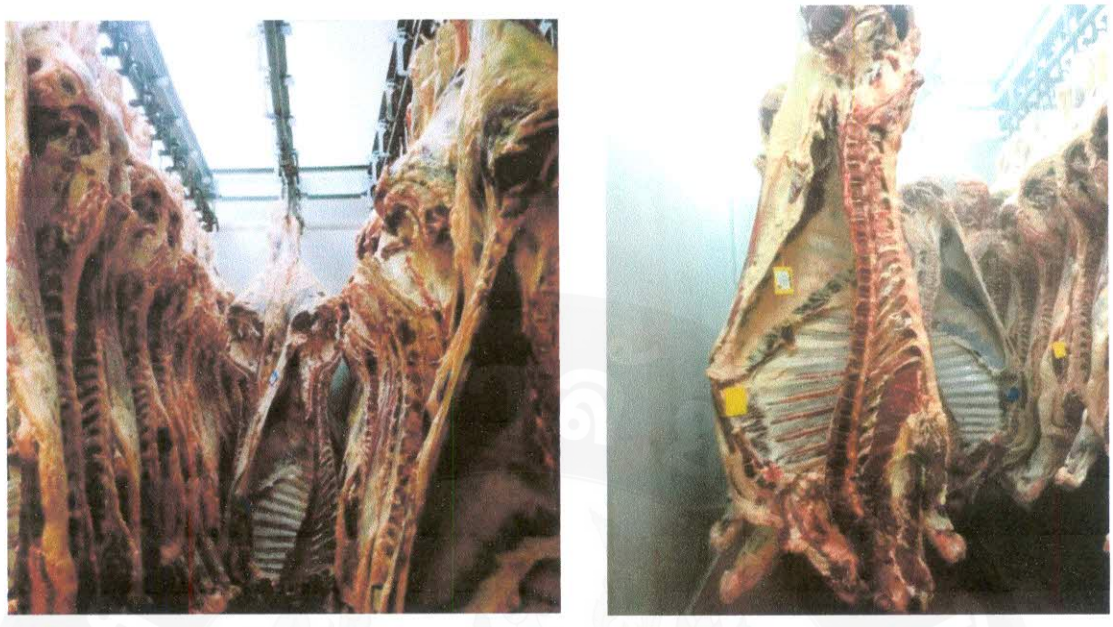


Figure 7 Carcasses aging at 0-4 degrees Celsius for 7 days

From 307 records of carcasses during 2015-2016, it was shown that culled cows aged 4.58±0.725 years while Esselmont and Kossaibati (1997) revealed that 41% of dairy cows at the end of 3rd lactation (2 years) were slaughtered. Moreover, Bazzoli et al. (2014) revealed that data included 20,995 slaughter records of 5 different breeds from 2003 to 2011: 2 dairy breeds [Holstein Friesian and Brown Swiss] and 3 dual-purpose breeds [Simmental, Alpine Grey, and Rendena] showed that the age in culling process was between 2-16 years of age at slaughter. Stelwagen and Dijkhuizen (1984) reported an average culling age of 5.7 years (4 th lactation) for dairy cows. Moreover, Jurie et al. (2006) revealed that the age of culling cows was among 4-9 years.

Average body condition score (BCS) was 3.52. (Rang of 2.00-5.00) Minchin et al. (2009b) reported that Holstein-Friesian cull cows in Irish were slaughtered at a mean BCS of 3. 0 which was corresponding to Vestergaard et al. (2007) who found that culled dairy cows had average BCS at 2.7and BSC increased when fattened for 1 and 2 months at 3.6and 4.2 . The study from Minchin et al. (2009a) indicated that culled dairy cows fattened with grass and concentrate for 27 weeks, the average BCS was 2.7 point and the cows that weighed more than 650 kg. had BCS at 3.5 points

which corresponding with Schnell et al. (1997) who studied on cull cows fed with a high-concentrate diet for 0, 14, 28, 42 or 56 d. The body condition scores of cull cow at starting fed were 3.3-4.6. After finishing, the ending body condition was increased with increasing the time on high-concentrate fed (scores of 3.5-6.8). This was corresponded to many studies showed that fattened culled dairy cows increased body condition score up to level 6 (scale of 1-9) which was worth finishing (Feuz, 1995; Sawyer et al., 2004). Interestingly, from the study of O'Donovan (2009), it showed that approximately 40% of Holstein-Friesian cows slaughtered at LW over 550 kg with a body condition score of 3.5. The Holstein-Friesian cows, it can be assumed that at least 55% of cull cows did not feed of finishing prior to slaughter based on their pre-slaughter BCS of 3 or less. On the other hand, after finishing period, approximately 25% of cull cows slaughtered had 3.5 or greater body condition score. Live weight and body condition score were useful predictors of cold carcass weight (R^2 =0.81). The correlation between BCS and live weight, warm carcass weight and chilled carcass weight were r= 0.636, 0.596 and 0.595, respectively ($p< 0.01$). However, there was no significant correlation between BCS and dressing percentage ($p>0.05$).

The marbling score was 2.72 according to ACFS 6001-2004 grading system (Setthakul & Opatpattanakit, 2005). The average marbling score of cull dairy cows was assessed by assessor 1 was 2.72 compared to 1.91 as by assessor 2. However, the correlation between assessors was r= 0.896 ($p<0.001$). The marbling score was similar to the study from Sukjai et al. (2012) who reported that culled dairy cows slaughter weight more than 460 kg had marbling score of 2.70± 0.22. Pfuhl et al. (2007) revealed that the Holstein bulls had higher marbling score than Charolais bulls was presented (2.78±0.55 and 2.06±0.64 respectively). Due to the Holstein cattle as a dairy breed accumulated more internal fat as an energy depot while Charolais as a beef breed was able to extend protein accretion in the carcass. This indicates different fat accumulation mechanisms between the breeds. Moreover, increasing age had a trend to increased marbling score as well. Pacheco et al. (2015) reported that the marbling in meat from 4 years cull cow (4.96 scores) was numerically lower than that of 4-8 years cull cow (6.64 scores) and more than 8 years cull cow (6.60

scores), these differences were not significant. Schnell et al. (1997) showed that cull cows were fed a high-concentrate diet for 0 day and 56 days. Increase time-on fed merely 56 days did not affect marbling score of cull cow carcasses compared to carcasses of non-fed cull cow. In other hand, Vestergaard et al. (2007) reported that culled dairy cows had visual marbling score increased after fattening for 1-2 months (2.9 and 3.7 scores) while culled dairy cows without fattening had visual marbling score of .23. Moreover, Aunn et al. (2009) studied that fattening culled dairy cows at the age of 3-5 years had average weight at 571-587 kg fed with concentrate mixed with pineapple and corn by-product. It was found that the cows had high marbling score of 3.5-4.0.

Carcass characteristics of culled dairy cow

Carcass quality of culled dairy cows was showed in Table 2. The result showed low and negative correlation between age and warm/chilled dressing percentages ($r = -0.137$ and -0.131, respectively) ($p<0.05$). The warm and chilled carcass weights were positively related to dressing percentage ($r = 0.357$-0.388, $p< 0.05$). However, the live weight was not related to dressing percentage ($p> 0.05$) (Table 3). Settakul and Noidad (2013) reported that fattening cows with higher intramuscular fat had higher dressing percentage. However, the marbling scores were not related to dressing percentage in the experiment 1 ($p>0.05$). Pfuhl et al. (2007) studied on carcasses quality of German Holstein, which had averaged live weight, warm carcass weight, chilled carcass weight and hide weight (588.2±39.4, 356.7 ±23.5, 351.8± 23.4, 45.43 kg, respectively) and hide weight of German Holstein bulls was significant lower than Charolais bulls Schnell et al. (1997) reported that cull cows with fed a high-concentrate had higher carcass weight and dressing percentage compared to non-fed cull cows a concentrate. However, cows were fed a concentrate diet for 28, 42, and 56 days had increased carcass weight and dressing percentage compared with cows fed for 0 and 14 days.

Carcass quality of culled dairy cows in Thailand was reported by Sukjai et al. (2012) that cows with more than 520 kg of live weight had higher warm carcass weight, chilled carcass weight, warm carcasses, chilled carcass percentage, fat

percentage, rib-eye area, back fat thickness and marbling score but had lower in red meat percentage because old cow had decreased muscles, bones and organs.. In contrast, accumulation of fat was increased (Schaefer, 2005). Accretion type of cows could change nutrients from feed and synthesize protein in order to extend the size of muscles such as Charolais cattle. On the other hand, secretion type of cows such as Holstein cow could change nutrients and synthesize in order to produce milk. Bellman et al. (2004b) found that the 2 species metabolic type had growth factors affected from different genes in the hyperplasia and hypertrophy processes. The secretion type had lower amounts of muscle fiber than accretion type. The difference of rate of differentiating muscle fibers cells occurred after fertilization, a cow with accretion type was greater than secretion type (Maltin et al., 2001). Charolais cattle had higher birth weight than Holstein Friesian at 20 percent (Bellman et al. 2004a). In addition, the muscles content in accretion type was higher than secretion type (Jurie et al. 2007) which corresponded with Maltin et al. (2001) reported that muscles fiber content and rib-eye area of Charolais steers were higher than Holstein Friesian steers.

Table 2 Descriptive statistics of carcass quality on culled dairy cows (n=307)

Traits	Mean	Minimum	Maximum	Std. Deviation
AGE	4.58	2.00	5.00	0.725
BCS	3.52	2.00	5.00	0.609
MBS-1	2.72	1.00	5.00	0.829
MBS-2	1.91	1.00	5.00	0.890
SW	581.11	422.00	836.00	66.732
WCW	313.74	222.60	511.30	38.913
CCW	312.22	221.90	506.90	38.292
HW	36.94	26.00	73.00	6.292
%WCW	53.99	44.46	61.62	2.477
%CCW	52.64	43.16	59.92	2.470
%HW	4.64	12.63	6.38	0.957
%Drip loss	2.49	0.42	3.99	0.478

BCS = Body condition score, Marbling score (MBS) = marbling score by using National Bureau of Agricultural Commodity and Food Standards standard reference which marbling scores were encoded as follows: 1 = traces to slight, 3 = modest to moderate, 5 = slightly abundant to moderately abundant. MBS-1: marbling score by assessor 1, MBS-2: marbling score by assessor 2, SW: slaughter weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: Hide weight, %WCW: Warm carcass percentage, %CCW= Chilled carcass percentage, %HW= Hide percentage, %Drip loss was recorded and calculated the carcass weight after aging 7 days.

1.2 Effects of sex and slaughter weight on carcass characteristics of dairy cattle

Carcass characteristics of fattening culled dairy cows and dairy steers with different slaughter weights were showed in Table 4-7. The results showed that the different of slaughter weight of culled dairy cow did not affect percentages of warm and chilled carcasses ($p>0.05$). but slaughter weight had influenced on warm carcass weight, chilled carcass weight, hide weight, hide weight percentage, fore quarter and hind quarter ($p<0.05$; Table 4). The slaughter weight of culled dairy cow was positively correlated with warm and chilled carcass weights, ($r=0.954$ and 0.936, respectively $p<0.001$). However, slaughter weight of culled dairy cow was not correlated with dressing percentage ($p>0.05$). The warm and chilled carcass weights of culled dairy cow were positively related to warm and chilled dressing percentages ($r= 0.298$-0.410, $p<0.001$) (Table 5). Carcass characteristics of fattening dairy steers with different slaughter weight were showed in Table 6. Increasing of slaughter weight was increased with steer age ($p<0.05$). The slaughter weight of dairy steer over 650 kg had a better marbling score than another groups (2.05 vs 1.33 and 1.68; $p<0.001$). The marbling scores of dairy steers were positively correlated with slaughter weight ($r=0.292$; $p<0.05$), warm and chilled carcass weights ($r=0.344$ and 0.345; $p<0.05$), and warm and chilled dressing ($r=0.292$ and 0.309; $p<0.05$) (Table 7).

Average slaughter weights of culled dairy cows and dairy steers were not different (580.85 kg vs 584.45 kg) ($p>0.05$). However, warm and chilled carcass weights of dairy steer were heavier than those of culled dairy cow ($p<0.05$). The warm and chilled dressing percentages of dairy steer were also higher than those of culled dairy cow ($p<0.05$). The marbling scores of dairy cow were higher than those

of dairy steer (1.85 vs 1.59; $p<0.01$). The marbling score of culled dairy cows with different slaughter weight were not different ($p>0.05$). Vestergaard et al. (2007); Sukjai et al. (2012); Noidad et al. (2014) had studied on influence of slaughter weight on carcass quality of culled dairy cows and steers. They also found that increasing slaughter weight had significant effect on increases in warm carcass weight, chilled carcass weight and hind weight ($p<0.05$). The effects of slaughter weight on carcass quality in fattening dairy cattle were similar to those in fattening beef cattle (Huffman et al.,1990; Sinpitakkul, 2011). Moreover, marbling scores were significantly enhanced as the slaughter weight increased ($p<0.05$) due to more accumulation of fat deposit. This was agreed with Opatpatanakit et al. (2004); Sinpitakkul (2011) who revealed that increases in slaughter weight resulted in greater hot carcass weight and marbling score of fattened beef steers.

Proportion of marbling score according to sex, cows group tended to have higher proportions of higher marbling score, especially marbling score of 3 (19%) compared to steer group (7%) as shown in Table 9. Additionally, it found no marbling score of 5 in both groups and only 3% in marbling score of 4 in steers and 12% in cows. This finding is consistent with Chaot et al. (2006) who reported that cows had significant higher USDA quality grades and marbling score than steers ($p<0.01$).

Table 3 Correlations of carcass quality on culled dairy cow (n=307)

	2	3	4	5	6	7	8	9	10	11
AGE	0.097	0.031	0.034	0.094	0.037	0.037	-0.125*	-0.137*	-0.131*	-0.215*
BCS		-0.064	-0.058	0.636**	0.596**	0.595**	0.392*	0.007	0.023	-0.042
MBS-1			0.896***	0.012	0.030	0.033	-0.085	0.055	0.063	-0.101
MBS-2				0.006	0.027	0.031	-0.097	0.065	0.075	-0.114*
SW					0.928***	0.926***	0.498**	-0.014	0.014	-0.199*
WCW						0.999***	0.506**	0.357*	0.381*	-0.137*
CCW							0.506**	0.359*	0.388*	-0.136*
HW								0.102	0.115*	0.746***
%HCW									0.995***	0.122*
%CCW										0.115*

*Significant correlation (p≤0.05), **Significant correlation (p≤0.01), ***Significant correlation (p≤0.001)

BCS=Body condition score, Marbling score (MBS); Assignment to a marbling degree was based on the carcass side using visual. Marbling score (MBS)=marbling score by using National Bureau of Agricultural Commodity and Food Standards standard reference which marbling scores were encoded as follows: 1=traces to slight, 3=modest to moderate, 5=slightly abundant to moderately abundant. MBS-1:

marbling score by assessor 1, MBS-2: marbling score by assessor 2. SW: Slaughter weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight.

Table 4 Carcass quality of fattening culled dairy cows with different slaughter weight

Traits	Slaughter Weight			SEM	P-value
	<550 (n=145)	550-650 (n=206)	>650 (n=61)		
SW	511.14^{C}	595.90^{b}	695.72^{a}	3.366	0.001
WCW	274.68^{C}	321.19^{b}	378.17^{a}	1.953	0.001
CCW	267.45^{C}	312.34^{b}	369.23^{a}	3.569	0.001
HW	31.48^{C}	35.94^{b}	40.95^{a}	0.276	0.001
%HCW	53.75	53.91	54.34	0.102	0.180
%CCW	52.34	52.42	53.05	0.118	0.133
%HW	6.166^{a}	6.034^{ab}	5.88^{b}	0.0363	0.032
MBS	1.80	1.86	1.98	0.041	0.346
Fore quarter	69.77^{c}	81.12^{b}	94.91^{a}	0.520	0.001
Hind quarter	66.59^{c}	78.02^{b}	91.94^{a}	0.480	0.001

$^{a, b, c}$ Least square means within the same row with different superscripts differ significantly ($p<0.05$)

Marbling score (MBS: 1-5); Assignment to a marbling score was based on the carcass side using visual assessments by beef cooperative staff. Marbling scores were encoded as follows: 1=traces to slight, 3=modest to moderate, 5=slightly abundant to moderately abundant. SW: Slaughter weight, WCW: Warm carcass weight CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of Warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight.

Table 5 Correlation of carcass quality on culled dairy cow (n=412)

	2	3	4	5	6	7	8	9	10
MBS	0.079	0.111*	0.084	0.057	0.116*	0.032	-0.014	0.119	0.106*
SW		0.954***	0.936***	0.632**	0.064	0.064	-0.143*	0.950***	0.870***
WCW			0.976***	0.607**	0.358*	0.298*	-0.129*	0.955***	0.953***
CCW				0.594**	0.336*	0.410**	-0.127*	0.930***	0.932***
HW					0.056	0.052	0.670***	0.598**	0.553**
%WCW						0.803***	0.018	0.222*	0.466*
%CCW							0.013	0.179*	0.396*
%HW								-0.138*	-0.116*
Fore quarter									0.830***
Hind quarter									0.000

*Significant correlation (p≤0.05), **Significant correlation (p≤0.01), ***Significant correlation (p≤0.001)

BCS=Body condition score, Marbling score (MBS); Assignment to a marbling score was based on the carcass side using visual. Marbling score (MBS)= marbling score by using National Bureau of Agricultural Commodity and Food Standards standard reference which marbling scores were encoded as follows: 1= traces to slight, 3 =modest to moderate, 5=slightly abundant to moderately abundant. MBS-1: marbling score by assessor 1, MBS-2: marbling score by assessor 2. SW: Slaughter weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight, Fore quarter, Hind quarter.

Table 6 Carcass characteristics of fattening dairy steers with different slaughter weight

Traits	Slaughter Weight (Steer)			SEM	P-value
	<550 (n=48)	550-650 (n=41)	>650 (n=19)		
SW	509.44^{c}	592.83^{b}	755.89^{a}	9.714	0.001
WCW	283.49^{c}	331.11^{b}	425.433^{a}	5.639	0.001
CCW	276.27^{c}	323.66^{b}	416.52^{a}	5.566	0.001
HW	37.67^{c}	43.02^{b}	53.11^{a}	0.777	0.001
%HCW	55.66	55.82	56.36	0.206	0.485
%CCW	54.24	54.56	55.18	0.205	0.264
%HW	7.40	7.26	7.03	0.081	0.267
MBS	1.33^{b}	1.68^{b}	2.05^{a}	0.072	0.001
Age	2.13^{c}	2.80^{b}	3.74^{a}	0.106	0.001
Fore quarter	72.26^{c}	83.99^{b}	106.61^{a}	1.371	0.001
Hind quarter	69.05^{c}	80.88^{b}	103.66^{a}	1.382	0.001

$^{a, b, c}$ Least square means within the same row with different superscripts differ significantly ($p<0.05$)

BCS=Body condition score, Marbling score (MBS); Assignment to a marbling score was based on the carcass side using visual. Marbling score (MBS)= marbling score by using National Bureau of Agricultural *Commodity and Food Standards standard reference which marbling scores* were encoded as follows: 1= traces to slight, 3 =modest to moderate, 5=slightly abundant to moderately abundant. MBS-1: marbling score by assessor 1, MBS-2: marbling score by assessor 2. SW: Slaughter weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: *Percentage of hide weight, Fore quarter, Hind quarter.*

Table 7 Correlation coefficients between carcass quality on fattening dairy steer (n=108)

	2	3	4	5	6	7	8	9	10
MBS	0.292*	0.344*	0.345*	0.116	0.292*	0.309*	-0.245*	0.344*	0.345**
SW		0.976***	0.976***	0.790***	0.079	0.120	-0.159	0.973***	0.973***
WCW			1.000***	0.756***	0.291**	0.329*	-0.176	0.998***	0.998***
CCW				0.757***	0.290**	0.330*	-0.174	0.998***	0.998***
HW					0.007	0.045	0.473**	0.754***	0.752***
%WCW						0.995***	-0.086	0.298*	0.301**
%CCW							-0.084	0.338*	0.340**
%HW								-0.174	-0.176
Fore Quarter									1.000***
Hind Quarter									0.000

*Significant correlation ($p \leq 0.05$), **Significant correlation ($p \leq 0.01$), ***Significant correlation ($p \leq 0.001$)

MBS=Marbling score, Assignment to a marbling score was based on the carcass side using visual assessments by beef cooperative staff. Marbling score was using National Bureau of Agricultural Commodity and Food Standards as standard reference which marbling scores were encoded as follows: 1= traces to slight, 3 =modest to moderate, 5=slightly abundant to moderately abundant. SW: Slaughter weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight,

Table 8 Carcass quality of fattening dairy cattle with different sex

Traits	Sex		SEM	P-value
	Cow (n=412)	Steer (n=108)		
SW	580.85	584.45	3.339	0.662
WCW	313.26^{b}	326.56^{a}	1.952	0.006
CCW	304.96^{b}	318.93^{a}	1.943	0.003
HW	35.12^{b}	42.42^{a}	0.300	0.001
%WCW	53.92^{b}	55.84^{a}	0.974	0.001
%CCW	52.48^{b}	54.53^{a}	0.109	0.001
%HW	6.06^{b}	7.28^{a}	0.039	0.001
MBS	1.85^{a}	1.59^{b}	0.035	0.003
Fore quarter	79.17^{b}	82.75^{a}	0.504	0.004
Hind quarter	76.06^{b}	79.63^{a}	0.480	0.003

$^{a, b}$ Least square means within the same row with different superscripts differ significantly ($p<0.05$)
Marbling score (MBS 1-5); Assignment to a marbling score was based on the carcass side using visual assessments by beef cooperative staff. Marbling scores were encoded as follows: 1= traces to slight, 3= modest to moderate, 5=slightly abundant to moderately abundant. SW: Slaughter weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weight.

Table 9 Proportion of marbling score according to sex

Marbling score	Sex, head (%)		Total, head (%)
	Cow (n=412)	Steer (n=108)	(n=520)
MBS 1	162 (39.32)	58 (53.70)	220(42.31)
MBS 2	158 (38.35)	39 (36.11)	197(37.88)
MBS 3	80 (19.42)	8 (7.41)	88 (16.92)
MBS 4	12 (2.91)	3 (2.78)	15 (2.88)
MBS 5	0(0.00)	0 (0.00)	0 (0.00)

Marbling score (MBS: 1-5); Assignment to a marbling score was based on the carcass side using visual assessments by beef cooperative staff. Marbling scores were encoded as follows: 1= traces to slight, 3= modest to moderate, 5= slightly abundant to moderately abundant.

Experiment 2 Study on carcass characteristics, meat quality, sensory evaluation and volatile compounds of culled dairy cows compared to crossbred Charolais steers and dairy steers

Characteristics of Charolais crossbred steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with different marbling score were presented in Table 10. The effect of breed had positive influenced on warm carcass weight, chilled carcass weight, hind weight, warm dressing (%), chilled dressing (%), hind percentage and rib-eyes area (REA). Warm and chilled carcass weight of CHA group were significantly different higher than HFM and HFF groups ($p<0.05$). Warm dressing (%) and chilled dressing (%) of CHA group also was higher significant different than HFM and HFF groups ($p<0.05$). This result was corresponding with Sukjai et al. (2012) who showed that warm carcass–and chilled carcass (%) of HFF had 55.24 and 54.30. Chainam and Opatpatanakit (2016) who found similar results in the warm dressing and chilled dressing of HFM group were greater than HFF group (55.84, 54.53 and 53.92, 52.48%, respectively) ($p<0.05$). Pujang et al. (2009) reported that culled >68.75% Holstein Friesian dairy cows were fed with pineapple by-product ad libitum

and concentrate for 92 days. The warm dressing percentages were 54.28% which was similar to this study. Moreover, this results showed that HFM group had greater warm dressing percentage than HFF group ($p<0.05$). For CHA group, the warm carcass percentage and chilled carcass percentages were 59% and 57.60%, respectively which confirmed the results of Prom-in et al. (2006) who reported that 50% Charolais steers were raised under production system of Kamphaegsaen Beef Cooperative, had similar warm carcass percentage and chilled carcass percentages (59% and 58%, respectively). Garrett (1971) found that Holstein steers had lower dressing percentage than beef type steers. Kögel et al. (2000) reported that generally, ability of Charolais bulls had greater protein accretion and high carcass yield. Pfuhl et al. (2007) revealed that Holstein bulls gained less BW with the same amount of nutrients than Charolais bulls which could be explained with the energy content of fat, which has more than twice the energy content of protein (2.23:1). Due to the higher energy density of fat, Holstein bulls have to utilize more nutrients to build up fat depots which were also indicated that Holstein bulls had a lower capability for protein accretion compared to Charolais bulls. Hence, Holstein bulls could not metabolize the nutrients for protein accretion and rerouted the ingested energy in internal fat depots. Bellmann et al. (2004) reported that beef cattle, such as the Charolais breed, were characterized by their ability to accrete synthesized substance as meat (accretion type). In contrast, dairy breeds such as the German Holstein were especially in secreting metabolized feed as milk (secretion type). Moreover, hide weight and hind percentage of CHA group was higher than HFF group ($p<0.05$) but HFM group did not significantly differ ($p>0.05$) from CHA group. HFF group was less REA than CHA and HFM groups ($p<0.05$) which was consistent to Opatpatanakit et al. (2007) who reported that loin eye area of Charolais crossbred steers (>2 year) was 85.47 cm^2 which was similar to this study (85.29 cm^2). Rib eye area (REA) of HFF group was 67.27 cm^2 which was corresponding with Vestergaard et al. (2007) who found similar results that loin eye area of culled dry dairy cows was 61.2 cm^2. CHA group had more hide weight and hide percentage than HFF group ($p<0.05$), while HFM group did not differ from other groups. It was found that rib-eye area of fattening dairy steers had similar with crossbred Charolais steers. Warris (2000) who reported that the hide yield in

percent was 5.1-8.5%. The yield in percent of Charolais bull (15-30 months old) was averaged 7.83% which is similar with hide percentage in this result (7.88%) However, hide percentage of this study was also corresponding to Arthur et al. (1995) who found hide percentage of 8% in Charolais sired crossbred at the age of approximately 16 months, which was around 28.1 kg of their slaughter weight. Moreover, Ralf et al (2007) found hide percentage of 7.73% and 8.08% in German Holstein and Charolais steer which there were no difference. The thickness of hide varied with species, age, sex and region of the body. There was no effect of marbling score and interaction of breed and marbling score on carcass characteristics of all groups did not differ ($p>0.05$)

pH value, color value (L*a*b*), Water holding capacity (%), thawing loss (%), grilling loss (%), chemical composition and textural parameter of Charolais crossbred steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with different marbling score (MBS<3 and MBS≥3) of the meat are summarized in Table 11.

1. pH value

Effect of breed had influenced on muscle pH_{45}. CHA and HFF groups had lower muscle pH_{45} than HFM group which CHA group had lower of pH_{45} (6.50) than HFF. It may be because CHA group had higher carcass weight and also had higher fat cover carcass than other groups which Smith et al. (1976); Sethakul et al. (2010) reported that the rate of fall of pH depends upon carcass temperature. Increasing accumulation of fat cover carcass was retarded and decreased temperature in carcass. The temperature of carcass was slowly down, thus affecting glycolysis catalyst to the pH-value decreases. pH at 7 d of all groups (CHA, HFM and HFF) did not differ (5.57, 5.61, 5.52, respectively) which is corresponding with Werner et al. (2004) in beef muscles the ultimate pH of 5.5-5.6 occurs at 18-36 h post mortem depending on species, muscle type and stress over the pre-slaughter period and immediately post-slaughter. pH measurements was used to monitor glycolytic changes in muscles. pH value at 7 day did not different in breed factor. English et al. (2016) reported that pH value of beef was gradually declined. Muscle pH at 0, 21, 42 and 62 d of aging were 5.66, 5.60, 5.55 and 5.52, respectively. pH value at 0 and 21 d

of aging did not different. Therefore, the pH values of meat were stable at 24 hours post-slaughtered.

Marbling score and interaction, pH muscle of all groups did not differ ($p>0.05$).

2. Color value (L*a*b*)

Effects of breed, marbling score, interaction of breed and marbling score had influenced on lightness (L*), redness (a*) and yellowness (b*) of Charolais crossbred steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF).

For breed effect, CHA group had greater lightness (L*) than HFM and HFF groups Chambaz et al. (2001) found that the *M. longissimus dorsi* of Charolais and Angus steers had brighter (L*) color than other beef breed Simmental, Limousin, Blonde d'Aquitaine and Piedmontese steers which was confirmed by heme iron content was lowest for Angus and Charolais steers in *longissimus dorsi* muscles. Moreover, there was a significant negative correlation between heme iron content and L* in both muscles (r=-0.77 in the *M. longissimus dorsi*). HFF group had lower lightness (L*) value than other groups ($p<0.05$) which was corresponding to Noidad et al. (2013) reported that fattening dairy steers was lower lightness (L*) value Kirchofer et al. (2002) reported that *Longissimus dorsi* muscle (LD) had 43.2% number of **α**-White fiber. Muscles were classified as red, intermediate, or white on the basis of the muscle fiber distribution (percent based on number of each fiber type). Muscles were classified as red if they had more than 40% β-red fibers, white if they had more than 40% **α**-white fibers, and all other muscles were classified as intermediate. Minchin et al. (2009) reported that lightness (L*) of Holstein–Friesian dairy cows which offered *ad-libitum* grass silage (GS), grass silage and concentrate at either 3 (GS + 3), 6 (GS + 6) or 9 (GS + 9) kg DM/cow/day were 32.2, 33.8, 33.3 and 32.1, respectively. Franco et al. (2009) who reported that lightness (L*) of Holstein-Friesian cull cows fed with commercial concentrate and corn silage for 0, 30, 60 days, were 35.29, 32.27 and 36.91, respectively which myoglobin concentrations were 6.82, 7.01 and 5.94, respectively. Noidad et al. (2009) reported dietary treatment affected L* (lightness)

and Warner-Bratzler shear force (WBSF) ($p<0.05$). Holstein-Friesian cull cows fed with concentrate and pineapple (PS) or corn by-product silage (CS) as a roughage source. PS beef was lighter (L*=41.21) and more tender (WBSF=4.22 kg.) than CS beef which L* (lightness) was similar to HFF group of this study (L*= 42.79). Moreover, Sethakul et al. (2010) reported that L* (lightness) of high % Brahmam steer fattened with pineapple peel silage as roughage for 3-4 months was 41.65. However, cattle fattened with concentrate and pineapple by-product silage showed great brightness beef compared to no supplemented group However, Setthakul and Lengnoodom (2015) revealed that culled dairy beef had rather darker than *Bos Taurus* beef which was a disadvantage of culled dairy cow. However, Pujang et al. (2009) reported dairy beef from cows fed with concentrate and pineapple by-product silage had brighter than those fed with corn by-product silage and concentrate (39.52 and 35.84, respectively). However, there was no effect of roughage source on redness (a*), yellowness (b*) and pH values. Redness (a*) of CHA group was greater than those HFM and HFF groups but, HFM beef had the lowest a* value. Therefore, this results could be explained that breed factor had influenced on lightness (L*), redness (a*) and yellowness (b*). Apart from breed factor, a stress in the pre-slaughter handling of animals is the most frequently factor caused the depletion of muscle glycogen reserves and the insufficient post-mortem production of lactic acid. Low lactic acid in ageing period had resulted in the change of color meat as PSE meat ($pH<5.4$). High brightness color had resulted to pH_u closely isoelectric point (pH 5.0), so high water holding capacity was occurred. Bright muscle had more free water to reflect light (Węglarz, 2010). At a higher muscle pH, proteins were able to bind more strongly with water, allowing less free water. When the proteins binded more water, the muscle fibers were swollen, leaving less space between muscle fibers. Therefore, meat that has a higher pH would be darker in color because there were less free water to reflect light (Page et al., 2001) Morover, Wulf et al. (1997) reported that the pH_U was correlated with L*, a* and b* values (r=-0.48, -0.52 and -0.60, respectively).

It was found that MBS≥3 group had greater L* and b* values than MBS<3 group ($p<0.05$). Marbling score is white fleck in *Longgissimus dorsi* when high marbling score had also increased white fleck leading to brightness color. Page et al. (2001)

muscle color differences observed between USDA quality grades. As quality grade increased, color values increased. Lightness (L*) value of Standard, Select, Choice and Prime were 38.48±3.10, 38.92±2.64, 40.06±2.45 and 42.67±2.31, respectively. The color of sex class, and breed type, steer carcasses had slightly higher color values (L*=39.62, a*=25.20, and b*=11.03) than heifer carcasses (L*=39.20, a*=24.78 and b*=10.80) ($p<0.05$). Dairy-type carcasses had higher muscle pH values and lower muscle color (pH=5.59, L*=37.56, a*=23.40 and b*=9.68) than either native-type (pH=5.50, L*=39.55, a*=25.13 and b*=11.00) or Brahman-type (pH=5.46, L*=39.75, a*=25.17, and b*=11.05) carcasses. Faustman and Cassens (1991) reported a higher percentage of metmyoglobin in beef from Holstein steers than in beef from beef-type steers, along with several other differences between Holstein and beef type carcasses in muscle metabolites that could affect muscle color. Wiyabot (2014) explained that the brightness varied with the amount of fat deposited (Marbling score), as well as by age when the animals were older, the brightness was decreases so the meat will be darker color. Redness (a*) value was inversely correlated with the lightness (L*) value ($p<0.05$). As the lightness (L*) increased, redness (a*) decreased. Consequently, this study found that MBS<3 group had higher redness (a*) values than MBS≥3 group.

Interaction of breed and marbling score had influenced to L* a* and b* values ($p<0.05$). CHA group had greater L* and b* values. MBS≥3 group had more brightness compared with MBS<3 group. CHA with MBS≥3 had significant higher L* value than HFM and HFF with MBS≥3 ($p<0.001$) which was due to positive correlation to IMF content. Fat had mainly white color in muscle so meat color will become brightness. CHA group had greater lightness (L*) than HFM and HFF groups in the both marbling group and HFF group had the darkest beef which was corresponding to Faustman and Cassens (1991). They reported that dairy-type steers (Holstein steers) had higher metmyoglobin content than beef-type steers.

3. Chemical composition

Breed factor had influenced on fat percentage. HFF group had higher accumulated fat content than CHA and HFM groups ($p<0.05$). Pfuhl et al. (2007)

studied on comparison of the meat quality in LD of German Holstein and Charolais bulls at 18 months of age. Holstein bulls showed a higher marbling score ($p<0.001$) than Charolais bulls (MBS=2.78 and 2.06, respectively) and the intramuscular fat content in the LD was greater than Charolais bulls (IMF=4.06 and 2.62, respectively) ($p=0.016$). Moreover, Bureš and Bartoň (2012) showed that marbling was correlated with intra-muscular ether extract percentage in Holsteins ($r=0.71$). Poojang et al. (2010) reported that marbling score of fattening dairy cows fed with by-product silages from pineapple and corn had 3.60±0.24 and 3.80±0.49, respectively. Pfuhl et al. (2007) explained that Charolais and Holstein bulls as large framed, late maturing breeds, raised and fattened under identical conditions showed differences in feed conversion, carcass composition and meat quality at the age of 18 months.

Holstein cattle as a dairy breed accumulated more internal fat as an energy depot. Charolais as a beef breed were able to extended protein accretion in the carcass. This indicates different fat accumulation mechanisms between the breeds. Matthes et al. (1996) reported a tendency for a greater inner fat content in dairy bulls. The Holstein bulls gained more fat in the body cavity, which was consistent to Dolezal et al. (1993), who found greater internal fat depots in large framed dairy breeds than in beef breeds. The amount of fat accretion varies with the intake of energy (Brosh et al., 1995). The identical feeding regime, the different fat accumulation in the investigated animals was possibly caused by different fat accumulation mechanisms (Kühn et al., 2002). They examined the visceral fat turnover in Holstein cows during lactation, and found fat as an energy source to compensate the metabolic workload of energy in the early lactation in combination with increased liver cell size, which reflects the role of the liver in fat turnover (Baldwin et al., 2004; Segert et al., 1996). These findings confirmed the ability of Holstein cattle as a dairy breed to accumulate fat as an energy depot and were consistent with the observations of Segert et al. (1996) who investigated the mobilization of fat depots in Holstein cows. They also concluded that mobilizing internal fat depots would stabilize the whole energy homeostasis in lactation in Holstein cows.

Table 10 Carcass characteristics (slaughter weight, warm carcass, chilled carcass, hide weight, warm dressing, chilled dressing, hide percentage and rib-eye area (REA)) from crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF)

Carcass characteristics	Breed (B)			SEM	Marbling score (M)		SEM	P-value		
	CHA (n=20)	HFM (n=20)	HFF (n=20)		MBS<3 (n=30)	MBS≥3 (n=30)		B	M	B*M
Slaughter weight (kg)	685.85	652.20	646.40	19.69	651.17	671.80	16.08	0.318	0.368	0.820
Warm carcass (kg)	413.35^{a}	375.94^{a}	356.00^{b}	12.08	374.96	388.57	9.86	0.005	0.334	0.627
Chilled carcass (kg)	406.10^{a}	366.66^{a}	352.41^{b}	12.14	369.09	381.01	9.91	0.008	0.399	0.845
Hide weight (kg)	54.10^{a}	48.45^{ab}	43.95^{b}	2.20	49.51	48.17	1.79	0.008	0.601	0.174
Warm dressing (%)	59.14^{a}	56.29^{b}	54.42^{c}	0.55	56.63	56.60	0.45	0.001	0.971	0.956
Chilled dressing (%)	57.60^{a}	54.88^{b}	52.88^{c}	0.57	55.15	55.09	0.46	0.001	0.924	0.987
Hide percentage (%)	7.87^{a}	7.44^{ab}	6.81^{b}	0.26	7.58	7.18	0.21	0.019	0.191	0.115
REA (cm^2)	85.29^{a}	83.67^{a}	67.27^{b}	1.83	77.09	80.47	1.50	0.001	0.101	0.366

$^{a, b, c}$ Least square means within the same row with different superscripts differ significantly ($p<0.05$)

MBS<3= Marbling score less than 3, MBS≥3= Marbling score more than or equal to 3, Marbling score (MBS); Assignment to a marbling score was based on the carcass side using visual assessments by of National Bureau of Agricultural Commodity and Food Standards. Marbling scores were encoded as follows: 1= traces to slight, 3 = modest to moderate, 5=slightly abundant to moderately abundant. SW: slaughter weight, WCW: Warm carcass weight, CCW: Chilled carcass weight, HW: hide weight, %WCW: Percentage of warm carcass weight, %CCW: Percentage of chilled carcass weight, %HW: Percentage of hide weigh, REA=Rib-eye area.

Table 11 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 (B)			SEM	Marbling score (M)		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										
$pH_{45\ min}$	6.50^{b}	6.68^{a}	6.54^{b}	0.050	6.61	6.54	0.041	0.035	0.216	0.812
$pH_{7\ day}$	5.57	5.61	5.52	0.043	5.589	5.54	0.035	0.400	0.353	0.308
Color value										
Lightness (L*)	44.63^{a}	43.66^{b}	42.79^{c}	0.138	42.33^{b}	45.06^{a}	0.113	0.001	0.001	0.001
Redness (a*)	18.39^{a}	17.19^{c}	17.46^{b}	0.112	19.93^{a}	15.42^{b}	0.092	0.001	0.001	0.001
Yellowness (b*)	7.34^{a}	6.79^{b}	6.23^{c}	0.089	6.56^{b}	7.01^{a}	0.073	0.001	0.001	0.001
Water Holding capacity (WHC)										
WHC (%)	48.19	50.49	46.57	1.327	43.63^{b}	53.21^{a}	1.084	0.153	0.001	0.145
Thawing loss (%)	5.62^{b}	5.01^{a}	6.77^{c}	0.267	5.51	6.09	0.218	0.002	0.082	0.001
Cooking loss (%)	19.54^{a}	20.26^{ab}	20.58^{b}	0.257	21.80^{a}	18.45^{b}	0.210	0.038	0.001	0.001
Chemical composition (%)										
Moisture	68.71	69.21	68.81	0.170	70.37^{a}	67.46^{b}	0.139	0.097	0.001	0.001
Protein	22.10^{a}	21.85^{b}	21.62^{b}	0.860	22.67^{a}	21.04^{b}	0.070	0.001	0.001	0.001
Fat	7.58^{b}	7.73^{b}	8.69^{a}	0.186	6.70^{b}	9.30^{a}	0.152	0.001	0.001	0.049
Textural parameter										
WBSF (kg)	5.78^{ab}	6.07^{a}	5.56^{b}	0.142	6.44^{a}	5.17^{b}	0.116	0.051	0.001	0.024
Hardness (g)	1382.47^{ba}	1398.54^{a}	1161.87^{b}	42.138	1565.13^{a}	1063.45^{b}	34.406	0.001	0.001	0.301
Cohesiveness	0.52	0.52	0.54	0.018	0.52	0.531	0.015	0.805	0.702	0.683
Springiness(mm)	0.99^{b}	1.26^{a}	1.26^{ba}	0.059	1.16	1.181	0.048	0.002	0.769	0.490
Gumminess (g)	722.50^{a}	726.73^{a}	618.62^{b}	28.963	818.08^{a}	560.49^{b}	23.648	0.016	0.001	0.227

^{a,b,c} Means within a row with different superscripts significantly differ (P<0.05)

Table 12 Correlation coefficients between meat quality (n=60) on crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
pH_{45}	0.420**	-0.150	0.152	0.093	0.000	-0.120	0.049	0.182	0.092	-0.013	-0.024	0.075	-0.062	-0.206	0.135	-0.262*	-0.023	0.059	0.113
pH_7		-0.222	0.098	0.215	-0.082	0.032	0.152	0.178	0.196	-0.136	-0.090	0.089	-0.106	0.027	0.137	-0.108	-0.112	-0.128	0.024
fat			-0.733***	-0.717***	0.735***	0.675**	-0.620**	0.025	-0.630**	0.026	0.058	-0.587**	-0.406**	0.553**	-0.739***	0.287*	0.191	0.059	-0.586**
moist				0.537**	-0.730***	-0.749***	0.667**	-0.162	0.653**	0.026	0.011	0.630**	0.462**	-0.792***	0.692**	-0.579**	-0.080	0.130	0.820**
protein					-0.727***	-0.658**	0.557**	0.047	0.637**	-0.015	-0.149	0.603**	0.321*	-0.385**	0.795***	-0.171	-0.425**	-0.303*	0.425**
IMG2						0.778***	-0.714**	0.066	-0.754***	0.061	0.068	-0.669**	-0.471**	0.585**	-0.802**	0.369**	0.255*	0.106	-0.640**
VIS							-0.703***	0.118	-0.645**	0.016	-0.020	-0.614**	-0.501**	0.689**	-0.820***	0.469**	0.372**	0.029	-0.744**
WBSF								-0.249	0.604**	-0.104	0.075	0.510**	0.471**	-0.676**	0.688**	-0.544**	-0.212	0.011	0.629**
REA									0.122	-0.175	-0.151	0.015	-0.178	0.322*	-0.102	0.435**	0.343**	-0.298*	-0.247
Hardness										-0.185	-0.063	0.833**	0.571**	-0.451**	0.682**	-0.193	-0.163	-0.234	0.591**
cohensiv											-0.263*	0.372**	0.137	0.029	0.023	-0.012	-0.018	-0.016	0.003
springines												-0.207	0.583**	-0.138	-0.135	-0.293*	0.073	0.383**	0.119
gummine													0.610**	-0.406**	0.645**	-0.185	-0.163	-0.227	0.569**
chewines														-0.420**	0.407**	-0.332**	-0.052	0.142	0.538**
L*															-.580**	.0735***	0.026	-0.330*	-0.763***
a*																-0.322*	-0.506**	-0.205	0.579**
b*																	0.083	-0.377**	-0.635**
WHC																		0.291*	-0.083
thawing																			0.195
grilling																			0.000

*Significant correlation (p≤0.05), **Significant correlation (p≤0.01), ***Significant correlation (p≤0.001)

Table 13 Correlations of meat quality on crossbred Charolais steers (CHA) (n=20)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
MBS	-0.159	-0.018	0.654**	-0.743***	-0.656**	0.783***	0.986***	-0.692**	0.083	-0.661	0.025	0.015	-0.624	-0.449**	0.662**	-0.807***	0.456**	0.387**	0.080	-0.722***
pH_{45}		0.420**	-0.150	0.150	0.093	0.000	-0.120	0.049	0.182	0.092	-0.013	-0.024	0.075	-0.062	-0.206	0.135	-0.262*	-0.023	0.059	0.113
pH_7			-0.222	0.098	0.215	-0.082	0.032	0.152	0.178	0.196	-0.136	-0.090	0.089	-0.106	0.027	0.137	-0.108	-0.112	-0.128	0.024
%fat				-0.733***	-0.717***	0.735***	0.675**	-0.620	0.025	-0.630**	0.026	0.058	-0.587**	-0.406**	0.553**	-0.739***	0.287*	0.191	0.059	-0.586**
%moisture					0.537**	-0.730***	-0.749***	0.667**	-0.162	0.653**	0.026	0.011	0.630**	0.462**	-0.792***	0.692**	-0.579**	-0.080	0.130	0.820***
%protein						-0.727**	-0.658**	0.557**	0.047	0.637**	-0.015	-0.149	0.603**	0.321*	-0.385**	0.795***	-0.171	-0.425**	-0.303*	0.425**
IMG2							0.778***	-0.714***	0.066	-0.754***	0.061	0.068	-0.669**	-0.471**	0.585**	-0.802***	0.369**	0.255*	0.106	-0.640**
VIS								-0.703***	0.118	-0.645**	0.016	-0.020	-0.614**	-0.501**	0.689**	-0.820***	0.469**	0.372**	0.029	-0.744***
WBSF									-0.249	0.604**	-0.104	0.075	0.510**	0.471**	-0.676**	0.688**	-0.544**	-0.212	0.011	0.629**
REA										0.122	-0.175	-0.151	0.015	-0.178	0.332*	-0.102	0.435*	0.343*	-0.298*	-0.247
Hardness											-0.185	-0.063	0.833***	0.571**	-0.451**	0.682**	-0.193	-0.163	-0.234	0.591**
cohensive												-0.263*	0.372*	0.137	0.029	0.023	-0.012	-0.018	-0.016	0.003
springiness													-0.207	0.583**	-0.138	-0.135	-0.293*	0.073	0.383**	0.119
gumminess														0.610**	-0.406**	0.645**	-0.185	-0.163	-0.277	0.569**
chewiness															-0.420**	0.407**	-0.332**	-0.052	0.142	0.538
L*																-0.50**	0.735***	0.026	-0.330*	-0.763***
a*																	-0.322*	-0.506**	-0.205	0.579**
b*																		0.083	-0.377**	-0.635**
WHC																			0.291*	-0.083
thawing																				0.195
grilling																				0.000

*Significant correlation ($p \leq 0.05$), **Significant correlation ($p \leq 0.01$), ***Significant correlation ($p \leq 0.001$)

Table 14 Correlations of meat quality on fattening dairy steers (HFM) (n=20)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
MBS	-0.370	0.010	0.678**	-0.694**	-0.841***	0.743***	1.000***	-0.758***	-0.102	-0.601**	-0.126	0.091	-0.599**	-0.424	0.883**	-0.878**	0.773**	0.662**	0.132	-0.716**
pH45		0.141	-0.121	0.279	0.206	0.057	-0.370	0.122	0.029	0.136	0.278	-0.229	0.344	0.069	-0.347	0.294	-0.470*	-0.294	-0.060	0.296
pH7			-0.449*	0.136	0.312	-0.184	0.010	0.423	-0.099	0.241	-0.199	0.100	0.036	0.144	-0.077	0.250	-0.331	-0.292	-0.009	0.155
%Fat				-0.747***	-0.819***	0.803***	0.678**	-0.756***	-0.065	-0.556*	0.000	0.029	-0.460*	-0.369	0.660**	-0.823**	0.648**	0.524*	0.226	-0.584**
%Moist					0.694**	-0.691**	-0.694**	0.647**	-0.166	0.311	0.177	-0.199	0.396	0.151	-0.775**	0.762**	-0.742**	-0.641**	0.071	0.676**
%Protein						-0.888***	-0.841***	0.911***	0.001	0.751***	-0.125	-0.153	0.522*	0.347	-0.887**	0.939**	-0.828**	-0.740	-0.251	0.692**
IMG2							0.743***	-0.798***	-0.058	-0.775***	0.073	0.127	-0.577**	-0.418	0.795**	-0.882**	0.731**	0.609**	0.176	-0.712**
VIS									-0.102	-0.601**	-0.126	0.091	-0.599**	-0.424	0.883**	-0.878**	0.773**	0.662**	0.132	-0.716**
WBSF										0.680**	-0.182	-0.179	0.424	0.260	-0.760**	0.871**	-0.767**	-0.662**	-0.218	0.621**
REA											-0.178	0.288	-0.148	0.044	-0.038	0.021	0.092	0.169	-0.276	0.035
Hardness												-0.048	0.693**	0.597**	-0.581**	0.716**	-0.648**	-0.502*	-0.169	0.476*
Cohensiv												-0.320	0.585**	0.217	0.032	-0.105	0.043	0.073	0.167	0.248
Springines													-0.261	0.549	0.083	-0.187	0.131	0.239	0.526*	-0.009
Gummine														0.651**	-0.465*	0.509*	-0.521*	-0.355	-0.001	0.600**
Chewines															-0.321	0.302	-0.353	-0.110	0.392	0.491*
L*																-0.905**	0.824**	0.758**	0.036	-0.826**
a*																	-0.839**	-0.752**	-0.275	0.712**
b*																		0.739**	-0.019	-0.703**
WHC																			0.047	-0.488*
thawing																				0.153
grilling																				0.000

*Significant correlation (p≤0.05), **Significant correlation (p≤0.01), ***Significant correlation (p≤0.001)

Table 15 Correlations of meat quality on culled dairy cows (HFF) (n=20)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
MBS	-0.030	0.070	0.610**	-0.848***	-0.148	0.820***	0.931***	-0.758***	0.088	-0.731***	0.248	-0.035	-0.589**	-0.353	0.821***	-0.587**	0.676**	-0.726***	-0.332	-0.884***
pH45		0.725**	0.020	0.013	-0.128	0.182	0.072	-0.286	0.596**	-0.073	-0.171	-0.172	-0.238	-0.409	-0.132	0.103	-0.193	0.065	0.226	-0.025
pH7			0.029	-0.072	-0.205	0.270	0.229	-0.256	0.463*	-0.160	-0.164	-0.315	-0.280	-0.613**	0.065	-0.186	-0.173	-0.057	-0.055	-0.191
%Fat				-0.787***	-0.309	0.639**	0.730**	-0.585**	0.314	-0.488*	0.075	0.063	-.787**	-0.312	-0.715***	-0.627**	0.487*	-0.761***	-0.746***	-0.746***
%moist					0.296	-0.809***	-0.862***	0.811***	-0.193	0.830***	-0.101	0.012	0.779***	0.461*	-0.935***	0.801***	-0.711***	0.913***	0.550*	0.916***
%protein						-0.298	-0.226	0.065	-0.445*	-0.021	0.127	0.006	0.130	0.039	-0.346	0.182	-0.405	0.381	0.361	0.298
IMG2							0.818***	-0.706***	0.360	-0.697**	0.028	0.056	-0.671**	-0.404	0.754***	-0.660**	0.641**	-0.774***	-.0363	-0.769***
VIS								-0.802***	0.173	-0.707***	0.221	-0.150	-0.584**	-0.535*	0.872***	-0.698**	0.661**	-0.822***	-0.478*	-0.938***
WBSF									-0.281	0.771***	-0.152	0.113	0.699**	0.536*	-0.764***	0.655**	-0.596**	0.713***	0.313	0.786***
REA										0.063	-0.290	0.029	-0.164	-0.239	0.107	-0.179	0.115	-0.138	-0.017	-0.206
Hardness											-0.260	0.036	0.834***	0.520*	-0.759***	0.627**	-0.497*	0.727***	0.347	0.724***
cohensiven												-0.312	0.298	0.080	0.156	0.115	0.149	-0.044	-0.305	-0.177
springiness													0.080	0.623**	-0.047	0.078	-0.196	0.078	0.145	0.141
gumminess														0.565**	-0.662**	0.667**	-0.408	0.703***	0.167	0.652**
chewiness															-0.430	0.539*	-0.254	0.505*	0.202	0.522*
L*																-0.845***	0.769***	-0.911***	-0.571**	-0.915***
a*																	-0.522*	0.829***	0.498*	0.743***
b*																		-0.752***	-0.366	-0.730***
WHC																			0.591**	0.885***
thawing																				0.527*
grilling																				0.000

*Significant correlation (p≤0.05), **Significant correlation (p≤0.01), ***Significant correlation (p≤0.001)

This result showed that breed factor did not affect moisture percentage. HFM and HFF groups did not differ in protein percentage ($p>0.05$), but CHA group had higher protein percentage than others ($p<0.05$). Moreover, HFF group with both marbling score did not differ in protein percentage ($p>0.05$). Bartoň and Bureš (2010) also reported that protein content of Czech Fleckvieh was significant higher than that of Charolais breed (211.8, and 206.2g/kg, respectively). The result showed that breed with high fat percentage had decreased protein percentage which corresponding to Ueda et al. (2007) reported that protein content has a negative correlation with fat content.

Marbling score factor had affected to moisture, protein and fat percentages ($p<0.05$) that MBS≥3 group had lower moisture and protein percentage while MBS≥3 group had higher fat percentage than MBS<3 group which was corresponding to Oler et al. (2015) who found that MBS≥3 group had affected to moisture and fat percentage while marbling score increased, moisture percentage decreased.

Moreover, the interaction of breed and marbling score had affected to chemical composition ($p<0.05$). The result showed that of all breed with MBS≥3 had lower moisture percentage which was inversed to fat percentage. Protein percentage of CHA with MBS<3 was higher than those of HFM and HFF. Beef-breed as CHA had capability for protein accretion while dairy-breed had mainly utilized more nutrients to build up fat depots.

4. Water holding capacity (%), thawing loss (%), and cooking loss (%)

WHC was not affected by breed ($p>0.05$). Significant difference in cooking loss (%) between CHA and HFF groups was found (19.54 vs. 20.58%). Waritthitham et al. (2010) reported that Charolais meat had a better water-holding capacity (less ageing, thawing and grilling loss) compared with Brahman so the percentages of slow- and fast-twitch fibers of LD muscle of Brahman and Charolais were 25.8 and 74.2%, 23.0 and 77.0%, respectively which CHA showed great fast-twitch fibers. Therefore, the percentage of slow- twitch fibers was positively correlated with cooking loss, whereas an inverse relation between percentages of fast-twitch fibers was observed. Moreover, Maltin et al. (2001) who found LD muscles of Charolais cattle had slow-

twitch fibers of 22.5% and fast-twitch fibers of 77.5%. However, slow- and fast-twitch fibers of LD muscle HF steer were 21.2% and 78.8%, respectively. Ozawa et al. (2000); Maltin et al. (2001) reported salers, Japanese Black and Holstein of slow- (21 to 29%) and fast-twitch fibers (71 to 79%) of LD muscle from salers, Japanese Black and Holstein have been described.

HFF group had higher thawing loss than CHA and HFM groups (5.01, 5.62 and 6.77, respectively) ($p<0.05$). Wegner et al. (2000) reported that Holstein Friesian (as a dairy type) had lower muscle fiber cross-sectional area than German Angus (as a beef type) (6,631 and 4,812 μm^2, respectively). The correlation between cross-sectional area and water holding capacity indicated that muscles with small fiber areas had high drip, thaw and ageing loss but low cooking and grilling loss (Waritthitham et al., 2010).

Beef with MBS≥3 group had higher WHC than beef with MBS<3 (43.63 vs. 53.21%), which was corresponded with Kim and Lee (2003) who investigated that drip loss of grade 1 beef Korean native beef with 9.87 % crude fat had lower drip loss of grade 3 beef (6.13 % crude fat) ($p<0.05$). Beef with MBS<3 showed higher cooking loss than beef with MBS≥3, (21.80 and 18.45%, respectively). This result was in agreed with Ozawa et al. (2000) who reported that the cooking loss of Japanese black steers was significantly lower in the highest marbling score beef.

Interaction of breed and marbling score had affected 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. Beef with MBS<3, HFF had higher thawing loss than CHA and HFM groups but beef with MBS≥3, HFM group had lower than CHA and HFF groups. HFM showed lowest thawing loss. As similar to Jung et al. (2015), they revealed that highly marbled beef showed less drip loss and cooking loss. Cho et al. (2005) reported that water-holding capacity and chemical composition of meat were influenced by IMF. As IMF was increased from 6.6% to 21.5%, moisture content was declined. Consequently, drip loss and water lost during cooking were lower in meat with high IMF (Frank et al., 2016). Aaslying et al. (2003) explained that cooking loss was combination of liquid and soluble matters which was apart from muscle, since thermal processing accelerated protein degradation and meat could not retain water

in the protein structure during cooking, which was a cause of less water in the muscle structure.

5. Warner-Bratzler shear force; WBSF

Warner-Bratzler shear force (WBSF) of HFF group showed lower than HFM group (5.56 and 6.07 kg, respectively) ($p<0.05$), but HFF group did not different with CHA group (5.56 and 5.78 kg, respectively) ($p>0.05$). This result showed that breed factor had affecting on beef tenderness which was consistent with Bureš and Bartoň (2012) found that breed factor had affected to shear force. Shear force values of Aberdeen Angus, Gascon, Holstein and Czech Fleckvieh were 36.0, 46.8, 58.5, 49.8 Newtons.

Meenongyai (2014) explained that factors affected to meat tenderness were breed, gender, age and marbling score (intramuscular fat content). The important factor was age of animal. The youth or maturity cattle had accreted muscle structure almost completely. The connective tissue had less intermolecular crosslink which had not resistance to biting and grinding of human teeth while chewing (Shutirak, 2017). Geesink et al. (1995) studied on WBSF of Friesian-Holstein cows, aged 3-11 years old, aging for 7 day showed high WBSF value (8.2 kg/cm^2). Sukjai et al. (2012) found that WBSF of culled dairy cow without fattening was 7.14-7.68 kg. Setthakul et al. (2012) reported that beef from dairy steer aged 3 years old, fed concentrate with pineapple by-product for 8 months had 3.9 kg of WBSF (7 aging day). Moreover, Prom-in (2005) revealed that beef from Charolais crossbred, aged 2 years old, fed by concentrate and roughage for 10 months aging 7 days had 4.9 kg of WBSF. However, the WBSF in this study had rather higher than due to age of fattening dairy steer (3-5 years old).

Moreover, Hanzelková et al. (2011) explained that meat tenderness was influenced by the genetic makeup of cattle. There is major interest in genetic selection in order to decrease problems with meat tenderness variation. Intramuscular fat content had influenced by genetic which showed that *Bos indicus* cattle had higher *calpastatin* activity compared to *Bos taurus* cattle, *Calpastatin* is the endogenous inhibitor specific to *calpain* which it would be inhibit the *calpain*

activity in postmortem muscle. However, *calpains* is importance to the tenderization of meat by breaking down part of the myofibrillar component of the muscle. So, *Bos Taurus* cattle had tendency greater tenderness and eating quality than *Bos indicus* cattle (Warner et al., 2004).

MBS≥3 group had significant lower WBSF ($p<0.05$). This result showed that high marbling score of beef were more tender. Mitsumoto et al. (1992) concluded that muscles containing large amount of intramuscular fat had a lower shear value and lower cooking loss than those containing a small amount of intramuscular fat. Moreover, Gregory et al. (1994) found that marbling score had negative correlation with WBSF and also had positive correlation with the score of tenderness and juiciness. This study indicated that fat percentage increased, WBSF value was decreased in CHA and HFF groups. In contrast, Okumura et al. (2007); Kim and Lee (2003) reported that marbling score did not affect to Warner-Bratzler shear force. Kuntapanit (1986) reported that intramuscular fat content did not directly affected to meat tenderness, but it would act as lubricant while chewing which it was feeling like the meat texture tender. Albrecht et al. (2006) reported that intramuscular fat was indicators of meat palatability which it would be stimulated the secretion of saliva which caused a juicy feeling in the mouth.

Moreover, the interaction of breed and marbling score also had affected on WBSF value ($p<0.05$). Beef with MBS<3, CHA and HFM groups had higher WBSF value than HFF group ($p<0.05$) while beef with MBS≥3, CHA, HFM and HFF groups did not differ in WBSF value (5.06, 5.21 and 5.25 kg, respectively) ($p>0.05$). This result showed that WBSF value of HFF had greatest which is indicated that HFF beef had more tender.

6. Texture profile analysis; TPA

Texture profile analysis (TPA) is simulated the mechanical process of mastication which this objective method measures the compression force of a probe and the related textural parameters of a test food during two cycles of deformation (Caine et al., 2003). The result of this study found that breed factor affected on hardness, springiness, gumminess and chewiness. Hardness and Gumminess of HFF group had significant lower than CHA and HFM groups which corresponding with fat

percentage of HFF group had greater than CHA and HFM groups (8.69, 7.58, 7.73%, respectively). Hardness of beef in this study rather low (1.16 kg) compared with Franco et al. (2007) who reported that beef from culled dairy cow, fattening for 2 months and 7 aging day, had 16.24 kg/cm^2 of hardness and was consist with Brady and Hunecke (1985) who measured hardness of roast beef by compression-hardness method at endpoint temperature 70 °C which the hardness was 24.59 kg but hardness of this study had similar with Brady and Hunecke (1985) reported that hardness was 1.89 kg when the hardness was measured by penetration-hardness method. In this study was measured by using cylinder probe and diameter was 6 mm. Sample size of beef was 1.3 x 1.3 x 2.5 cm. As the result, the measurement of the hardness resembled penetration so the hardness value was low and similar to Brady and Hunecke (1985); Huidobro et al. (2002) reported that the value of hardness from grilled beef at 80 degrees celcius of core temperature was 66.55 N or 6.66 kg/cm^2 which had higher than this study (1.06-1.56 kg/cm^2). High temperature of grilling caused to lose moisture and shrink. As the result, grilled beef became harder. The higher of temperature and the longer grilling time had affected on hardness.

Gumminess of CHA, HFM and HFF groups was 0.72, 0.73 and 0.62 kg, respectively. HFF group had lower gumminess than CHA and HFM groups ($p<0.05$). This result was different from Franco et al. (2007) who studied gumminess of beef from culled cows was 7.88 kg/cm^2. Beef with MBS≥3 had lower gumminess than beef with MBS<3. HFF and HFM groups had significant higher springiness and chewiness than CHA group. Springiness of HFF group was 0.62 which was closed to the study of Franco et al. (2007) who found that springiness of culled dairy beef was 0.52. However, chewiness was low due to calculation from the value of hardness* cohesiveness* springiness, as the result, chewiness values was different from Franco et al. (2007). Marbling score had effected on the values of hardness, gumminess and chewiness. MBS≥3 group had lower the values of hardness, gumminess and chewiness than MBS<3 group. The interaction of breed and marbling score was not detected.

Correlation of meat quality, WBSF, TPA, color value and WHC of CHA, HFM and HFF groups were shown in Table 12-15. Fat percentage had positively correlated on

image processing technique assessment (IMG2), human visual appraisals (VIS) and lightness (L*) (r=0.735, 0.675, 0.553, 0.287, respectively; p<0.01) and fat percentage had negatively correlated on hardness (r=-0.630, p<0.01). WBSF had positively correlated with hardness, gumminess, chewiness, redness and grilling loss. Image processing technique assessment (Level score; IMG2) had positively correlated with human visual appraisals (VIS) MBS of CHA group had positively correlated with on fat percentage, IMG2, VIS, lightness (L*), yellowness (b*) and WHC (r=0.783, 0.986, 0.662, 0.456 and 0.387, respectively; p<0.01) but had negatively correlated with WBSF and grilling loss (r= -0.692 and -0.722; p<0.01). Fat percentage of CHA group had positively correlated with IMG2, VIS and lightness (L*) (r=0.735, 0.675, 0.553; p<0.01) but had negatively correlated with hardness, gumminess, chewiness and grilling loss (r=-0.630, -0.587,-0.406 and -0.586, respectively; p<0.01). Fat percentage of CHA group had a positively correlated with yellow (b*) (r=0.287; p<0.05). WBSF of CHA group had positively correlated with hardness and gumminess (r=0.604, 0.510 and 0.471, respectively; p<0.01). Image processing technique assessment (Level score; IMG2) had positively correlated with human visual appraisals (VIS), lightness (L*) and yellow (b*) (r=0.778, 0.585, and 0.369, respectively; p<0.01). IMG2 of CHA group had negatively correlated with WBSF and hardness (r=-0.714 and -0.754; p<0.01) (Table 13).

MBS of HFM group had positively correlated with fat percentage, IMG2, VIS, lightness (L*), yellowness (b*) (r=0.678, 0.743, 1.000, 0.883 and 0.773, respectively; p<0.01) (Table 14). Fat percentage of HFM group had positively correlated with IMG2, VIS, lightness (L*) and yellowness (b*) (r=0.803, 0.678, 0.660 and 0.648, respectively; p<0.01). Fat percentage also had negatively correlated with WBSF and hardness (r= -0.756 and -0.556, respectively; p<0.01). WBSF of HFM group had positively correlated with hardness (r=0.680; p<0.01).

MBS of HFF group had positively correlated with fat percentage, IMG2, VIS, lightness (L*) and yellowness (b*) (r=0.610, 0.820, 0.931, 0.821 and 0.676, respectively; p<0.01) and had negatively correlated with WBSF and hardness (r=-0.758 and -0.731, respectively; p<0.01) (Table 15). Fat percentage of HFF group had positively correlated with IMG2 and VIS (r=0.639 and 0.730, respectively; p<0.01). Fat

percentage also had negatively correlated with WBSF and hardness (r=-0.585 and -0.488, respectively; p<0.01). WBSF of HFF group had positively correlated with hardness, gumminess and gumminess (r=0.771, 0.699, 0.536, respectively; p<0.01).

7. Relationships of marbling score grading between marbling score by human visual appraisal (VIS) and image processing technique (IMG)

The average marbling score by human visual appraisal (VIS), %marbling fat (IMG1), level score (IMG2) and fat percentage of chemical analyze were 2.62, 9.98, 2.51 and 7.54, respectively (Table 16).

Positive and linear relationships of marbling score grading between human visual appraisal (VIS) and image processing technique (IMG) were found on %marbling fat (IMG1) and level score of image processing technique (IMG2). Marbling score grading by human visual appraisal (VIS) had positively correlated with image processing technique (IMG1) (r=0.708; p<0.01). The marbling score by human visual appraisal (VIS) had positively correlated with level score of image processing technique (IMG2) (r=0.778; p<0.01). Moreover, the marbling score by human visual appraisal (VIS) had positively correlated with fat percentage (r=0.675; p<0.01). %Marbling fat (IMG1) had positively correlated with fat percentage (r=0.680; p<0.01). Level score (IMG2) had also positively correlated with fat percentage (r=0.73; p<0.01) (Table 17). This study showed that application of image processing technique (IMG) could be useful as a tool for marbling score grading in order to minimize human mistakes and bias

Table 16 Descriptive statistics of marbling score by human visual appraisals (VIS) and image processing technique (IMG) assessments on beef steak (n=60)

	N	Minimum	Maximum	Mean	Std. deviation
IMG1	60	2.90	17.40	9.98	3.28
IMG2	60	1.00	4.00	2.51	0.778
VIS	60	1.00	4.00.	2.62	0.783
%IMF	60	4.66	10.25	7.54	1.483

VIS=Human visual appraisals; IMG1=Image processing technique on %marbling fat; IMG2=Image processing technique on level score; %Fat= fat percentage (chemical analysis)

Table 17 Correlations of human visual appraisals (VIS) and image processing technique (IMG) assessments on beef steak (n=60)

	IMG1	IMG2	VIS	%Fat
IMG1	-	0.880**	0.708**	0.680**
IMG2	-	-	0.778**	0.735**
VIS	-	-	-	0.675**

*Significant correlation ($p \leq 0.05$), **Significant correlation ($p \leq 0.01$), ***Significant correlation ($p \leq 0.001$)

VIS=Human visual appraisals; IMG1=Image processing technique on %marbling fat; IMG2=Image processing technique on level score; % Fat= fat percentage (chemical analysis)

8. Fatty acid profile of raw and grilled beef

Breed, marbling score, and interaction factors had influence on fatty acid composition in raw beef (Table 18). Raw beef of CHA and HFF groups had higher C10:0, C12:0, C14:0, C18:1n9c, C18:3n6, C18:3n3 than HFM group ($p<0.05$) but HFM group had greater C20:4n6 than CHA and HFF groups ($p<0.05$). Beef of CHA and HFF groups had distinguished on saturate fatty acids (SFA), especially myristic acid (C14:0), palmitic acid (C16:0) and steric acid (C18:0). Moreover, 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 (Westerling & Hedrick, 1979; Larick & Turner, 1990). In the part of polyunsaturate fatty acids (PUFA), particularly Ɣ-linolenic acid (C18:3n6), Linolenic acid (C18:3n3) had distinguished on CHA and HFF groups which the both of MUFA and PUFA had efficacy to reduce cholesterol levels in the blood. However, HFM group showed higher arachidonic acid (C20:4n6) than CHA and HFF groups which

increased arachidonic acid content in adipose tissue had been associated with a higher risk of coronary artery disease (Seah et al., 2017).

In addition, 30% of fatty acid content in beef was oleic acid (C18:1n9c) which oleic acid (C18:1n9c) was the main fatty acid in the intramuscular fat in cattle; it had been positively correlated with cooked beef fat flavor (Larick & Turner, 1990). The PUFA-n3 of CHA group was greater than others and HFM group had PUFA-n3 greater than HFF group ($p<0.05$). The ratio of PUFA/SFA, MUFA/SFA, n-6/n-3 of CHA group had lower than HFM and HFF group ($p<0.05$). The ratio of PUFA/SFA and n-6/n-3 were main nutritional indices which had implicated on cancers and coronary heart disease. The recommendation of PUFA/SFA ratio should be increased to above 0.4. Normally, the PUFA/SFA ratio of beef was low at around 0.1, except for double-muscled animals which were very lean (<1% intramuscular fat) where PUFA/SFA ratio were typically 0.5-0.7. However, intramuscular fat content was negatively correlated with PUFA/SFA ratio (Scollan, 2003). However, this result revealed that PUFA/SFA ratio of all groups were lower (0.030-0.090) than intake's recommendation by Department of health. The ratio of n-6/n-3 was indicator of risk factor on cancers and coronary heart disease, especially the formation of blood colts leading to a heart attack (Wood et al., 2003). The n-6/n-3 ratio of CHA group was greater than HFM and HFF groups (3.169, 5.099, 6.169, respectively) ($p<0.001$). n-6/n-3 ratio of CHA group was similar with German recommendation that consumer should decrease the n-6/n-3 ratio in the diet to levels ≤5:1. The ratio of n-6/n-3 in HFM, HFF groups in this study was similar with Hollo et al. (2001) who reported that the ratio of n-6/n-3 fatty acids of Holstein-Friesian was 7.085. Therefore, the influence of breed on fatty acid composition was confirmed by De Smet et al. (2004) who revealed that difference of fatty acid composition between breeds arise due to the difference of gene expression or enzymatic activity involving in fatty acid synthesis.

Marbling score had influenced on fatty acid composition of raw 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, saturated fatty acid (SFA) and monounsaturated fatty acids (MUFA) than beef with MBS<3 ($p<0.05$). Therefore, this study indicated that oleic acid (C18:1n9c) increased as increasing marbling score De

Smet et al. (2004) reported that difference in fat content had an influence on fatty acid composition. Specially, oleic acid (C18:1n9c), main fatty acid in the intramuscular fat of cattle and sheep, showed positive correlation with cooked beef fat flavor (Larick & Turner, 1990). Oleic acid had beneficial for decreasing plasma total cholesterol and total low-density lipoprotein cholesterol in humans (Grundy, 1989). The content of SFA and MUFA were increased with increasing fatness, leading to a decrease in the relative proportion of PUFA and PUFA/SFA ratio. Moreover, Hwang and Joo (2017) reported that sensory overall palatability was positively correlated with the proportion of MUFA but was negatively correlated proportions of SFA and polyunsaturated fatty acid PUFA. In particular, the proportion of oleic acid was strongly and positively correlated with fat content ($r=0.91$, $p<0.001$).

In addition, MBS≥3 group had lower C20:1, C24:1, C20:3n3, C20:4n6 and PUFA/SFA ratio than MBS<3 groups ($p<0.05$). De Smet et al. (2004) reported that the intramuscular fat (%) were affected to PUFA/SFA ratio which was agreed with Cho et al. (2005) who reported that Korean Hanwoo (11.29%) and Australian Angus beef (5.72 %fat) found that PUFA/SFA ratio of LD was 0.06 and 0.16 respectively which high intramuscular fat of Korean Hanwoo was similar in this studied (0.03). For the PUFA/SFA ratio of MBS≥3 group was inferior compared with MBS<3 group. De Smet et al. (2004) explained that beef was normally low PUFA/SFA ratio compared with pork because of the bio-hydrogenation of unsaturated fatty acids in the rumen. Hence, the PUFA/SFA ratio of beef could be drop to a value of 0.05 in fat breeds such as Wagyu breed and could be rise to more than 0.5 in very lean breeds such as double-muscled animals. Warren et al. (2008) also revealed that among non-nutritional factors, age was an important factor affecting fatty acid composition. The progress of age resulting in the increase of, subcutaneous tissue and muscle fat contents while the ratio of polyunsaturated (PUFA) to saturated (SFA) fatty acids declined. Kazala et al. (1999) revealed that C16:0 and C18:0 of steer were higher than heifer, in other hand, C18:1n9c (oleic acid) of heifer were higher than steer (43.65 and 41.63, respectively; $p<0.05$) which similar to our study that C16:0 and C18:0 of CHA group were higher than HFF group (46.54 and 43.71 respectively), but C18:1n9c of both CHA and HFF groups did not differ. Hwang and Joo (2017) revealed that

Hanwoo beef with high fat percentage (25.39%) had higher C18:1c9 (oleic acid) than Hanwoo beef with low fat percentage (5.94%). MBS≥3 group had higher oleic acid than MBS<3 group which similar with Hwang and Joo (2017).

The interaction of breed and marbling score had affected on fatty acid composition of C14:0, C15:0, C20:0, C17:1, C20:1, C18n:2n6t, C20:3n3, C20:4n6, PUFA-n3 and n6/n3 ratio ($p<0.05$). SFA of C14:0, C15:0, C20:0 had high content in MBS≥3 of HFF group. However, MBS<3 of HFM group was a notable on C20:4n6. The both MBS of CHA group and MBS<3 of HFM group had great PUFA-n3 and n-6/n-3 ratio. This result showed that the interaction of breed and marbling score had affected on the important fatty acid composition as oleic acid, linoleic acid, linolenic acid and arachidonic acid.

Breed, marbling score, and interaction factors had influence on fatty acid composition in grilled beef (Table 19). Grilled beef of HFM group had significant different higher C12:0 (Lauric acid), C14:0 (myristic acid), C16:0 (palmitic acid), C17:0 (heptadecanoic acid), C18:0 (steric acid), C16:1 (palmitoleic acid), C18:1n9c (oleic acid), SFA, MUFA, n3 than CHA and HFF groups ($p<0.05$). HFM and HFF groups had greater C18:1n9c (oleic acid) than CHA group ($p<0.05$). Therefore, this result indicated grilling beef had decreased C14:0, C16:0, C18:0, C16:1, C18:1n9c, SFA MUFA and PUFA-n3 compared with raw beef which was corresponding to Slover et al. (1987) revealed that cooked beef C14:0, C16:0, C18:0, C16:1, C18:1n9c and C18:2n6 had lower than raw beef. Duckett and Wagner (1998) reported that cooking reduced percentages of palmitic acid (C16:0) and oleic acid (C18:1n9c). Overall, cooking reduced the content of oleic, linoleic, and linolenic acids and increased stearic acid content with no change in myristic or palmitic acids. These changes in the percentage of the various 18-carbon fatty acids indicate that oxidation occurred during cooking.

Grilled beef of CHA and HFF groups were increased SFA and MUFA compared with raw beef of them but there was no change in HFM group. Thus, the study revealed that grilled beef of HFM group had the greatest C18:1n9c, MUFA and PUFA-n3. It could be concluding that grilled beef of HFM group had excellent C18:1n9c PUFA-n3 and n-6/n-3 ratio. Consumption cooked beefsteak of HFM would contribute

increased overall palatability and reduced the cholesterol level in blood (Meeprom, 2013). MUFA of HFM group were higher than those of CHA group (44.98 and 32.69, respectively; $p<0.05$). Moreover, MUFA/SFA ratio of HFM and HFF groups showed greater than those of CHA group ($p<0.05$). The n6/n3 ratio of HFM group had the greatest (5.54) compared with CHA and HFF groups (10.41 and 10.02, respectively). Additionally, after cooking HFH group had increased SFA content resulted in lower PUFA/SFA ratio of HFM group compared to CHA and HFF groups ($p<0.05$).

Marbling score had influenced on fatty acid composition of grilled beef ($p<0.05$). MBS<3 group had significant higher C20:0 (Arachidic acid), C21:0, C14:1 (Myristoleic acid), C16:1 (Palmitoleic acid), C17:1 (Heptadecenoic acid), C22:1n9, C18:2n6t (Linolelaidic acid), C20:3n3, C20:5n3 (Eicosapentaenoic acid) and MUFA/SFA than MBS≥3 group ($p<0.05$). Especially, C14:1 and C16:1 fatty acid showed the highest in MBS<3 group. MBS≥3 group had significant greater C10:0 (Capric acid), C15:1 (Pentadecenoic acid), C18:3n3 (Linolenic acid), C20:2 (Eicosadienoic acid), C22:2n2 (Docosadienoic acid), and C22:6n3 (Docosahexaenoic acid) than MBS<3 group ($p<0.05$). MUFA/SFA of MBS<3 had significant higher than MBS≥3 (1.04 and 0.93; $p<0.05$). Meeprom (2013) reported that MUFA/SFA ratio of steer was 0.83. After finishing for 4 months, MUFA/SFA ratio was increased to 1.04 because increasing of intramuscular fat in beef had resulted from marbling adipocyte expanding. Therefore, increasing marbling adipocyte was increased intracellular MUFA due to high oleic acid accumulation. Ruminant animal had high oleic acid content in tissue from finishing diet (St. John et al., 1987).

The interaction of breed and marbling score had influence on fatty acid composition of C12:0, C14:0, C18:0, C20:0, C21:0, C14:1, C15:1, C16:1, C18:1n9c, C24:1, C18:3n6, C18:3n3, C20:5n3, C22:2n2, C22:6n2, SFA, MUFA, n3, PUFA/SFA ratio, MUFA/SFA ratio and n6/n3 ratio ($p<0.05$). SFA of C12:0, C14:0, C18:0, C20:0, C21:0, C22:0, C23:0 had high content in MBS≥3 of HFM group. MBS≥3 of HFM group had higher content on MUFA of C14:1, C16 and C18:1n9c than the others. MBS≥3 of HFM group had higher content on total SFA, MUFA and n3 than the others. MBS<3 of CHA and HFF groups had greater PUFA/SFA ratio than the other (0.040 and 0.043, respectively). CHA and HFM groups had greater n6/n3 ratio the others (6.730 and

4.887, respectively). This result showed that the interaction of breed and marbling score had affected on the important fatty acid compositions as myristic acid, steric acid, palmitoleic, oleic acid and linolenic acid.

Table 18 Fatty acid profiles in raw beef of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with different breed and marbling score

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}	0.005	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}	0.010	0.012	0.001	0.213
C14:0	Myristic acid	5.29^{a}	3.92^{b}	4.88^{a}	0.196	3.99^{b}	5.40^{a}	0.160	0.001	0.001	0.020
C15:0		0.36	0.34	0.35	0.036	0.31	0.38	0.029	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}	0.685	0.001	0.001	0.226
C17:0		5.39	4.79	5.53	0.277	5.13	5.34	0.226	0.175	0.529	0.587
C18:0	Steric acid	16.35^{a}	10.96^{c}	13.91^{b}	0.702	12.41^{b}	15.06^{a}	0.573	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}	0.007	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	0.084	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}	0.240	0.022	0.001	0.286
C17:1		0.66^{a}	0.55^{a}	0.95^{a}	0.039	0.64^{b}	0.80^{a}	0.032	0.001	0.006	0.001
C18:1n9t	Elaidic acid	1.02^{a}	0.78^{b}	1.15^{a}	0.080	0.83^{b}	1.14^{a}	0.065	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}	1.152	0.001	0.001	0.267
C20:1		0.14^{a}	0.09^{b}	0.09^{b}	0.008	0.12^{a}	0.10^{b}	0.006	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}	0.007	0.033	0.007	0.068
PUFA											

Table 18 (Continued)

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
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	0.001	0.006	0.001
C20:4n6	Arachidonic acid	0.20^{b}	0.44^{a}	0.20^{b}	0.023	0.38^{a}	0.18^{b}	0.019	0.001	0.001	0.001
SFA		62.14^{a}	44.98^{c}	50.54^{b}	1.371	46.26^{b}	58.85^{a}	1.119	0.001	0.001	0.481
MUFA		53.79^{a}	43.18^{b}	51.72^{a}	1.553	44.21^{b}	54.92^{a}	1.268	0.001	0.001	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	0.001	0.505	0.001
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	0.001

[a,b,c] Means with different superscripts are significantly different ($p<0.05$) between the breeds, marbling score and interaction.

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, C20:3n3

Table 19 Fatty acid profiles in grilled beef of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with different breed and marbling score

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
C10:0	Capric acid	0.05	0.05	0.04	0.003	0.04^{b}	0.05^{a}	0.003	0.069	0.019	0.191
C12:0	Lauric acid	0.10^{b}	0.16^{a}	0.09^{b}	0.007	0.12	0.11	0.005	0.001	0.570	0.011
C14:0	Myristic acid	3.06^{b}	4.24^{a}	2.69^{b}	0.192	3.26	3.40	0.156	0.001	0.536	0.030
C15:0	Pentadecanoic acid	0.19^{b}	0.30^{a}	0.20^{b}	0.017	0.24	0.22	0.014	0.001	0.168	0.076
C16:0	Palmitic acid	23.21^{b}	29.52^{a}	23.99^{b}	1.569	24.76	26.39	1.281	0.029	0.386	0.097
C17:0	Heptadecanoic acid	3.89^{b}	5.54^{a}	4.69^{b}	1.162	4.60	4.82	0.132	0.001	0.248	0.001
C18:0	Steric acid	9.34^{b}	10.99^{a}	9.84^{b}	0.312	9.68	10.43	0.255	0.008	0.060	0.001
C20:0	Arachidic Acid	0.06	0.10	0.07	0.010	0.09^{a}	0.06^{b}	0.009	0.080	0.021	0.001
C21:0		0.05^{b}	0.10^{a}	0.05^{b}	0.010	0.10^{a}	0.04^{b}	0.008	0.002	0.001	0.002
C22:0	Behenic Acid	0.05^{b}	0.09^{a}	0.08^{a}	0.008	0.08	0.07	0.007	0.010	0.496	0.001
C23:0	Tricosanoic Acid	0.07^{b}	0.10^{a}	0.03^{b}	0.012	0.08	0.06	0.010	0.005	0.140	0.002
C24:0	Lignoceric Acid	0.04	0.04	0.06	0.008	0.05	0.04	0.007	0.199	0.319	0.489
C14:1	Myristoleic acid	0.81^{b}	1.50^{a}	0.86^{b}	0.071	1.15^{a}	0.96^{b}	0.058	0.001	0.041	0.006
C15:1	Pentadecenoic acid	0.05^{a}	0.03^{b}	0.03^{b}	0.007	0.03^{b}	0.05^{a}	0.006	0.031	0.021	0.003
C16:1	Palmitoleic acid	3.16^{b}	5.74^{c}	3.99^{a}	0.220	4.79^{a}	3.79^{b}	0.179	0.001	0.002	0.001
C17:1	Heptadecenoic acid	0.34^{b}	0.51^{a}	0.41^{b}	0.028	0.48^{a}	0.36^{b}	0.023	0.003	0.002	0.075
C18:1n9t	Elaidic acid	0.57^{b}	0.90^{a}	0.77^{a}	0.047	0.80	0.70	0.039	0.001	0.080	0.797
C18:1n9c	Oleic acid	28.73^{b}	37.74^{a}	32.65^{ab}	2.267	33.83	32.25	1.851	0.047	0.556	0.016

Table 19 (Continued)

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
C20:1	Eicosenic acid	0.17^{b}	0.32^{a}	0.32^{a}	0.027	0.29	0.25	0.022	0.003	0.141	0.241
C22:1n9		0.25^{a}	0.11^{b}	0.32^{a}	0.021	0.25^{a}	0.19^{b}	0.017	0.001	0.037	0.791
C24:1	Nervonic acid	0.09^{a}	0.10^{a}	0.04^{b}	0.009	0.07	0.09	0.007	0.001	0.117	0.018
C18:2n6t	Linolelaidic acid	0.03	0.06	0.05	0.008	0.07^{a}	0.02^{b}	0.006	0.145	0.001	0.231
C18:2n6c	Linoleic acid	1.06	1.12	1.22	0.069	1.05	1.21	0.056	0.272	0.078	0.427
C18:3n6	γ-Linolenic acid	0.05	0.05	0.03	0.007	0.05	0.04	0.006	0.176	0.147	0.001
C18:3n3	Linolenic acid	0.10	0.11	0.10	0.008	0.09^{b}	0.11^{a}	0.007	0.292	0.028	0.003
C20:2	Eicosadienoic acid	0.08^{ab}	0.10^{a}	0.06^{b}	0.009	0.05^{b}	0.11^{a}	0.007	0.014	0.001	0.080
C20:3n6	Eicosatrienoic acid	0.14	0.17	0.17	0.010	0.16	0.16	0.008	0.066	0.767	0.184
C20:3n3		0.05^{b}	0.15^{a}	0.06^{b}	0.012	0.10^{a}	0.07^{b}	0.010	0.001	0.034	0.100
C20:4n6	Arachidonic acid	0.04	0.03	0.03	0.007	0.03	0.03	0.005	0.376	0.337	0.376
C20:5n3	Eicosapentaenoic acid	0.123^{a}	0.050^{b}	0.105^{a}	0.015	0.12^{a}	0.07^{b}	0.012	0.013	0.023	0.007
C22:2n2	Docosadienoic acid	0.05^{ab}	0.07^{a}	0.05^{b}	0.006	0.05^{b}	0.06^{a}	0.005	0.047	0.029	0.032
C22:6n3	Docosahexaenoic acid	0.10^{b}	0.24^{a}	0.05^{c}	0.012	0.10^{b}	0.16^{a}	0.010	0.001	0.001	0.001
SFA	Saturate fatty acid	35.59^{b}	44.74^{a}	36.02^{b}	2.149	37.69	39.87	1.755	0.018	0.396	0.033
MUFA	Monounsaturate fatty acid	32.69^{b}	44.98^{a}	37.49^{ab}	2.502	39.78	37.01	2.043	0.015	0.357	0.010
PUFA	Polyunsaturate fatty acid	1.23	1.31	1.38	0.080	1.22	1.39	0.066	0.474	0.100	0.286
n6		1.31	1.43	1.49	0.086	1.35	1.46	0.070	0.371	0.300	0.242
n3		0.15^{b}	0.27^{a}	0.16^{b}	0.016	0.20	0.18	0.013	0.001	0.447	0.003

Table 19 (Continued)

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
PUFA/SFA	0.04[a]	0.03[b]	0.04[a]	0.001	0.03	0.03	0.001	0.001	0.337	0.001
MUFA/SFA	0.92[c]	1.00[b]	1.04[a]	0.012	1.04[a]	0.93[b]	0.009	0.001	0.001	0.001
n6/n3	10.41[a]	5.54[b]	10.02[a]	0.634	8.64	8.67	0.518	0.001	0.973	0.001

[a,b,c] Means with different superscripts are significantly different ($p<0.05$) between the breeds, marbling score and interaction.

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, C20:3n3

9. Trained panel preference scores

Comparisons of preference scores with difference breeds are presented in Table 20-21. The preference scores were evaluated by trained panelists using 9 hedonic scales method. Trained panelists were rated the preference of color, appearance flavor texture and overall acceptability on 1-9 scales (1=Dislike extremely, 5=neither like nor dislike and 9=Like extremely). The evaluation was divided into 2 groups as according to marbling score (<3 and ≥3).

The result showed that attributes of appearance, color, flavor, and texture did not differ in MBS<3 group ($p>0.05$). The overall acceptability attribute of CHA group had greater than HFM group ($p<0.05$), but CHA group did not differ with HFF group ($p>0.05$). Interestingly, CHA group were tendency greater on flavor score than other groups ($p<0.062$) which affected on increases in the overall acceptability attribute of CHA group. Differences in flavor attributes were determined due to breed, in agreement to Melton (1990) who reported that meat flavor was influenced by genetics factors. Traditionally, flavor of red meat developed during cooking through degradation and reactions of water-soluble compounds. The species flavor originates in the fatty tissue. Wasserman and Spinelli (1972) reported that the important of develop a species' characteristic aroma were the both lipids and water-soluble components which was meat lipids act as a solvent for the volatile compounds that accumulate during cooking. Corbin et al. (2015) reported that although tenderness had been cited as the most important factor affecting beef palatability, additional when tenderness reached an acceptable level, flavor became the next most important driver of beef eating satisfaction. Increased flavor score as increasing overall acceptability. Furthermore, overall consumer acceptability was highly correlated with flavor compared to tenderness or juiciness. (O'Quinn et al., 2012).

In addition, the preference evaluation of MBS≥3 group showed that all breed did not differ in all attribute ($p<0.05$). The flavor attribute of MBS≥3 group did not differ among breed ($p>0.05$). Therefore, this result indicated that increased flavor score as increasing marbling score. Results of current study were consistent with several published research showed increased beef palatability and flavor scores with

increased fat or marbling level (Emerson et al., 2013; Corbin et al., 2015). Koch et al. (1976) compared rib steak from Hereford, Angus, Jersey, South Devon, Limousin, Charolais and Simmental breed and found that taste panel scores for flavor of Jersey and Charolais were not different each other. Moreover, tenderness attribute of Jersey as dairy cattle breeds showed more tender than Charolais. However, Thonney et al. (1991) reported that taste panel scores for tenderness and flavor of rib eye steaks were significantly higher in Holstein, as well as overall acceptability compared with Simmental-Angus breeds. Kosowska et al. (2017) reported that the palatability of meat differed significantly as affected by the breed. For example, beef originating from Friesian cattle was characterized by stronger greasy flavor notes and aftertaste compared to meat of Pirenaica breed cattle, which was due to differences in volatiles composition. Savell et al. (1987) revealed that increasing the amount of marbling in top loin steaks had a positive impact on the eating quality of beef. As C18:1 was the main fatty acid in the intramuscular fat in cattles, it had been positively correlated with cooked beef fat flavor (Larick & Turner, 1990). Dryden and Marchello (1970) reported that the *Longissimus dorsi* muscle with high percentages of oleate generally scored higher in taste panel evaluations which was corresponding with increasing oleic acid content of HFM and HFF groups with MBS≥3 (28.73, 37.74 and 32.65 mg/g dry sample) was increased the overall acceptability score compared with CHA group (6.57, 7.00 and 7.57, respectively) ($p>0.05$).

For sensory evaluation ~~of~~ with three breeds of MBS<3, CHA and HFF groups did not differ in overall acceptability. MBS≥3 group, the preference score showed no difference among breeds.

10. Quantitative Descriptive Analysis, QDA

This study was compared the sensory evaluation of CHA, HFM and HFF with differ marbling score (MBS<3 and MBS≥3) by consider the beef sample 4 attributes includes 1) Texture includes juiciness, denseness, cohesiveness, fibrosity 2) Flavor includes beefy, grilled, milky, salty 3) Taste includes umami, sweetness, oily 4) Color includes edge color, center color, brown, red (Table 22).

Table 20 Sensory evaluation of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with less marbling score (MBS<3) by 9 hedonic scale

Attributes	[1/]Score			[2/]SEM	P-value
	CHA	HFM	HFF		
Appearance	7.29±1.60	6.14±0.69	6.57±1.51	0.454	0.226
Color	7.29±1.60	6.14±0.90	6.71±1.60	0.532	0.338
Flavor	7.26±1.60	5.43±1.13	6.14±1.35	0.519	0.062
Texture	7.57±1.99	7.00±0.58	7.57±1.27	0.530	0.685
Overall acceptability	7.79±1.29[b]	6.21±0.70[a]	7.14±0.90[ab]	0.375	0.027

[abc] Mean within the same row with different superscripts significantly ($p<0.05$).

[1/]9 hedonic scale; score: 1= Dislike extremely, 9 =like extremely,

[2/] Standard error of the mean.

Table 21 Sensory evaluation of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF) with more than or equal marbling score (MBS≥3) by 9 hedonic scale

Attributes	[1/]Score			[2/]SEM	P-value
	CHA	HFM	HFF		
Appearance	7.00±1.15	6.57±0.53	6.71±0.76	0.323	0.641
Color	6.71±1.11	7.00±0.82	6.43±1.27	0.410	0.623
Flavor	7.57±0.96	7.00±0.82	7.00±1.41	0.415	0.543
Texture	6.29±1.80	7.29±0.49	7.29±0.95	0.457	0.230
Overall acceptability	6.57±1.72	7.00±0.82	7.57±0.79	0.449	0.311

[abc] Mean within the same row with different superscripts significantly ($p<0.05$).

[1/]9 hedonic scale; score: 1= Dislike extremely, 9 =like extremely,

[2/]Standard error of the mean.

Table 22 Sensory descriptive attributes of crossbred Charolais steers, fattening dairy steers and culled dairy cows with different breed and marbling score

Traits	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
Texture										
Juiciness	5.08	5.28	5.18	0.184	5.19	5.17	0.150	0.754	0.911	0.001
Denseness	9.43^{b}	11.03^{a}	9.12^{b}	0.191	10.05	9.67	0.156	0.001	0.092	0.023
Cohesiveness	5.49	5.12	5.65	0.181	5.05^{b}	5.79^{a}	0.148	0.113	0.001	0.218
Fibrosity	6.13	6.56	6.56	0.208	5.67^{b}	7.17^{a}	0.170	0.242	0.001	0.101
Flavor										
Beefy	8.36	8.49	8.16	0.215	7.88^{b}	8.79^{a}	0.175	0.555	0.001	0.001
Grill	3.35	3.23	2.80	0.202	3.33	2.92	0.166	0.138	0.082	0.158
Milky	1.55^{b}	2.09^{a}	1.32^{b}	0.178	0.81^{b}	2.50^{a}	0.145	0.013	0.001	0.084
Salty	3.13^{a}	2.54^{b}	1.94^{c}	0.203	2.52	2.54	0.166	0.001	0.940	0.781
Taste										
Umami	9.25^{a}	9.24^{a}	6.88^{b}	0.203	6.50^{b}	10.42^{a}	0.166	0.001	0.001	0.001
Sweetness	4.89	4.85	4.80	0.196	2.57^{b}	7.13^{a}	0.160	0.950	0.001	0.071
Oily	2.16^{b}	3.60^{a}	2.56^{b}	0.218	2.38^{b}	3.17^{a}	0.178	0.001	0.003	0.134

Table 22 (Continued)

Traits	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
Color										
Edge	10.77^{b}	11.31^{a}	11.17^{ab}	0.195	11.00	11.17	0.159	0.136	0.463	0.002
Center	5.56^{c}	6.71^{b}	7.55^{a}	0.203	5.50^{b}	7.71^{a}	0.166	0.001	0.001	0.009
Brown	12.66	12.64	12.35	0.139	12.47	12.63	0.114	0.215	0.359	0.019
Red	3.80^{ba}	2.31^{b}	3.33^{a}	0.183	2.71^{b}	3.58^{a}	0.149	0.001	0.001	0.001

^{abc} Mean within the same row with different superscripts significantly ($p<0.05$).

For breed factor, CHA, HFM, HFF groups were significant different on denseness, milky, salty, umami, oily, center color and red color attributes ($p<0.05$). Denseness of CHA and HFF groups were significant lower than HFM group ($p<0.05$) which was corresponding with WBSF was decreased on CHA and HFF groups (5.78 and 5.56 kg) as well as decreasing hardness of TPA (1382.47 and 1161.87 g). The result indicated that CHA and HFF groups had more tender than HFM group. Flavor attribute, milky flavor of HFM group had significant higher than CHA and HFF groups ($p<0.05$). Kosowska et al. (2017) beef from Friesian cattle was characterized by stronger greasy flavor notes and aftertaste compared to meat of Pirenaica breed cattle, due to differences in volatiles composition.

Volatile compound of HFM group of this study showed superior in 1-Octanol and butyrolactone (as a fatty, waxy, oily milky, creamy flavor) which was predominant with Holstein breed with the both sex as well as increased acetoin and butyrolactone as increased marbling score. Elmore et al. (2004) reported that breed factor had influence on acetone between grilled beef from Holstein-Friesian steers and Aberdeen Angus. Angus beef had higher acetone than Holstein-Friesian beef and acetoin of Holstein-Friesian beef was higher than that of Aberdeen Angus. However, HFM group showed greater milky flavor than HFF group. It result from HFF group was generally produced milk thus releasing milk of HFF group may be lose flavor aroma compound as well. Brewer (2006) reported that flavor resulted from the combination of basic tastes derived from water-soluble compounds.

Moreover, salty flavor of CHA group was higher than HFM and HFF groups ($p<0.05$). Maughan (2011) reported consumer liking had positive correlation with brothy, umami, roast beef, juicy, browned, fatty, and salty of beef. Taste attribute, umami flavor of CHA and HFM groups had significant higher than HFF group ($p<0.05$) and oily flavor of HFM group had higher score than CHA and HFF groups. Umami was taste described as savory, brothy or beefy. It is produced by flavor-potentiating compounds, such as MSG (monosodium glutamate), IMP (5-nucleotides, 5'-inosine monophosphate) and GMP (5'-guanosine monophosphate) (Yamasaki & Maekawa, 1978).

The color of edge and center of CHA group had brighter score than HFM and HFF ($p<0.05$) which was corresponding to CHA group showed higher L* (Lightness) than HFM

and HFF group (44.63, 43.66 and 42.79, respectively; $p<0.05$) as well as yellowness (b*) (7.34, 6.79 and 6.23, respectively; $p<0.05$). Moreover, CHA and HFF groups had more redness than HFM group ($p<0.05$) which was consisted to of CHA and HFF groups had also higher a* (redness) than HFM group (18.39, 17.46 and 17.19, respectively; $p<0.05$). Interestingly, HFM group had a great flavor of milky, oily and umami taste. Gorraiz et al. (2002) found beef cattle and beef dairy differences on flavor between them, dairy beef from Friesian cattle had a stronger fatty flavor, aftertaste and the content of several volatile compounds than beef breed that from Pirenaica cattle. Moreover, sex of the animal had affected the odor characteristics of the meat fat besides, it a slight influence over the aromatic characteristics of lean meat.

Marbling score factor, there were significant difference in cohesiveness, fibrosity, beefy, milky, umami, sweetness, oily, center color and red color. Cohesiveness, fibrosity of MBS≥3 group had significant higher than MBS<3 group which was corresponding with cohesiveness and springiness increased on MBS≥3 group. Flavor attribute, beefy and milky of MBS≥3 group were higher than MBS<3 group. Beef with increasing fat percentage was increased beefy and milky flavor. Quinn et al. (2012) revealed that USDA quality grade had the greatest on beef flavor which participants showed a strong preference for the flavors of products with high percentages of IM fat that contained greater amounts of monounsaturated fatty acids and lesser amounts of saturated and polyunsaturated fatty acids. Panelists preferred samples with flavors described as beefy/brothy, browned/ grilled, buttery/beef fat, nutty/nutty roasted and sweet. Moreover, desirable beef flavor attributes such as fat-like, beef identity, brown/roasted, overall sweet, salty, and umami, were higher in greater quality grades (Legako et al., 2016).

Beef flavor, which developed when heat was applied, depended on the amounts and proportions of precursor compounds present. Meat is composed of water, proteins, lipids, carbohydrates, minerals and vitamins. Of these, proteins, lipids and carbohydrates play primary roles in flavor development because they include numerous compounds which are capable of developing into important flavor precursors when heated (Spanier & Miller, 1993; Mottram, 1998). Corbin et al. (2007) found that high fat percentage of beef had positively correlated with fat-like, bloody/serumy, umami, metallic, oxidized,

salty, and overall sweet flavors, as well as initial flavor impact. Moreover, effect of fat level on consumer sensory panel ratings for tenderness, juiciness, flavor and overall liking had increased with increasing fat percentage. Corbin et al. (2015) found that American Wagyu beef that high fat level (18.37%) had greater beef flavor, fat-like and umami flavor than low fat level group. In the part of taste attribute, MBS≥3 group had significant greater umami, sweetness and oily score than MBS<3 group. Color attribute, center color and red color of MBS≥3 group were greater than those of MBS<3 group. Interaction factor had affected on juiciness, denseness, beefy, umami, edge color, center color, brown color and red color ($p<0.05$). Therefore, this study found that HFF group was outstanding on tender and similar with CHA group. Inversely, taste of umami with HFF group was the weakest. HFM group had a greatest milky flavor and oily taste as result the umami taste was excellent. Increasing marbling score enhanced flavor of beefy and milky, taste of umami, sweetness and oily. Juiciness, denseness, beefy flavor and umami taste were influenced by the interaction of breed and marbling score.

11. Volatile compound

Interaction of breed and marbling score on volatile compounds identified of raw beef were showed in Table 23. Twenty-three compounds were identified in the headspace extract of raw beef. 15 compounds was affected on breed such as acetone, 2-methyl-propanoic acid ethyl ester, 2,3-butanedione, toluene, butanoic acid, ethyl ester, hexanal, heptanal, 1-pentanol, acetoin, 1-hexanol, 1-octanol, octanoic acid ethyl ester, 1-octen-3-ol, 1-octanal, and hexanoic acid. CHA and HFM groups had greater propanoic acid, 2-methyl-, ethyl ester, butanoic acid, ethyl ester (Fruity) and 2,3-Butanedione (sweet, buttery) than HFF group. HFM and HFF groups had greater octanoic acid, ethyl ester, 1-Pentanol (mild odor, fuel oil, fermented, bread, cereal), 1-hexanol (Green, fruity, apple-skin) and 1-octanol (fatty, waxy, citrus, oily) than CHA group. HFM group had the highest 1-octen-3-ol (mushroom). Breed, marbling score and their interaction had influenced on 1-octanal. HFF group and MBS≥3 group had a greater 1-octanal (green, lemon, citrus, aldehyde).

Marbling score had affected on 11 compounds such as acetone, 2-methyl-propanoic acid ethyl ester, 2,3-butanedione, heptanal, acetoin, 1-octanol, nonanal,

acetic acid, 2-ethyl-1-hexanol, 1-octanal and butanoic acid. Wang et al. (2017) reported that raw beef was detected only four types of aldehydes such as hexanal, octanal, nonanal, and decanal. Aldehydes mainly resulted from the oxidation and degradation of lipids, such as the nonanal resulting from oxidation of oleic acid (Tan and Ding, 2004) and hexanal from oxidation of linoleic acid (Dang Wang and Xu, 2007). Beef with MBS<3 group had greater abundances of heptanal and acetoin compared beef with MBS≥3 group ($p<0.05$). MBS≥3 had greater 2,3-Butanedione (sweet, buttery) (0.012 and 0.035; $p<0.05$) than MBS<3 as well as 1-octanol (fatty, waxy), nonanal (citrus-like, soapy) and fatty, 1-octanal (waxy, citrus, oily) was increased with increasing marbling score. It was corresponding to Legako et al. (2016) who showed that beef steaks from higher quality grade were more desirable to consumers, and had greater headspace abundances of 2,3-butanedione. Moreover, Wang et al. (2017) found that ketones group as 2,3-butanedione were identified in raw beef and cooked beef. Ketones resulted from lipid oxidative degradation and had an aroma of oil and are very significant for beef taste. Wang et al. (2017) most of the straight chain aldehydes derived from the oxidation of unsaturated fatty acids. The aldehydes as representative of aromas contributed to aroma and were also the precursor in the Maillard reaction to form aromas.

Moreover, the interaction of breed and marbling score affected on 9 compounds such as acetone, 2-methyl-propanoic acid ethyl ester, toluene, hexanal, heptanal, acetoin, 2-hydroxy-propanoic acid ethyl ester (S)-, 1-octanol and 1-octanal. Breed affected on beef flavor, several researches had been confirmed that palatability of meat had significantly affected by breed. Nitrogen- and sulfur compounds, free amino acids, alcohols, aldehydes and ketones in the flavor volatiles differed among beef from different cattle breeds (Brewer, 2006). The fact that beef from the Friesian breed showed stronger fatty flavor and aftertaste were related to their different fatty acid composition of intramuscular fat, predominantly caused by genetic control of animal lipid metabolism (Larick et al., 1989)

The table 24, it showed interaction of breed and marbling score on volatile compounds identified of grilled beef. The development of a characteristic flavor of cooked meat was attributable to volatiles generated during heating as a result of the following processes: Maillard reaction, lipid oxidation, interactions between Maillard

reaction products and lipid oxidation products, and thermal degradation of thiamine. Hundreds of volatile compounds were determined in cooked meat included products of lipid and fatty acid oxidation, e.g. aliphatic hydrocarbons, aldehydes, ketones, alcohols, carboxylic acids, and esters (Kosowska et al., 2017).

Breed factor had affected on 11 compounds of grilled beef (octane, 2-methyl-butanal, trichloromethane, Toluene, methyl-pyrazine (nutty, brown, musty, roasted), acetoin (sweet buttery creamy dairy milky fatty), 1-hexanol, acetic acid, 1-octanol, diethyl carbitol and hexanoic acid). Two strecker degradation aldehydes, 2-methyl butanal, 3-methyl butanal, were quantified in this study. The strecker reaction ~~is~~ was often perceived as a reaction within the Maillard reaction and, typically, the Strecker reaction involved the oxidative deamination and decarboxylation of **α**-amino acid in the presence of an **α**-dicarbonyl compound which 3-methylbutanal and 2-methylbutanal had leucine and isoleucine as an amino acid precursor of flavor, respectively. HFM and HFF groups had higher 2-methylbutanal (nutty burnt, onion) than CHA group. CHA and HFM groups had higher methyl-pyrazine (nutty, brown, musty, roasted) than HFF group. CHA and HFM groups had 1-octanol (fatty, waxy, citrus, oily) than HFF group which was corresponding with milky flavor (1.55, 2.09 and 1.32, respectively). Elmore et al. (2004) reported that breed factor had influenced on acetone between grilled beef from Holstein-Friesian steers and Aberdeen Angus. Angus had higher acetone than Holstein-Friesian and acetoin of Holstein-Friesian beef was higher than that of Aberdeen Angus beef but there was no different. However, HFM and HFF groups showed similar with several volatile compounds of Holstein-Friesian steers of Elmore et al. (2004) such as octane, 2-methyl-butanal, 3-methyl Butanal, toluene, hexanal, heptanal, octanal, 1-pentanol, 1-hexanol, 1-octanol, 1-octen-3-ol, acetone, acetoin, and benzaldehyde. The mostly of volatile compound was from lipid oxidation products such as ketone, alcohol and aldehyde. Insausti et al., (2005) revealed that beef flavor could be affected by breed of cattle. Nitrogen- and sulfur compounds, free amino acids, alcohols, aldehydes and ketones in the flavor volatiles differed among beef from different cattle breeds. Sato et al. (1995) showed that beef derived from Wagyu cattle had better sensory quality than those made with fat from dairy cattle. The former yield had more volatile

compounds and higher concentrations of volatile acids such as ketones and lactones. Samples made with dairy beef fat had relatively high contents of aldehydes and alcohols. Mottram (1994) found that the main sources of volatiles in cooked meat were the thermal degradation of lipid and the Maillard reaction, which occured between amino acids and sugars. Elmore (1999) Heat-induced oxidation of fatty acids, particularly unsaturated fatty acids, produced degradation products, such as aldehydes, ketones, and alcohols, which might have intrinsic flavors. Aroma-active volatiles were then form mainly as a result of lipid oxidation processes, e.g. nonanal, 2,3-octanedione, pentanal, 3-hydroxy-2-butanone, 2-pentyl furan, 1-octen-3-ol, butanoic acid, pentanal and hexanoic acid (Stetzer et al., 2008).

Marbling score factor had influence on 11 volatile compounds such as hexane, butanoic acid, 2-oxo-, trichloromethane, methyl-pyrazine, 1-hexanol, acetic acid, 1-octen-3-ol, 2-ethyl-1-hexanol, diethyl carbitol and hexanoic acid. Beef with MBS≥3 has increased the alcohol group as octen-3-ol and 2-ethyl-1-hexanol than Beef with MBS<3. Elmore *et al*. (2004) reported that flavour volatile compounds in grilled beef had various alcohols (1-octen-3-ol, cis-2-octen-1-ol) and, aldehydes (pentenal, hexenal, heptenal, octenal) as result of oxidation products of 18:2 n-6. Fatty acids such as oleic, linoleic, and linolenic acids were the main sources of saturated n-aldehydes. The importance of n-aldehydes in cooked beef was the result of thermal lipid degradation (Legako et al., 2016). Moreover, heat-induced oxidation of fatty acids, particularly unsaturated fatty acids, produced degradation products, such as aliphatic aldehydes, ketones and alcohols which might have intrinsic flavors (Elmore et al., 1999). Mottram, (1998) described that heating unsaturated fatty acids induced oxidation producing intermediate hydroperoxides that decomposed via free radical mechanisms eventually resulting in aldehydes, unsaturated alcohols, ketones and lactones, which had relatively low detection thresholds.

Thirteen compounds were affected by interaction of breed and marbling score such as Octane, 2-methyl-butanal, 2-oxo-butanoic acid, trichloromethane, 1-pentanol, methyl-pyrazine, 2,6-dimethyl-pyrazine, 1-hexanol, acetic acid, 2-ethyl-1-hexanol, 1-octanol, diethyl carbitol and butyrolactone. CHA and HFM group had greater butyrolactone (milky, creamy) which related to milky flavor of sensory descriptive attributes evaluation. Sato et al. (1995) reported that dairy beef contained volatiles and

high concentrations of volatile acids, lactones and aldehydes but it had lower volatiles and concentrations compared to Wagyu meat characterized by the high content of aldehydes and alcohols.

A comparison of the aroma volatiles compounds of breed with different marbling core (MBS<3 and MBS≥3) showed as Table 25-26. Raw CHA beef with MBS≥3 had greater 2-methyl-propanoic acid ethyl ester and nonanal (sweet, fatty, green) compared with MBS<3 those with ($p<0.05$). HFM beef with MBS≥3 had greater 2,3-butanedione (buttery aroma) than MBS<3 which consisted to milky flavor and oily taste on sensory descriptive evaluation of trained panelisists also comfirmed that HFM beef with MBS≥3 had higher overall acceptability score than CHA beef but there was not different ($p>0.05$). O'Quinn et al. (2012) revealed that volatiles identified, 2, 3-butanedione and acetoin (3-hydroxy-2-butanone) were positively correlated with flavors described as buttery/beef fat, beefy/brothy, browned/grilled, and sweet. Both volatiles were most closely correlated with ratings for overall flavor desirability. HFF beef with MBS≥3 had greater toluene and hexanoic acid (sweaty) than those with MBS<3 ($p<0.01$).

Grilled CHA beef, with MBS<3 had higher 1-Hexanol (green, fruity, apple-skin), diethyl carbitol and butyrolactone (Milky, creamy, peach-like) than those with MBS≥3. HFM beef with MBS<3 showed higher hexane, 2-methyl-butanal, trichloromethane, methyl pyrazine (roasted aroma) and acetic acid on HFM beef with MBS≥3, however, HFM with MBS≥3 had higher hexanal (Green, grassy, fatty), 1-pentanol (fusel, fermented, bread, cereal), 1-hexanol (green, fruity, apple-skin), and butyrolactone (Milky, creamy, peach-like) than those with MBS<3 ($p<0.02$). HFF beef with MBS<3 had higher octane, trichloromethane, acetic acid (sour, vinegar), benzaldehyde (almond, nutty, woody), but lower acetoin (3-Hydroxy-2-butanone) and butyrolactone than those with MBS≥3. Sato et al. (1995) showed that beef originating from Friesian cattle is characterized by stronger fatty flavor notes and a dairy breed contains lactones and aldehydes volatiles and high concentrations of volatile acids. Therefore, this result indicated that dairy beef had prominent on milky flavor. Moreover, Legako et al. (2015) found that two ketones group, 2,3-butanedione and acetoin (3-hydroxy-2-butanone) were significantly different among quality grades. Both 2,3-butanedione and 3-hydroxy-2-butanone were greater in prime steaks than Low choice and standard steaks.

A comparison of the aroma volatiles compounds of raw and grilled beef with different marbling score was showed in Table 27-28. Raw beef with MBS<3 affected 2,3-butanedione, toluene, butanoic acid ethyl ester, heptanal, 1-pentanol, 1-hexanol, octanoic acid, ethyl ester, 1-octen-3-ol, and hexanoic acid ($p<0.05$). HFM Beef with MBS<3 had higher toluene, butanoic acid, ethyl ester, heptanal, 1-pentanol, 1-hexanol, octanoic acid, ethyl ester, 1-octen-3-ol and hexanoicacid than CHA and HFF beefs ($p<0.05$) except 2,3-butanedioneo. Meanwhile, CHA beef with MBS<3 had greater 2,3-butanedioneo (buttery) compared with HFM beef. However, Beef with MBS≥3 affected on acetone. Quinn et al. (2012) revealed that USDA quality grade had the greatest on beef flavor which participants showed a strong preference for the flavors of products with high percentages of IM fat that contained greater amounts of monounsaturated fatty acids and lesser amounts of saturated and polyunsaturated fatty acids. Grilled beef with MBS<3 had affected on 2-methyl-butanal, trichloromethane, toluene, methyl-pyrazine (pungent, sweet, roasty), 2,6-dimethyl pyrazine (roasted, nutty), 1-hexanol, nonanal (sweet, fatty, green), acetic acid, 1-octanol (penetraing aromatic odor, fatty, waxy, citrus, oily) and diethyl carbitol. HFM with MBS<3 had greater 2-methyl-butanal, methyl pyrazine and 2,6-dimethyl pyrazine than CHA and HFF beefs. CHA beef with MBS<3 had greater 1-hexanol (green, fruity, apple-skin), nonanal (sweet, fatty, green) and 1-octanol, 2-methyl-butanal (pungent, sweet, roasty), trichloromethane, toluene, methyl-pyrazine, 2,6-dimethyl pyrazine, acetic acid and diethyl carbitol. Grilled beef with MBS≥3 had affected hexane, octane, methyl-pyrazine, acetoin and butyrolactone. CHA and HFM beefs with MBS≥3 had greater hexane, methyl pyrazine, acetoin than HFF beef. HFM beef with MBS≥3 had greater butyrolactone as well as HFF beef. This result had corresponding with great milky flavor of HFM beef. This result showed that butyrolactone as a milky, creamy flavor was predominant with Holstein cattle with the both sex as well as increased acetoin (3-Hydroxy-2-butanone) and butyrolactone as increased marbling score. Moreover, styrene and naphthalene were discovered on volatile compounds identified in different breed on grilled beef.

Table 23 Interaction of breed and marbling score on volatile compounds identified of raw beef

Volatile Compound (Raw beef / DB-wax)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)									
				Breed			SEM	Marbling Score		SEM	P-value		
				CHA	HFM	HFF		MBS<3	MBS≥3		B	M	B*M
Hexane	Faint peculiar odor	599	600	0.481	0.373	0.454	0.430	0.398	0.474	0.096	0.797	0.587	0.699
Acetone	-	808	814	0.041	0.063	0.045	0.008	0.012	0.046	0.007	0.003	0.003	0.004
Propanoic acid, 2-methyl-, ethyl ester	-	958	960	0.009	0.007	0.003	0.001	0.004	0.008	0.001	0.005	0.003	0.001
2,3-Butanedione	Sweet, buttery	970	964	0.035	0.023	0.014	0.005	0.012	0.035	0.004	0.025	0.001	0.151
Trichloromethane	-	1013	1037	0.029	0.055	0.035	0.009	0.040	0.040	0.007	0.128	0.997	0.544
Toluene	-	1024	1043	0.015	0.032	0.016	0.003	0.019	0.023	0.002	0.001	0.183	0.027
Butanoic acid, ethyl ester	Fruity	1027	1024	0.113	0.168	0.071	0.021	0.102	0.133	0.017	0.023	0.232	0.255
Hexanal	Green, grassy, fatty	1070	1083	0.016	0.051	0.069	0.012	0.016	0.029	0.010	0.030	0.363	0.031
Heptanal	fruity, fatty, sweet, oil	1210	1184	0.004	0.007	0.001	0.001	0.007	0.001	0.000	0.001	0.001	0.001
Hexanoic acid, ethyl ester	Hexanoic acid, ethenyl ester	1231	1238	0.016	0.081	0.039	0.030	0.020	0.070	0.025	0.346	0.179	0.107
1-Pentanol	Fusel, fermented, bread, cereal	1254	1255	0.004	0.103	0.029	0.023	0.045	0.046	0.019	0.024	0.992	0.863
Acetoin	-	1278	1280	0.236	0.465	0.277	0.062	0.342	0.125	0.050	0.001	0.010	0.055

Table 23 (Continued)

23 Volatile Compound (Raw beef / DB-wax)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)									
				Breed			SEM	Marbling Score		SEM	P-value		
				CHA	HFM	HFF		MBS<3	MBS≥3		B	M	B*M
Propanoic acid, 2-hydroxy-, ethyl ester, (S)-	-	1341	1341	0.135	0.074	0.106	0.026	0.123	0.087	0.021	0.292	0.249	0.022
1-Hexanol	Green, fruity, apple-skin	1355	1359	0.001	0.021	0.005	0.003	0.010	0.008	0.003	0.002	0.700	0.623
1-Octanol	Penetraing aromatic odor, fatty, waxy, citrus, oily	1389	1396	0.010	0.022	0.043	0.002	0.007	0.014	0.002	0.001	0.016	0.005
Nonanal	Sweet,fatty,green	1433	1451	0.030	0.025	0.023	0.005	0.019	0.033	0.004	0.517	0.024	0.130
Octanoic acid, ethyl ester	-	1278	1280	0.011	0.020	0.039	0.002	0.010	0.010	0.002	0.001	0.746	0.163
Acetic acid	Sour, vinegar	1444	1448	0.011	0.017	0.013	0.007	0.004	0.023	0.006	0.797	0.043	0.819
1-Octen-3-ol	Mushoom	1449	1443	0.005	0.040	0.005	0.008	0.019	0.014	0.006	0.010	0.557	0.684
2-ethyl-1-hexanol	Resin, flower, green	1490	1484	0.006	0.004	0.004	0.001	0.003	0.007	0.001	0.236	0.006	0.204
1-Octanal	Green,lemon,citrus, aldehyde	1560	1558	0.010	0.022	0.04	0.002	0.007	0.014	0.002	0.001	0.016	0.005
Butanoic acid	Rancid	1631	1620	0.010	0.011	0.006	0.003	0.015	0.018	0.002	0.345	0.000	0.345
Hexanoic acid	Sweaty	1835	1844	0.000	0.035	0.015	0.007	0.012	0.022	0.006	0.015	0.269	0.667

[abc] Mean within the same row with different superscripts significantly ($p<0.05$).

Table 24 Interaction of breed and marbling score on volatile compounds identified of grilled beef

Volatile Compound (Grill beef / DB-wax)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)									
				Breed			SEM	Marbling Score		SEM	P-value		
				CHA	HFM	HFF		MBS<3	MBS≥3		B	M	B*M
Hexane	Faint peculiar odor	599	600	0.772	0.570	0.165	0.199	0.838	0.167	0.162	0.131	0.013	0.210
Octane	-	800	800	0.025	0.042	0.028	0.018	0.027	0.037	0.004	0.047	0.068	0.015
2-methylbutanal	Pungent, sweet, roasty	909	909	0.011	0.026	0.019	0.001	0.017	0.020	0.001	0.001	0.140	0.001
3-methylbutanal	Meaty, fish, aldehyde, fatty	913	931.2	0.018	0.022	0.017	0.002	0.018	0.019	0.002	0.238	0.681	0.461
Butanoic acid, 2-oxo-	-	953	911	0.006	0.009	0.012	0.002	0.012	0.007	0.001	0.076	0.022	0.001
Trichloromethane	-	1014	1037	0.068	0.251	0.074	0.028	0.201	0.061	0.023	0.001	0.001	0.001
Toluene	-	1026	1043	0.046	0.080	0.084	0.007	0.066	0.073	0.005	0.002	0.363	0.872
Hexanal	Green, grassy, fatty	1072	1078	1.752	0.196	0.312	0.499	1.033	0.474	0.407	0.086	0.351	0.123
Heptanal	Sopy/fruity, fatty, sweet, oil	1182	1181	0.046	0.007	0.015	0.010	0.030	0.015	0.010	0.098	0.306	0.158
Styrene	Sweet, balsamic, floral	1251	1252	0.023	0.005	0.004	0.010	0.017	0.004	0.008	0.355	0.265	0.338
	Extremely penetrating												
1-Pentanol	Fusel, fermented, bread, cereal	1256	1258	0.101	0.021	0.050	0.026	0.059	0.056	0.021	0.125	0.936	0.039
Methyl-pyrazine,	Nutty, brown, musty, roasted	1263	1263	0.005	0.006	0.003	0.000	0.005	0.004	0.000	0.001	0.041	0.041
Acetoin	-	1281	1280	0.415	0.456	0.186	0.064	0.333	0.371	0.053	0.025	0.624	0.752
Octanal	Green, lemon, citrus-like, aldehyde	1285	1287	0.033	0.010	0.008	0.008	0.023	0.010	0.007	0.094	0.181	0.245
2,6-dimethyl-pyrazine	Roasted, nutty	1321	1325	0.005	0.005	0.005	0.001	0.007	0.004	0.001	0.979	0.007	0.001
1-Hexanol	Green, fruity, apple-skin	1358	1359	0.048	0.008	0.018	0.004	0.031	0.019	0.003	0.001	0.026	0.001
Nonanal	Sweet,fatty,green	1392	1390	0.075	0.055	0.033	0.014	0.056	0.052	0.011	0.134	0.808	0.128
Acetic acid	Sour, vinegar	1453	1451	0.009	0.038	0.025	0.005	0.039	0.008	0.004	0.002	0.001	0.001

Table 24 (Continued)

33 Volatile Compound (Grill beef / DB-wax)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)									
				Breed			SEM	Marbling Score		SEM	P-value		
				CHA	HFM	HFF		MBS<3	MBS≥3		B	M	B*M
1-Octen-3-ol	Mushoom	1454	1456	0.029	0.021	0.033	0.009	0.009	0.047	0.008	0.649	0.004	0.104
2-ethyl 1-hexanol	Resin, flower, green	1493	1492	0.003	0.003	0.004	0.000	0.001	0.006	0.000	0.427	0.001	0.002
Benzaldehyde	Almond, nutty, woody	1524	1520	0.012	0.006	0.007	0.002	0.010	0.007	0.001	0.089	0.127	0.233
1-Octanol	Penetraing aromatic odor, fatty, waxy, citrus, oily	1564	1569	0.019	0.011	0.007	0.002	0.012	0.013	0.002	0.007	0.815	0.014
Diethyl carbitol	-	1630	1619	0.008	0.006	0.004	0.000	0.007	0.005	0.000	0.001	0.039	0.002
Butanoic acid	Sweaty, rancid	1634	1627	0.005	0.006	0.004	0.002	0.007	0.004	0.001	0.869	0.160	0.686
Butyrolactone	Milky, creamy, peach-like	1636	1643	0.007	0.007	0.004	0.001	0.006	0.005	0.001	0.127	0.393	0.004
Naphthalene	-	1748	1749	0.048	0.050	0.045	0.007	0.040	0.055	0.006	0.870	0.084	0.234
Hexanoic acid	Sweaty, rancid	1839	1844	0.004	0.007	0.004	0.001	0.002	0.009	0.001	0.032	0.001	0.571

[abc] Mean within the same row with different superscripts significantly ($p<0.05$)

Table 25 Volatile compounds identified in different marbling score raw beef of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF)

Volatile compound (DB-Wax_Raw beef)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)											
				CHA		SEM	p-value	HFM		SEM	p-value	HFF		SEM	p-value
				ML	MM			ML	MM			ML	MM		
Hexane	Faint peculiar odor	599	600	0.386	0.577	0.161	0.612	0.415^{ba}	0.331^{b}	0.021	0.016	0.394	0.514	0.098	0.599
Acetone	-	808	814	0.035	0.048	0.005	0.158	-	-	-	-	-	0.091	-	-
Propanoic acid, 2-methyl-, ethylester	-	958	960	0.006^{b}	0.012^{a}	0.002	0.013	-	0.013-	-	-	0.005	-	-	-
2,3-Butanedione	Sweet, buttery	970	964	0.031	0.038	0.004	0.435	0.006^{b}	0.040^{a}	0.008	0.007	-	0.028	-	-
Trichloromethane	-	1013	1037	0.036	0.022	0.006	0.305	0.048	0.063	0.010	0.546	0.035	0.035	0.008	0.980
Toluene	-	1024	1043	0.012	0.018	0.002	0.226	0.036	0.028	0.003	0.252	0.009^{b}	0.024^{a}	0.004	0.043
Butanoic acid, ethylester	Fruity	1027	1024	0.097	0.129	0.013	0.248	0.180	0.157	0.014	0.470	0.030	0.034	0.010	0.870
Hexanal	Green, grassy, fatty	1070	1083	0.031	-	-	-	0.016	0.082	0.024	0.195	-	-	-	-
Heptanal	Sopy/fruity, fatty, sweet, oil	1210	1184	0.006	0.003	0.001	0.159	0.014	-	-	-	-	-	-	-
Hexanoic acid, ethylester	-	1231	1238	0.032	-	-	-	-	0.040	-	-	0.029	0.050	0.014	0.512
1-Pentanol	Fusel, fermented, bread, cereal	1254	1255	0.008	-	-	-	0.109	0.097	0.034	0.884	0.019	0.039	0.009	0.314

Table 25 (Continued)

Volatile compound (DB-Wax_Raw beef)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)											
				CHA		SEM	p-value	HFM		SEM	p-value	HFF		SEM	p-value
				ML	MM			ML	MM			ML	MM		
Acetoin	-	1278	1280	0.472	-	-	-	0.554	0.376	0.090	0.380	-	-	-	-
2-hydroxy ethylester Propanoic acid	-	1341	1341	0.090	0.180	0.031	0.167	0.148	-	-	-	0.131	0.081	0.033	0.510
1-Hexanol	Green, fruity, apple-skin	1355	1359	0.003	-	-	-	0.024	0.019	0.005	0.652	0.003	0.007	0.001	0.226
1-Octanol	Penetraing aromatic odor, fatty, waxy, citrus, oily	1389	1396	-	0.021	-	-	0.022	0.022	0.003	0.921	-	-	-	-
Nonanal	Sweet,fatty,green	1433	1451	0.015^{b}	0.045^{a}	0.008	0.053	0.025	0.026	0.003	0.792	0.018	0.027	0.005	0.374
Octanoic acid ethylester	-	1278	1280	0.008	0.013	0.001	0.067	0.023	0.016	0.003	0.358	-	-	-	-
Acetic acid	Sour, vinegar	1444	1448	0.002	0.019	0.005	0.098	0.004	0.031	0.012	0.312	0.006	0.020	0.005	0.113
1-Octen-3-ol	Mushroom, earthy,	1449	1443	0.009	0.002	0.003	0.238	0.047	0.033	0.012	0.622	0.002	0.007	0.002	0.271
1-Hexanol, 2-ethyl-	-	1490	1484	0.005	0.007	0.001	0.537	-	0.007	-	-	0.003	0.006	0.003	0.267
1-Octanal	-	1560	1558	-	0.021	-	-	0.022	0.022	0.003	0.921	-	-	-	-
Butanoic acid	Sweaty, rancid	1631	1620	-	0.020	-	-	-	0.022	-	-	-	0.011	-	-
Hexanoic acid	Floral, lavender	1444	1448	-	-	-	-	0.030	0.041	0.011	0.695	0.006^{b}	0.025^{a}	0.005	0.019

[abc] Mean within the same row with different superscripts significantly ($p<0.05$)

Table 26 Volatile compounds identified in different marbling score on grilled beef of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF)

Volatile compound (DB-Wax_Grill beef)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)											
				CHA		SEM	p-value	HFM		SEM	p-value	HFF		SEM	p-value
				ML	MM			ML	MM			ML	MM		
Hexane	Faint peculiar odor	599	600	0.434	0.205	0.114	0.360	0.964[a]	0.176[b]	0.179	0.001	0.211	0.119	0.029	0.109
Octane	-	800	800	0.022	0.029	0.003	0.278	0.025	0.060	0.010	0.076	0.033[a]	0.024[b]	0.003	0.034
2-methyl-butanal	Pungent, sweet, roasty	909	909	-	0.020	-	-	0.034[a]	0.018[b]	0.004	0.010	0.019	0.020	0.001	0.584
3-methyl-butanal	Meaty, fish, aldehyde, fatty	913	931.2	0.015	0.020	0.002	0.281	0.024	0.021	0.003	0.632	0.016	0.018	0.001	0.505
Butanoic acid 2oxo	-	953	911	-	0.012	-	-	0.019	-	-	-	0.016	0.008	0.003	0.154
Trichloromethane	-	1014	1037	0.086	0.051	0.012	0.175	0.431[a]	0.071[b]	0.091	0.018	0.087[a]	0.061[b]	0.007	0.058
Toluene	-	1026	1043	0.039	0.052	0.005	0.280	0.078	0.082	0.007	0.794	0.082	0.086	0.006	0.750
Hexanal	Green, grassy, fatty	1072	1078	2.940	0.467	0.914	0.221	0.115[b]	0.297[a]	0.044	0.006	0.063	0.561	0.185	0.205
1-Hexanol 2-ethyl	-	1493	1492	-	0.006	-	-	-	0.006	-	-	0.003	0.005	0.000	0.069
Heptanal	Sopy/fruity, fatty, sweet, oil	1182	1181	0.073	0.018	0.022	0.240	0.006	0.008	0.002	0.665	0.011	0.020	0.005	0.423
Styrene	Sweet, balsamic, floral	1251	1252	0.042	0.003	0.018	0.325	0.006	0.004	0.001	0.454	0.003	0.004	0.001	0.712
1-Pentanol	Extremely penetrating Fusel, fermented, bread, cereal	1256	1258	0.162	0.041	0.045	0.205	0.008[b]	0.033[a]	0.006	0.001	0.006	0.094	0.027	0.094
Methyl pyrazine	Nutty, brown, musty, roasted	1263	1263	0.005	0.005	0.001	0.599	0.007[a]	0.005[b]	0.001	0.003	0.003	0.002	0.000	0.292
Acetoin	-	1281	1280	0.371	0.459	0.087	0.666	0.477	0.435	0.053	0.739	0.153[b]	0.219[a]	0.016	0.007

Table 26 (Continued)

Volatile compound (DB-Wax_Grill beef)	Aroma Descriptor	RI. Cal	RI. Ref.	Peak Area (sample/Int std)											
				CHA		SEM	p-value	HFM		SEM	p-value	HFF		SEM	p-value
				ML	MM			ML	MM			ML	MM		
Octanal	Citrus-like, green	1285	1287	0.051	0.014	0.015	0.251	0.009	0.010	0.002	0.898	0.010	0.006	0.002	0.221
2-ethyl-6-methylpyrazine	-	1321	1325	0.005	0.006	0.001	0.667	0.011	-	-	-	0.005	0.006	0.001	0.705
1-Hexanol	Green, fruity, apple-skin	1358	1359	0.082^{a}	0.014^{b}	0.016	0.001	0.004^{b}	0.013^{a}	0.002	0.014	0.006	0.030	0.013	0.159
Nonanal	Citrus-like, soapy	1392	1390	0.092	0.058	0.016	0.329	0.032	0.077	0.018	0.259	0.045	0.022	0.007	0.102
Aceticacid	Sour, vinegar	1453	1451	0.005	0.003	0.002	0.213	0.069^{a}	0.008^{b}	0.014	0.003	0.044^{a}	0.006^{b}	0.010	0.038
1-Octen-3-ol	Mushroom, earthy, fungal	1454	1456	0.026	0.031	0.013	0.853	-	0.042	-	-	-	0.066	-	-
Benzaldehyde	Almond, nutty, woody	1524	1520	0.015	0.008	0.000	0.173	0.006	0.006	0.001	0.869	0.009^{a}	0.006^{b}	0.001	0.034
1-Octanol	Waxy, green, citrus, orange	1564	1569	0.023	0.015	0.003	0.162	0.005	0.017	0.003	0.065	0.008	0.007	0.001	0.538
Diethyl carbitol	-	1630	1619	0.010^{a}	0.005^{b}	0.001	0.005	0.006	0.006	0.000	0.689	0.004	0.004	0.000	0.531
Butanoic acid	Sweaty, rancid	1634	1627	0.006	0.005	0.002	0.911	0.008	0.004	0.002	0.304	0.007	0.002	0.001	0.082
Butyrolactone	Milky, creamy, peach-like	1636	1643	0.011^{a}	0.003^{b}	0.002	0.075	0.005^{b}	0.008^{a}	0.001	0.022	0.003^{b}	0.005^{a}	0.000	0.017
Naphthalene	-	1748	1749	0.051	0.045	0.006	0.693	0.037	0.063	0.008	0.111	0.033	0.057	0.009	0.198
Hexanoic acid	Floral, lavender	1839	1844	-	0.007	-	-	0.005	0.011	0.002	0.063	-	0.009	-	-

^{abc} Mean within the same row with different superscripts significantly ($p<0.05$)

Table 27 Volatile compounds identified in different breed on raw beef of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF)

Volatile compound (DB-Wax_Raw)	Aroma Descriptor	RI. Cal	RI. Ref	ML			SEM	p-value	MM			SEM	p-value
				CHA	HFM	HFF			CHA	HFM	HFF		
Hexane	Faint peculiar odor	599	600	0.386	0.415	0.394	0.058	0.983	0.577	0.331	0.514	0.108	0.694
Acetone	-	808	814	0.04	-	-	-	-	0.048^{b}	-	0.091^{a}	0.015	0.193
2-methyl-propanoic acid, ethylester	-	958	960	0.006	0.000	0.005	0.001	0.092	0.012	0.013	-	0.002	0.704
2,3-Butanedione	Buttery	970	964	0.031^{a}	0.006^{b}	-	0.005	0.032	0.038	0.040	0.028	0.004	0.538
Trichloromethane	-	1013	1037	0.036	0.048	0.035	0.006	0.715	0.022	0.063	0.035	0.009	0.150
Toluene	-	1024	1043	0.01^{b}	0.04^{a}	0.01^{b}	0.005	0.001	0.018	0.028	0.024	0.003	0.394
Butanoic acid, ethylester	-	1027	1024	0.09^{b}	0.18^{a}	0.03^{c}	0.023	0.002	0.129	0.157	0.113	0.021	0.730
Hexanal	Green, grassy, fatty	1070	1083	0.031	0.016	0.000	0.006	0.069	-	0.086	-	-	-
Heptanal	Sopy/fruity, fatty, sweet, oil	1210	1184	0.006^{b}	0.014^{a}	-	0.001	0.008	0.003	-	-	-	-
Hexanoic acid, ethylester	-	1231	1238	0.032	-	0.029	0.007	0.074	-	0.161	0.050	0.038	0.231
1-Pentanol	-	1254	1255	0.008^{a}	0.109^{b}	0.019^{b}	0.016	0.001	-	0.014	0.039	0.007	0.063
Acetoin	-	1278	1280	0.472	0.554	-	0.084	0.528	-	0.376	-	0.081	0.065
2-hydroxy-propanoic acid, ethylester, (S)-	-	1341	1341	0.090	0.148	0.131	0.023	0.613	0.180	-	0.081	0.033	0.140
1-Hexanol	-	1355	1359	0.003^{b}	0.024^{a}	0.003^{b}	0.004	0.001	-	0.019	0.007	0.004	0.170
1-Octanol	Penetraing aromatic odor, fatty, waxy, citrus, oily	1389	1396	-	0.022	-	-	-	0.021	0.022	-	0.004	0.889

Table 27 (Continued)

Volatile compound (DB-Wax_Raw)	Aroma Descriptor	RI. Cal	RI. Ref	ML			SEM	p-value	MM			SEM	p-value
				CHA	HFM	HFF			CHA	HFM	HFF		
Nonanal	citrus-like, soapy	1433	1451	0.015	0.025	0.018	0.003	0.544	0.045	0.026	0.027	0.005	0.195
Octanoic acid, ethyl ester	-	1278	1280	0.008^{b}	0.023^{a}	-	0.002	0.005	0.013	0.016	-	0.010	0.633
Aceticacid	Sour, vinegar	1444	1448	0.002	0.004	0.006	0.001	0.598	0.019	0.031	0.020	0.006	0.816
1-Octen-3-ol	Mushoom	1449	1443	0.009^{b}	0.047^{a}	0.002^{b}	0.007	0.000	0.002	0.033	0.007	0.009	0.343
1-Hexanol, 2-ethyl-	-	1490	1484	0.005	-	0.003	0.001	0340	0.007	0.007	0.006	0.001	0.807
1-Octanal	-	1560	1558	-	-	-	-	-	0.020	0.022	0.011	0.003	0.374
Hexanoicacid	Sweaty, rancid	1631	1620	-	0.030^{b}	0.006^{a}	0.006	0.020	-	0.041	0.025	0.009	0.196

^{abc} Mean within the same row with different superscripts significantly ($p<0.05$)

Table 28 Volatile compounds identified in different breed on grilled beef of crossbred Charolais steers (CHA), fattening dairy steers (HFM) and culled dairy cows (HFF)

Volatile compound (DB-Wax_Grilled)	Aroma Descriptor	RI. Cal	RI. Ref	ML			SEM	p-value	MM			SEM	p-value
				CHA	HFM	HFF			CHA	HFM	HFF		
Hexane	Faint peculiar odor	599	600	0.439	0.600	0.111	0.131	0.346	0.205^{s}	0.176^{s}	0.119^{b}	0.014	0.004
Octane	-	800	800	0.02	0.03	0.03	0.002	0.180	0.03^{b}	0.06^{a}	0.024^{b}	0.007	0.042
2-methyl-butanal	Pungent, sweet, roasty	909	909	-	0.034^{a}	0.019^{b}	0.004	0.005	0.022	0.018	0.020	0.001	0.509
3-methyl-butanal	Meaty, fish, aldehyde, fatty	913	931.2	0.02	0.02	0.02	0.002	0.131	0.020	0.021	0.018	0.002	0.850
2-oxo-butanoic acid	-	953	911	-	0.018	0.015	0.003	0.535	0.012	-	0.008	0.002	0.316
Trichloromethane	-	1014	1037	0.09^{b}	0.43^{a}	0.09^{b}	0.064	0.007	0.051	0.071	0.061	0.004	0.116
Toluene	-	1026	1043	0.04^{b}	0.08^{a}	0.08^{a}	0.008	0.028	0.052	0.082	0.086	0.007	0.084
Hexanal	Green, grassy, fatty	1072	1078	2.94	0.095	0.063	0.682	0.134	0.565	0.297	0.561	0.112	0.161
2-ethyl- 1-hexanol	-	1493	1492	-	-	0.003	-	-	0.006	0.006	0.005	0.000	0.252
Heptanal	Sopy/fruity, fatty, sweet, oil	1182	1181	0.024	0.060	0.010	0.006	0.560	0.018	0.008	0.020	0.004	0.381
Styrene	Sweet, balsamic, floral	1251	1252	0.040	0.010	-	0.012	0.374	0.003	0.004	0.004	0.001	0.954
1-Pentanol	Fusel, fermented, bread, cereal	1256	1258	0.158	0.008	0.005	0.034	0.103	0.041	0.033	0.094	0.016	0.238
Methylpyrazine	Nutty, brown, musty, roasted	1263	1263	0.005^{b}	0.007^{a}	0.003^{b}	0.001	0.010	0.005^{a}	0.005^{a}	0.0023^{b}	0.002	0.029
Acetoin	-	1281	1280	0.37	0.48	0.15	0.077	0.233	0.459^{a}	0.435^{a}	0.219^{b}	0.044	0.019
Octanal	Citrus-like, green	1285	1287	0.05	0.01	0.01	0.011	0.189	0.014	0.010	0.006	0.002	0.153
2,6-dimethyl pyrazine	Musty, potato, cocoa	1321	1325	0.005^{b}	0.01^{a}	0.005^{b}	0.001	0.006	0.006	-	0.006	0.002	0.971
1-Hexanol	Green, fruity, apple-skin	1358	1359	0.08^{a}	0.004^{b}	0.006^{b}	0.013	0.001	0.014	0.013	0.030	0.005	0.317
Nonanal	citrus-like, soapy	1392	1390	0.09^{a}	0.03^{b}	0.05^{ab}	0.012	0.054	0.058	0.077	0.022	0.014	0.303

Table 28 (Continued)

Volatile compound (DB-Wax_Grilled)	Aroma Descriptor	RI. Cal	RI. Ref	ML			SEM	p-value	MM			SEM	p-value
				CHA	HFM	HFF			CHA	HFM	HFF		
Acetic acid	Sour, vinegar	1453	1451	0.01^{b}	0.07^{a}	0.04^{a}	0.010	0.006	0.012	0.008	0.006	0.002	0.495
1-Octen-3-ol	Mushoom	1454	1456	0.03	-	-	-	-	0.032	0.042	0.066	0.009	0.331
Benzaldehyde	Almond, nutty, woody	1524	1520	0.02	0.01	0.01	0.002	0.172	0.008	0.006	0.006	0.000	0.443
1-Octanol	Penetraing aromatic odor, fatty, citrus, oily	1564	1569	0.02^{a}	0.01^{b}	0.01^{a}	0.003	0.001	0.015	0.017	0.007	0.003	0.227
Diethyl carbitol	-	1630	1619	0.01^{b}	0.003^{a}	0.005^{a}	0.001	0.004	0.005	0.006	0.004	0.000	0.119
Butanoic acid	Sweaty, rancid	1634	1627	0.01	0.01	0.01	0.002	0.912	0.005	0.004	0.002	0.001	0.080
Butyrolactone	Milky, creamy, peach-like	1636	1643	0.01	0.01	0.00	0.001	0.080	0.003^{c}	0.008^{a}	0.005^{b}	0.001	0.001
Naphthalene	-	1748	1749	0.05	0.04	0.03	0.006	0.497	0.045	0.063	0.057	0.005	0.413
Hexanoic acid	Sweaty, rancid	1839	1844	-	0.01	-	-	-	0.007	0.011	0.009	0.001	0.394

^{abc} Mean within the same row with different superscripts significantly ($p<0.05$)

CHAPTER 5

CONCLUSIONS

This study was aimed to investigate carcass characteristics, meat quality and sensory evaluation of culled dairy cows, fattening dairy steers and crossbred Charolais steers. The study was divided into 2 experiments.

Experiment 1 undertook to study potential of culled dairy. Three hundred and seven culled dairy cows were slaughtered at Ibrorheem slaughterhouse. The results showed that most of farmers bought cows from middlemen who had no records of sire and dam leading to lack of information about pedigree or proportion of breed inheritance. However, it was found that there were mostly proportions of more than 87.5% Holstein Friesian inheritance in culled cows. The reasons for culling were reproductive problems such as infertility, low production, old cow and udder or mastitis problems. It was found that culled cows were fattened for 4-5 months to gain more body weight or until 450-600 kg of slaughter weight. Diets were the same as milking cows' diet consisted of 70:30 (ratio of concentrate to roughage). The 24% crude protein concentrate was fed at 2.5-3.0 kg/h/d. Roughage was pineapple or corn by-products and sometimes supplemented with palm meal. For carcass characteristics, culled dairy cows had average age of 4.58±0.73 years old, BCS of 3.52±0.61 and marbling score of 2.72±0.83. Average live weight was 581.11±66.73 kg which average weights of warm carcass, chilled carcass and hind were 313.70±38.91, 312.22±38.29 and 36.94±6.29 kg, respectively. Percentage of the warm and chilled carcass weight were 53.99 and 52.64%. Moreover, effects of slaughter weight and sex on carcass characteristics of dairy cattle were also studied. Data of 520 records during 2014-2016 were 412 culled dairy cows (>4 years old and 580.85±3.76 kg of slaughter weight) fattened with concentrate and roughage for 4-5 months and 108 fattening dairy steers (>2 years old and 584.45±7.33 kg of slaughter weight) fattened for 10-12 months. The results showed that the slaughter weight of culled dairy cow did not affect percentages of warm and chilled carcasses but had influenced on warm carcass weight, chilled carcass weight, hide weight, hide weight percentage, fore

quarter and hind quarter ($p<0.05$). There was no effect of slaughter weight on percentages of warm and chilled carcasses ($p>0.05$). Live weight of culled dairy cow was positively correlated with warm and chilled carcass weights, respectively ($r= 0.954$ and 0.936, $p<0.001$). Slaughter weight of dairy steer over 650 kg had a better marbling score than the others (2.05 vs 1.33 and 1.68; $p<0.001$). However, warm and chilled carcass weights of dairy steer were heavier than those of culled dairy cow ($p< 0.05$). Warm and chilled dressing percentages of dairy steer were also higher than those of culled dairy cow ($p<0.05$). Marbling score of dairy cow was higher than those of dairy steer (1.85 vs 1.59; $p<0.01$).

In Experiment 2, breed factor had positively influenced on warm carcass, chilled carcass, hide weight, warm dressing, chilled dressing, hide percentage and rib-eyes area (REA). Warm and chilled carcass of CHA group both in kg and percentage were significantly higher than the others. Moreover, HFM group had greater warm dressing percentage than HFF group. The HFF group had inferior carcass characteristics compared to the others. There was no effect of marbling score and interaction of breed and marbling score on carcass characteristics. Positive and linear relationships of marbling score grading between human visual appraisals (VIS). Image processing techniques (IMG) were found on %marbling fat (IMG1) and score level (IMG2). Marbling score grading by VIS had positive correlated with %marbling fat (IMG1) ($r=0.708$, $p<0.01$). The marbling score by human visual appraisal (VIS) also had positively correlated with score level (IMG2) ($r=0.778$, $p<0.01$). Moreover, marbling score of VIS had positively correlated with fat percentage ($r=0.675$, $p<0.01$). This study showed that application of image processing technique (IMG) could be useful as a tool for marbling score grading in order to minimize human mistakes and bias. The HFM group had higher in muscle pH_{45} than CHA and HFF groups. However, there was no difference in ultimate pH. At marbling score more than and equal to 3, L*and b* values were not different among breeds. However, a* values were significantly different among breeds at MBS<3, then decreased at MBS≥3 which CHA and HFF groups had higher a* values than HFM group. At MBS<3, thawing loss of HFF group was higher than those of other groups and decreased at MBS≥3 whereas thawing loss of CHA and HFM groups increased at MBS≥3. However, cooking losses were

decreased as marbling score increased. As marbling score increased, contents of moisture and protein in beef and shear force value significantly decreased whereas fat content in beef significantly increased. Moreover, all beef with MBS≥3 had no significant difference in shear force value (5.06-5.21 kg).

Raw CHA and HFF beefs had higher C14:0, C18:1n9c, C18:3n6, C18:3n3 than HFM beef but HFM beef had greater C20:4n6 (Arachidonic acid) than CHA and HFF beefs ($p<0.05$). CHA and HFF beefs also had notable the MUFA content especially oleic acid. In the part of polyunsaturated fatty acid (PUFA), particularly Ɣ-linolenic acid (C18:3n6), linolenic acid (C18:3n3) had distinguished on CHA and HFF groups which both of MUFA and PUFA had efficiency to reduce cholesterol levels in the blood. The ratio of PUFA/SFA and MUFA/SFA of CHA group had inferior than HFM and HFF groups but it had superior on n6/n3 ratio ($p<0.05$). As marbling score increased, there were increases in oleic acid (C18:1n9c), linoleic acid (C18:2n6c), linolenic acid (C18:3n3). For the PUFA/SFA ratio of beef with MBS≥3 was inferior compared with beef with MBS<3. Grilled HFM and HFF beefs had greater oleic acid than CHA group ($p<0.05$). However, there was no effect of marbling score on oleic acid ($p>0.05$). Grilled CHA and HFF beefs had lower SFA and MUFA compared to raw beef. Grilled HFM beef had the greatest in C18:1n9c, SFA, MUFA and PUFA-n3 which was corresponding with volatile compound of HFM beef, beef with higher marbling score had great butyrolactone (milky, creamy). After cooking, HFM beef had higher SFA content. It had affected to lower PUFA/SFA ratio of HFM beef but it had a great n6/n3 ratio. It was found that there was no difference in attributes of appearance, color, flavor, and texture ($p>0.05$). The overall acceptability attribute of CHA and HFF beef had greater than HFM beef with MBS<3 ($p<0.05$). Interestingly, CHA beef tended to have more flavor score than other groups ($p=0.062$). Trained panelists could not detect sensory attributes between breeds except overall acceptability of beef with MBS<3.

Sensory descriptive attributes of beef, Chalorais and Holstein cow beefs were tender than Holstein steer beef. Moreover, beefs from Chalorais and Holstein steer had detectable umami taste. Holstein steer beef had the greatest quantities of milky flavor and oily taste. As marbling score increased, it showed increases in beefy, milky

flavor and also great umami, sweetness and oily. High marbling score beef had great methyl-pyrazine (Nutty, brown, musty, roasted) and butyrolactone (milky, creamy) in grilled beef from Holstein steer. Butyrolactone (milky, creamy) was higher in dairy cow beef with high marbling score.

It could be concluded that culled dairy cow had inferior carcass quality compared to Chalorais and Holstein steer. However, beef from culled dairy cow had no difference in meat color, fat and protein contents in meat, shear force value, sensory attributes compared to the others when beef had marbling score up to score 3. Moreover, Holstein steer showed higher C18:1n9c (oleic acid), SFA, MUFA, PUFA-n3 and n6/n3 ratio in grilled beef. Grilled beefs from Holstein steer and Holstein cow group had greater oleic acid than CHA group. Beef from Holstein steer had superior milky/salty flavor and umami/oily taste but had higher denseness compare to beefs from Chalorais and Holstein cow. Dairy beef had predominant on butyrolactone as a milky, creamy flavor while higher butyrolactone was found in beef with marbling score more than 3.

From economic return, it could be recommended that fattening Chalorais steers had high return than dairy steers for 10-12 months (28,000 and 18,000 baht/head, respectively) while of culled dairy cows, fattened for 4-5 months had return about 15,800 baht/head. Dairy steers had slightly higher income than culled dairy cows (2,200 baht/head). Even though dairy steers had great carcass weight and percentage, fattening period was lasted 10-12 months including growing period of 15 months. Therefore, fattening of culled dairy cow showed good economic return, lower fattening cost and shorter fattening period compared to dairy steer.

This study showed that dairy beef had great opportunities in premium beef market. Dairy cattle should be fattened until slaughter weight over 650 kg which had a better weight carcass and marbling score. Dairy cattle had lower carcass weight and carcass percentage compared to Chalorais steers but beef from Holstein steer had great rib-eye area. Interestingly, dairy steer had better carcass weight and carcass percentage meanwhile dairy cow had superior on marbling scores. Higher fat percentage, more tenderness, desirable meat color and sensory acceptability were found in dairy beef with marbling score more than 3. Beef from Holstein steer had

superior milky flavor and umami taste. Interestingly, dairy beef had predominant on butyrolactone as a milky, creamy flavor.

Therefore, beef from dairy steer and cow showed marketing opportunity shifting from traditional market to premium beef market. Consumers also have new choice for premium beef instead of imported beef as well as farmers have chances for generating more income and return from fattening dairy cattle both steer and cow.

REFERENCES

Aaslying, M. D., Bejerholm, C., Ertbjerg, P. Bertram, H. C. & Andersen, H. J. 2003. Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. **Food Qual. Pref.,** 14, 288-277.

ACFS. 2004. **Thai agricultural commodity and food standard TACFS 6001-2004.** BEEF file:///C:/Users/WiN%2010/Downloads/Documents/023.pdf. (31 October 2016).

Alfaia, C. P. M., Castro, M. L. F., Martins, S. I. V., Portugal, A. P. V., Alves, S. P. A., Fontes, C. M. G. A., Bessa, R. J. B., Prates & J. A. M. 2007. Effect of slaughter season on fatty acid composition, conjugated linoleic acid isomers and nutritional value of intramuscular fat in Barrosa-PDO veal. **Meat Sci.,** 75, 44–52.

Albrecht, E., Teuscher, F., Ender, K. & Wegner, J. 2006. Growth and breed-related change of muscle bundle structure in cattle. **J. Anim. Sci.,** 8, 2959-2964.

AMSA. 1995. **Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Fresh Meat.** Chicago, IL.: American Meat Science Association.

Anon. 1994. **National Livestock Language.** Cattle: Bovine AUS-MEAT Limited, Brisbane.

Andersen, H. J., Niels, O., Jette, F. Y. & Margreth, T. 2005. Feeding and meat quality a future approach. **Meat Science,** 70, 543–554.

AOAC. 1996. **Official Methods of Analysis.** Arlington, VA.: Association of Official Analytical Chemists.

ASTM. 2011. ASTM F 2925-11 Standard specification for tenderness marketing claims associated with meat cuts derived from beef. (Vol. 2014).

Armbruster, G., Nour, A. Y. M., Thonney, M. L. & Stouffer, J. R. 1983. Changes in cooking losses and sensory attributes of Angus and Holstein beef with increasing carcass weight, marbling score or *longissimus* ether extract. **Journal of Food Science,** 48, 835-838.

Aunn, P., Opatpattanakit, Y. & Sethakul, J. 2009. Productive performance and carcass quality of fattening dairy cows fed with pineapple or corn by-product silage as a roughage source. In **Proceedings of the 1th Meat Science Technology,** 17-18 December 2009, Bangkok.

Ba, H. V., Hwang, I. H., Dawoon, J. & Amna, T. 2012. Principle of meat aroma flavors and future prospect. pp. 145-176. In I. Akyar (Ed.). **Latest research into quality control.** Croatia: In Tech.

Baldwin, R. L., Macleod, K. R. & Capuco, A. V. 2004. Visceral tissue growth and proliferation during the bovine lactation cycle. **J. Dairy Sci.,** 87, 2977-2986.

Bureš, D. & Bartoˇn, L. 2012. Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages. **Czech J. Anim. Sci.,** 57, 34–43.

Bartoň L., Kott T., Bureš D., Rehák D., Zahrádková R. & Kottová B. 2010. The polymorphisms of stearoyl-CoA desaturase (SCD1) and sterol regulatory element binding protein-1 (SREBP-1) genes and their association with the fatty acid profile of muscle and subcutaneous fat in Fleckvieh bulls. **Meat. Sci.,** 85, 15–20.

Bauer, F. 1983. Free glutamic acid in meat products. **Ernahrung,** 7, 688.

Bazzoli, I., De Marchi, M., Cecchinato, A., Berry, D. P. & Bittante, G. 2014. Factors associated with age at slaughter and carcass weight, price, and value of dairy cull cows. **J. Dairy Sci.,** 97, 1082–1091.

Bellmann, O., Wegner, J., Teuscher, F., Schneider, F. & Ender, K. 2004. Muscle characteristics and corresponding hormone concentrations in different types of cattle. **Livest. Prod. Sci.,** 85, 45-57.

Boakye, K. 1993. Changes in pH and water holding properties of *Longissimus dorsi* muscle during beef ageing. **Meat Science,** 34, 335-349.

Boleman, S. J., Boleman, S. L., Miller, R. K., Taylor, J. F., Cross, H. R., Wheeler, T. L., Koohmaraie, M., Shackelford, S. D., Miller, M. F., West, R. L., Johnson, D. D. & Savell, J. W. 1997. Consumer evaluation of beef of known categories of tenderness. **Journal of Animal Science,** 75, 1521-1524.

Bourne, M. C. 1978. Texture profile analysis. **Food Technol.,** 32(7), 62–66.

Brady, P. L. & Hunecke, M. E. 1985. Correlations of Sensory and Instrumental Evaluations of Roast Beef Texture. **Journal of Food Science,** 50(2), 300–303.

Brewer, M. S. 2006. **The chemistry of beef flavor - executive summary.** [Online]. Available http://www.beefissuesquarterly.com/CMDocs/BeefResearch/PEExecutive_Summaries/The_Chemistry_of_Beef_Flavor.pdf (22 August 2017).

Brosh, A., Aharoni, Y., Levy, D. & Holzer, Z. 1995. Effect of diet energy concentration and of age of Holstein-Friesian bull calves on growth rate, urea space and fat deposition, and ruminal volume. **J. Anim. Sci.,** 73, 1666-1673.

Bruce, H. L., Beilken, S. L & Leppard, P. 2005. Textural descriptions of cooked steaks from bovine M. *longissimus thoracis et lumborum* from different production and aging regimes. **Journal of Food Science,** 70, 309-316.

Bunmee, T., Jaturasith, S., Yammuen-art, S., Phatsara, C., Kreuzer, M. & Wicke, M. 2011. Effect of finishing diets on growth performance and carcass characteristics of culled dairy cows. **Journal of Agriculture,** 27(2), 113-120.

Bunmee, T., Jaturasitha, S., Chaiwang, N., Kreuzer, M. & Wicke, M. 2012. Utilization of agro-food industry by-products in the finishing of culled dairy cows: effects on meat quality. **CMU J Nat Sci.,** 11, 295-302.

Bunmee, T., Jaturasitha, S., Wicke, M. & Kreuzer, M. 2015. Effects of different finishing feeding strategies for culled cows on lipid and organoleptic characteristics of the meat. **Songklana karin Journal of Science and Technology,** 37(2), 109-117.

Bureš, D. & Bartoň, L. 2012. Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages. **Czech Journal Animal Science,** 57(1), 34–43.

Caine, W. R., Aalhus, J. L., Best, D. R., Dugan, M. E. R. & Jeremiah, L. E. 2003. Relationship of texture profile analysis and Warner-Bratzler shear force with sensory characteristics of beef rib steaks. **Meat Science,** 64, 333–339.

Carden, L. A. & Baird, S. B. 2000. Flavors. pp. 201-214. In G. L. Christen & J. S. Smith (eds.). **Food Chemistry: Principles and Applications.** West Sacramento, CA.: Science Technology System.

Castellini, C., Berri, C., Le Bihan-Duval, E. & Martino, G. 2008. Qualitative attributes and consumer perception of organic and free-range poultry meat. **World's Poult. Sci. J.,** 64, 500–512.

Cerny, C. 2012. Savory flavors. In Nollet, L. M. L. (eds.). **Handbook of meat, poultry and seafood quality.** 2nd ed. Chichester: Wiley- Blackwell.

Chainam, J. & Opatpatanakit, Y. 2016. **Carcass quality of culled dairy cows and fattening dairy steers raised by members of beef cluster cooperative in Thailand.** 62nd International Congress of Meat Science and Technology, 14-19th August 2016, Bangkok, Thailand.

Chambaz, A., Scheeder, M. R. L., Kreuzer, M. & Dufey, P. A. 2001. Characteristics of steers of six beef breeds fattened from eight months of age and slaughtered at a target level of intramuscular fat. **Arch. Anim. Breed.,** 44, 473-488.

Chen, K., Sun, X., Qin, C. & Tang, X. 2010. Color grading of beef fat by using computer vision and support vector machine. **Computers and electronics in agriculture,** 70, 27-32.

Cho, S. H., Park, B. Y., Kim, J. H., Hwang, I. H., Kim, J. H. &Lee, J. M. 2005. Fatty acid profiles and sensory properties of *longissimus dorsi,* triceps brachii, and semi-membranosus muscles from Korean Hanwoo and Australian Angus beef. **Asian-Aust. J. Anim. Sci.,** 18, 1786-1793.

Choat, W. T., Paterson, J. A., Rainey, B. M., King, M. C., Smith, G. C., Belk, K. E. & Lipsey, R. J. 2006. The effects of cattle sex on carcass characteristics and *longissimus* muscle palatability. **Journal Animal Science,** 84, 1820-1826.

Chumngoen, W. & Tan, F. J. 2015. Relationships between Descriptive Sensory Attributes and Physico chemical Analysis of Broiler and Taiwan Native Chicken Breast Meat. **Asian-Australasian Journal of Animal Sciences,** 28(7), 1028-1037.

Chung, K. Y., Lunt, D. K., Kawachi, H., Yano, H. & Smith, S. B. 2007. Lipogenesis and stearoyl-CoA desaturase gene expression and enzyme activity in adipose tissue of short- and long-fed Angus and Wagyu steers fed corn- or hay-based diets. **Journal of Animal Sciences,** 85, 380-387.

Ćirić, J., Lukić, M., Radulović, S., Janjić, J., Glamočlija, N., Marković, R. & Ž Baltić, M. 2017. The relationship between the carcass characteristics and meat composition of young Simmental beef cattle. **IOP Conference Series: Earth and Environmental Science,** 85, 012061.

Cooke, D. W. I., Monahan, F. J., Brophy, P. O. & Boland, M. P. 2004. Comparison of concentrates or concentrates plus forages in a total mixed ration or discrete ingredient format: effects on beef production parameters and on beef composition, colour, texture and fatty acid profile. **Irish Journal of Agriculture and Food Research,** 43, 201–216.

Corbin, C. H., O'Quinn, T. G., Garmyn, A. J., Legako, J. F., Hunt, M. R., Dinh, T. T. N. & Rathmann, R. J. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling level and quality treatment. **Meat Science,** 100, 24-31.

Cranwell, C. D., Unruh, J. A., Brethour, J. R. & Simms, D. D. 1996. Influence of steroid implants and concentrate feeding on carcass and *longissimus* muscle sensory and collagen characteristics of cull beef cows. **Journal of Animal Science,** 74, 1777–1783.

Daley, C. A., Abbott, A., Doyle, P. S., Nader, G. A. & Larson, S. 2010. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. **Nutrition Journal,** 9(1), 10.

Dang, L. Y., Wang, Z. & Xu, S. Y. 2007. Combination of solid-phase micro extraction and simultaneous distillation extraction methods with GC to analysis of aroma components in parma ham flavor. **Food and Fermentntation Industries,** 33(8), 132–137.

Demirel, G., Ozpinar, H., Nazli, B. & Keser, O. 2006. Fatty acids of lamb meat from two breeds fed different forage: concentrate ratio. **Meat Science,** 72, 229-235.

Department of livestock development. 2012. **Beef Strategies 2012-2016.** [Online]. Available http://region2.dld.go.th/th/images/GM_2558/Doc/255911/%E0%B8%A2%E0%B8%B8%E0%B8%97%E0%B8%98%E0%B8%A8%E0%B8%B2%E0%B8%AA%E0%B8%95%E0%B8%A3%E0%B9%8C%E0%B9%82%E0%B8%84%E0%B9%80%E0%B8%99%E0%B8%B7%E0%B9%89%E0%B8%AD.pdf (31 October 2016).

_____. 2014. **Report dairy cow.** [Online]. Available http://ict.dld.go.th/th2/images/stories/stat_web/yearly/2557/book2557/03.pdf (31 October 2016).

De Smet, S., Raes, K. & Demeyer, D. 2004. Meat fatty acid composition as affected by fatness and genetic factors: a review. **Animal Research,** 53, 81-98.

Descalzo, A. M., Insani, E. M., Biolatto, A., Sancho, A. M., Garcia, P. T., Pensel, N. A & Josifovich. J. A. 2005. Influence of pasture or grain-based diets supplemented with vitamin E on antioxidant/oxidative balance of Argentine beef. **Meat Science,** (70), 35-44.

Dolezal, H. G., Smith, G. C., Savell, J. W. & Carpenter, Z. L. 1982. Comparison of subcutaneous fat thickness, marbling and quality grade for predicting palatability of beef. **Journal of Food Science,** 47(2), 397–401.

Dolezal, H. G., Tatum, J. D., Williams, F. L. 1993. Effects of Feeder Cattle Frame Size, Muscle Thickness and Age Class on Days Fed, Weight, and Carcass **Composition. J. Anim. Sci.,** 712975-2985.

Domínguez, R., Gómez, M., Fonseca, S. & Lorenzo, J. M. 2014. Influence of thermal treatment on formation of volatile compounds, cooking loss and lipid oxidation in foal meat. **LWT - Food Science and Technology,** 58(2), 439-445.

Dransfield, E., Martin, J. F., Bauchart, D., Abouelkaram, S., Lepetit, J. & Culioli, J. 2003. Meat quality and composition of three muscles from French cull cows and young bulls. **Journal of Animal Science,** 76, 387–399.

Dryden, F. D. & Marchello, J. A. 1970. Influence of total lipid and fatty acid composition upon the palatability of three bovine muscles. **Journal of Animal Science,** 31, 36–41.

Duckett, S. K., Pratt, S. L. & Pavan, E. 2009. Corn oil or corn grain supplementation to steers grazing endophyte-free tall fescue. II. Effects on subcutaneous fatty acid content and lipogenic gene expression. **Journal of Animal Science,** 87, 1120-1128.

Ekeren, P. A., Smith, D. R., Lunt, D. K. & Smith, S. B. 1992. Ruminal biohydrogenation of fatty acids from high-oleate sunflower seeds. **Journal of Animal Science,** 70, 2574-2580.

Elmore, J. S., Warren, H. E., Mottram, D. S., Scollan, N. D., Enser, M., Richardson, I. & Wood, J. D. 2004. Comparison of the aroma volatiles and fatty acid compositions of grilled beef muscle from Aberdeen Angus and Holstein Friesian steers fed diets based on silage or concentrates. **Meat Science,** 68, 27-33.

Elmore, J. S., Mottram, D. S., Enser, M. & Wood, J. D. 1999. Effect of the polyunsaturated fatty acid composition of beef muscle on the profile of aroma volatiles. **Journal of Agricultural and Food Chemistry,** 47(6), 1619–1625.

Emerson, M. R., Woerner, D. R., Belk, K. E. & Tatum, J. D. 2013. Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes. **Journal of Animal Science,** 91(2), 1024–1034.

Enser, M., Hallett, K. G., Hewett, B., Fursey, G. A. J., Wood, J. D. & Harrington, G. 1998. Fatty acid content composition of UK beef lamb muscle in relation to production system and implications for human nutrition. **Meat Science,** 49, 329-341.

Evans, R. D., Dillon, P., Shalloo, L., Wallace, M. & Garrick, D. J. 2004. An economic comparison of dual-purpose and Holstein-Friesian cow breeds in a seasonal grass-based treatment under different milk production scenarios. **Irish Journal of Agriculture and Food Research,** 43, 1–16.

Esslemont, R. J. & Kossaibati, M. A. 1997. The costs of production diseases in dairy herds in England. **Vet J.,** 154(1), 41-51.

Faustman, C. R. & Cassens, G. 1991. The effect of cattle breed and muscle type on discoloration and various biochemical parameters in fresh beef. **J. Anim. Sci.,** 69, 184–193.

Feuz, D. M. 1995. Marketing cull cows – how & when?. pp.134-143. In **Proceedings, The Range Beef Cow Symposium XIV.** Gering, Nebraska.

Folch, J., Lee, M. & Stanley, D. H. S. 1957. A simple method for the isolation and purification of total lipids from animal tissues. **Journal of Biological Chemistry,** 226, 467-509.

Frank, D., Joo, S. T. & Warner, R. 2016. Consumer acceptability of intramuscular fat. **Korean J. Food Sci. An.,** 36, 699-708.

Franco, D., Bispo, E., Gonzlez, L., Vzquez, J. A. & Moreno, T. 2007. Effect of finishing and ageing time on quality attributes of loin from the meat of Holstein-Friesian cull cows. **Meat Science,** 83, 484–491.

French, P., Stanton, C., Lawless, F., O'Riordan, E. G., Monahan, F. J., Caffrey, P. J. & Moloney, A. P. 2000. Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate-based diets. **Journal of Animal Science,** 78, 2849–2855.

Garcia, P. T., Pensel, N. A., Sancho, A. M., Latimori, N. J., Kloster, A. M., Amigone, M. A. & Casal, J. J. 2008. Beef lipids in relation to animal breed and nutrition in Argentina. **Meat Science,** 79, 500-508.

Garmyn, A. J., Hilton, G. G., Mateescu, R. G., Morgan, J. B., Reecy, J. M., Tait, R. G., Beitz, Jr. D., Duan, C. Q., Schoonmaker, J. P., Mayes, M. S., Drewnoski, M. E., Liu, Q. & VanOverbek, D. L. 2011. Estimation of relationships between mineral concentration and fatty acid composition of *longissimus muscle* and beef palatability traits. **Journal of Animal Science,** 89, 2849-2858.

Garrett, W. N. 1971. Energetic efficiency of beef and dairy steers. **J. Anim. Sci.,** 32, 451- 456.

Geesink, G. H., Koolmees, P. A., van Laack, H. L. J. M. & Smulders, F. J. M. 1995. Determinants of tenderisation in beef Longissimus dorsi and Triceps brachii muscles. **Meat Science,** 41(1), 7–17.

Gorraiz, C., Beriain, M. J., Chasco, J. & Insausti, K. 2002. Effect of aging time on volatile compounds, odor, and flavor of cooked beef from Pirenaica and Friesian bulls and heifers. **Journal of Food Science,** 67, 916-922

Grosch, W. 1987. Reactions of hydroperoxides-products of low molecular weight. pp. 95-139. In H. W. S. Chan (ed.). **Autoxidation of unsaturated lipids.** London: Academic Press.

Gruber, S. L., Tatum, J. D., Scanga, J. A., Chapman, P. L., Smith, G. C. & Belk, K. E. 2006. Effects of postmortem aging and USDA quality grade on Warner-Bratzler shear force values of seventeen individual beef muscles. **Journal of Animal Science,** 84(12), 3387-3396.

Hanzelková, Š, Simeonovová, J., Hampel, D., Dufek, A. & Šubrt, J. 2011. The effect of breed, sex and ageing time on tenderness of beef meat. **Acta Veter. Brno,** 80, 191-196.

Harintranon, A. 2001. **Research and development breeding dairy Thailand.** The report of the 4th Conferences and dairy products. Chulalongkorn University, Bangkok.

Hwang, Y. H. & Seon, T. J. 2017. Fatty Acid Profiles, Meat Quality, and Sensory Palatability of Grain-fed and Grass-fed Beef from Hanwoo, American, and Australian Crossbred Cattle. **Korean J. Food Sci. Anim Resour.,** 37(2), 153–161.

Holló, G., Csapó, J., Szúcs, E., Tözsér, J., Repa, I. & Holló, I. 2001. Influence of breed, slaughter weight and gender on chemical composition of beef. Part 2. Fatty acid composition of fat in rib samples. **Asian-Aust. Journal of Animal Science,** 14(12), 1719-1723.

Huffman, R. D., Williams, S. E., Hargrovg, D. D., Johnson, D. D. & Marsha, T. T. 1990. Effect of percentage Brahman and Angus slaughter and end point on feedlot performance and carcass characteristics. **Journal Animal Science,** 68, 2243-2252.

Huidobro, F. R., Miguel, E., Onega, E., Blázquez, B. 2002. Changes in meat quality characteristics of bovine meat during the first 6 days post mortem. **Meat Science,** 65, 1439-1446.

Huffman, K. L., Miller, M. F., Hoover, L. C., Wu, C. K., Brittin, H. C. & Ramsey, C. B. 1996. Effect of beef tenderness on consumer satisfaction with steaks consumed in the home and restaurant. **Journal of Animal Science,** 74, 91–97.

Jaturasitha, S. 2007. **Meat management.** 3rd ed. Chiang Mai, Thailand: Mingmuang Press.

Jirasuwannakul, N. 2011. **Development of image analysis software for beef quality grading.** Bangkok: Thailand Research Fund (TRF).

Jung, E. Y., Hwang, Y. H. & Joo, S. T. 2015. Chemical components and meat quality traits related to palatability of ten primal cuts from Hanwoo carcasses. **Korean J. Food Sci. An.,** 35, 859-866.

Jurie, C., Picard., B., Hocquette, J. F. & Dransfield, E. 2007. Muscle and meat quality characteristics of Holstein and salers cull cow. **Meat Science,** 77, 459-466.

Keane, M. G. 2003. Beef production from Holstein-Friesian bulls and steers of New Zealand and European/American descent, and Belgian Blue Holstein-Friesians, slaughtered at two weights. **Livestock Production Science,** 84, 207-218.

Jurie, C., Martin, J. F., Listrat, A., Jailler, R., Culioli, J. & Picard, B. 2006. Effects of age and breed of beef bulls on growth parameters, carcass and muscle characteristics. **Animal Science,** 80, 257-263.

Kazala, E. C., Lozeman, F. J., Mir, P. S., Laroche, A., Bailey, D. R. & Weselake, R. J. 1999. Relationship of fatty acid composition to intramuscular fat content in beef from crossbred Wagyu cattle. **Journal of Animal Science,** 77(7), 1717.

Kelava, N. U., Ivankovic, A. & Konjacic, M. 2013. Effect of breed and age on beef carcass quality, fatness and fatty acid composition. **Archiv Tierzucht,** 56(97), 958-970.

Kerth, C. R. & Miller, R. K. 2015. Beef flavor: are views from chemistry to consumer. **Journal of the Science of Food and Agriculture,** 95, 2783–279.

Kerry, J., Kerry, J. & Ledward, D. 2002. **Meat processing: improving quality.** Cambridge, England: Woodhead Publishing Limited and CRC Press LLC.

Killinger, K. M., Calkins, C. R., Umberger, W. J., Feuz, D. M. & Eskridge, K. M. 2004. Consumer sensory acceptance and value for beef steaks of similar tenderness, but differing in marbling level1. **Journal of Animal Science,** 82(11), 3294–3301.

Kim, C. J. & Lee, E. S. 2003. Effects of quality grade on the chemical, physical and sensory characteristics of Hanwoo (Korean native cattle) beef. **Meat Science,** 63, 397-405.

Kirchofer, K. S., Calkins, C. R. & Gwartney, B. L. 2002. Fiber-type composition of muscles of the beef chuck and round. **J. Anim. Sci.,** 80, 2872–2878.

Klettner, P. G. 1993. Frankfurter-type sausage influence of heat treatment on firmness and color. **Fleischwirtschaft,** 73(3), 296-298.

Koch, R. M., Dikeman, M. E., Allen, D. M., May, M., Crouse, J. D. & Campion, D. R. 1976. Characterisation of biological types of cattle. III. Carcass composition, quality and palatability. **Journal of Animal Science,** 43, 48-62.

Koch, R. M., Dikeman, M. E. & Crouse, J. D. 1982. Characterization of biological type of cattle (cycle III) carcass composition, quality and palatability. **Journal of Animal Science,** 54, 35-45.

Kögel, J., Pick, M., Rott, J., Hollowich, W., Sarreiter, R., Mehler, N. 2000. Kreuzung sversuch mit Charolais, Blonde d'Aquitaine und Limuosin auf Fleckvieh-Kühe. **Züchtungskunde,** 72, 201-216.

Kosowska, M., Majcher, M. A. & Fortuna, T. 2017. Volatile compounds in meat and meat products. **Food Sci. Technol, Campinas.** [Online]. Available http://www.scielo.br/pdf/cta/2017nahead/0101-2061-cta-1678-457X08416.pdf (23 October 2017).

Kühn, C. Bellmann, O., Voidt, J., Wegner, J., Guiard, V. & Ender, K. 2002. An experimental approach for studying the genetic and physiological background of nutrient transformation in cattle with respect to nutrient secretion and accretion type. **Arch. Tierz., Dummerstorf,** 45, 317-330.

Kuntapanit, C. 1986. **Meat science.** Bangkok: Thaiwattanapanit.

Lambertz, C., Panprasert, P., Holtz, W., Moors, E., Jaturasitha, S., Wicke, M. & Gauly, M. 2014. Carcass Characteristics and meat quality of swamp buffaloes (*Bubalus bubalis*) fattened at different feeding. **Asian-Australasian Journal of Animal Sciences,** 27(4), 551-560.

Larick, D. K. & Turner, B. E. 1990. Head space volatiles and sensory characteristics of ground beef from forage- and grain fed heifer. **Journal of Food Sciences,** 54, 649-654.

Larick, D. K., Turner, B. E., Koch, R. M. & Crouse, J. D. 1989. Influence of phospholipid content and fatty acid composition of individual phospholipids in muscle

from Bison, Hereford and Brahman steers on flavor. **Journal of Food Science,** 54(3), 521-526.

Lawrie, R. A. 1998. **Meat science.** 6th ed. Oxford, UK.: Pergamon Press.

Lawrie, R. A. & Ledward, D. A. 2006. **Lawrie's meat science.** 7th ed. Cambridge, England: Woodhead Publishing.

Legakoa, J. F., Brooks, J. C., O' Quinnc, T. G., Hagand, T. D. J., Polkinghornee, R., Farmerd, L. J. & Miller, M. F. 2015. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. **Meat Science,** 100, 291–300.

Leheska, J. M., Thompson, L. D., Howe, J. C., Hentges, E., Boyce, J., Brooks, J. C., Shriver, B., Hoover, L. & Miller, M. F. 2008. Effects of conventional and grass-feeding systems on the nutrient composition of beef. **Journal of Animal Science,** 86, 3575-85.

Lepetit, J., Sale, P. & Ouali, A. 1986. Post-morterm evaluation of rheological properties of the myofibrilar structure. **Meat Science,** 16, 161-174.

Lorenzen, C. L., Davuluri, V. K., Adhikari, K. & Grün, I. U. 2005. Effect of end point temperature and degree of doneness on sensory and instrumental flavor profile of beefsteaks. **Journal of Food Science,** 70(2), 113-118.

Lorenzen, C. L., Miller, R. K., Taylor, J. F., Neely, T. R., Tatum, J. D., Wise, J. W. & Savell, J. W. 2003. Beef Customer Satisfaction: Trained sensory panel ratings and Warner-Bratzler shear force values1. **Journal of Animal Science,** 81(1), 143–149.

Lertwittayanuruk, B. 2007. **Cattle and buffalo industry of Thailand.** Beef Board of the 1st Nakorn pathom: Extension and training office, Kasetsart University Kumpangsan Campus.

Li, X., Ekerljung, M., Lundstrom, K. & Lunden, A. 2013. Association of polymorphisms *at* DGAT1, leptin, SCD1, CAPN1 and *CAST* genes with color, marbling and water holding capacity in meat from beef cattle populations in Sweden. **Meat Science,** 94, 153–158.

Liu, X. D., Jayasena, D. D., Jung, Y., Jung, S., Kang, B. S., Heo, K. N., Lee, J. H. & Jo, C. 2012. Differential proteome analysis of breast and thigh muscles between

Korean native chickens and commercial broilers. **Asian-Australasian Journal of Animal Sciences,** 25(6), 895- 902.

Lyon, B. G. & Lyon, C. E. 2001. Meat quality: sensory and instrumental evaluations. pp. 97-120. In Sams, A. R. (ed.). **Poultry Meat Processing.** New York: CRC Press.

Ma, Q. L., Hamid, N., Bekhit, A. E. D., Robertson, J. & Law, T. F. 2013. Optimization of headspace solid phase microextraction (HS-SPME) for gas chromatography mass spectrometry (GC–MS) analysis of aroma compounds in cooked beef using response surface methodology. **Micro-chemical Journal,** 111, 16-24.

Machiels, D., Van Ruth, S. M., Posthumus, M. A. & Istasse, L. 2003. Gas chromate graphy-olfactometry analysis of the volatile compounds of two commercial Irish beef meats. **Talanta,** 60, 755-764.

Machiels, D., Istasse, L. & Ruth, S. M. 2004. Gas chromatography-olfactometry analysis of beef meat originating from differently fed Belgian Blue, Limousin and Aberdeen Angus bulls. **Food Chemistry,** 86, 377-383.

Maltin, C. A., Lobley, G. E., Grant, C. M., Miller, L. A., Kyle, D. J., Horgan, G. W., Mattews, K. R. & Sinclair, K. D. 2001. Factors influencing beef eating quality: 2. Effects of nutritional regimen and genotype on muscle fibre characteristics. **Journal of Animal Science,** 72, 279-287.

Maltin, C. A., Lobley, G. E., Grant, C. M., Miller, L. A., Kyle, D. J., Horgan, G. W., Matthews, K. R. & Sinclair, K. D. 2001. Factors influencing beef eating quality 2. Effects of nutritional regimen and genotype on muscle fiber characteristics. **Anim. Sci.,** 72, 279-287.

Maughan, C., Tansawat, R., Cornforth, D., Ward, R. & Martini, S. 2011. Development of a beef flavor lexicon and its application to compare the flavor profile and consumer acceptance of rib steaks from grass- or grain-fed cattle. **Meat Sci.,** 90, 116-121.

Matthes, H. D., Nürnberg, K., Wegner, J., Bittner, G., Jentsch, W. & Derno, M. 1996 Schlachtkörperzusammensetzung restriktiv gefütterter Jungbullen unterschiedlich adaptierter Rinderrassen. **Arch. Tierz., Dummerstorf,** 39(1), 17-24.

Malterre, C. 1986. Production de viande de vaches de réforme. Paris: INRA.

Mann, N. 2000. Dietary lean red meat and human evolution. **Eur. J. Nutr.,** 39, 71-9.

Matulis, R. J., McKeith, F. K., Faulkner, D. B., Berger, L. L. & George, P. 1987. Growth and carcass characteristics of cull cows after different time-on-feed. **Journal of Animal Science,** 65(3), 669-674.

Marino, R., Albenzio, M., della Malva, A., Santillo, A., Loizzo, P. & Sevi, A. 2013. Proteolytic pattern of myofibrillar protein and meat tenderness as affected by breed and aging time. **Meat Science,** 95, 281-287.

May, S. G., Sturdivant, C. A., Lunt, D. K., Miller, R. K. & Smith, S. B. 1993. Comparison of sensory characteristics and fatty acid composition between Wagyu crossbred and Angus steers. **Meat Science,** 35, 289–298.

Meenongyai, W. 2014. Factors affecting on beef tenderness. **Khon Kaen Agr. J.,** 42 (3), 443-452. (in Thai).

Meeprom, C. 2013. Effect of oleic acid enriched oils supplementation on performance, carcass and beef quality of crossbred Brahman steers. Thesis. Suranaree University of technology.

Meilgaard, M. C., Civille, G. V. & Carr, B. T. 2007. **Sensory Evaluation Techniques.** 4th ed. Boca Raton: CRC Press.

Meinert, L., Andersen, L. T., Bredie, W. L. P., Bjergegaard, Ch. & Aaslyng, M. D. 2007. Chemical and sensory characterization of pan-fried pork flavor: Interaction between raw meat quality, ageing and frying temperature. **Meat Science,** 75(2), 229-242.

Melton, S. L. 1990. Effects of feeds on flavor of red meat: a review. **Journal of Animal Science,** 68(12), 4421-4435.

Melton, S. L., Black, J. M., Davis, G. W. & Backus, W. R. 1982. Flavor and selected chemical components of ground beef from steers back grounded on pasture and fed corn up to 140 days. **Journal of Food Science,** 47(3), 699-704.

Melton, S. L., Amiri, M., Davis, G. W. & Backus, W. R. 1982. Flavor and chemical characteristics of ground beef from grass-, forage-grain-, and grain-finished steers. **Journal of Animal Science,** 55, 77–87.

Metcalfe, L.D., Schmitz, A. A. & Pelka, J. R. 1966. Rapid preparation of fatty acid esters from lipid for gas chromatographic analysis. **Journal *of* Analytical Chemistry,** 38, 514-515.

Miller, R. K. 2012. Sensory Evaluation of Beef Flavor. pp. 311–326. In Nollet, L. M. L. (editor). **Handbook of Meat, Poultry and Seafood Quality.** 2nd ed. New York: John Wiley & Sons, Inc.

Miller, M. F., Cross, H. R., Crouse, J. D. & Jenkins, T. G. 1987. Effect of feed energy intake on collagen characteristics and muscle quality of mature cows. **Meat Science,** 21, 287.

Minchin, W., O'Donovan, M. A., Kenny, D. A., Shalloo, L. & Buckley, F. 2007. An evaluation of the most economic fattening strategies for cull dairy cows. pp. 87-107. In **Proceedings of the 33rd Agricultural research forum.** Ireland: Tullamore Court Hotel.

Minchin, W., Buckley, F., Kenny, D., Monahan, A. F. J., Shalloo, L. & O'Donovan, M. 2009a. Effect of grass silage and concentrate based finishing strategies on cull dairy cow performance, carcass and meat quality characteristics. **Meat Science,** 81, 93–101.

Minchin, W., Buckley, F., Kenny, D. A., Keane, M. G., Shalloo, L. & O'Donovan, M. 2009b. Prediction of cull cow carcass characteristics from live weight and body condition score measured pre slaughter. **Irish Journal of Agricultural and Food Research,** 48, 75–86.

Mitsumoto, M., Mitsuhashi, T., & Ozawa, S. 1992. Influence of slaughter weight, sire, concentrate feeding and muscle on the physical and chemical characteristics in Japanese black beef. **Asian-Australasian Journal of Animal Science,** 5, 629–634.

Mottram, D. S. 1994. Some aspects of the chemistry of meat flavour. pp. 210-230. In **Flavour of Meat and Meat Products.** Springer, Boston, MA: Chapman & Hall.

_____. 1998. Flavor formation in meat and meat products: a review. **Food Chemistry,** 62, 415-424.

Monsón, F., Sañudo, C. & Sierra, I. 2005. Influence of breed and ageing time on the sensory meat quality and consumer acceptability in intensively reared beef. **Meat Science,** 71, 471-479.

Murray, J. M., Delahunty, C. M. & Baxter, I. A. 2001. Descriptive sensory analysis: past, present and future. **International Food Research Journal,** 34, 461-471.

Nishimura, T., Liu, A., Hattori, A. & Takahashi, K. 1998. Changes in mechanical strength of intramuscular connective tissue during postmortem aging of beef. **Journal Animal Science,** 76, 528–532.

Noidad, S., Limsupawanit, R. & Sethakul, J. 2009. Effect of ageing periods on meat quality of finished dairy cow fed with pineapple or corn by-product silage as a roughage source. **King mongkut's agricultural Journal,** 28(2), 52-60.

Noidad, S., Lertpatarakomol, R. & Rakthong, M. 2014. Preliminary study on carcass quality of culled dairy cows. pp. 116-120. In **Proceedings of the 5th Meat Science Technology** 25-26 July 2014, Bangkok.

Noidad, S., Chaosap, C., Sitthigripong, R. & Sethakul, J. 2013. Effect of Muscle Types on quality of dairy beef bulls. pp. 41-46. In **Proceedings of the 4th Meat Science and Technology** 19 July 2013, Rama Garden Hotel, Bangkok.

Nuernberg, K., Dannenberger, D., Nuernberg, G., Ender, K., Voigt, J., Scollan, N. D., Wood, J. D., Nute, G. R. & Richardson, R. I. 2005. Effect of a grass-based and a concentrate feeding system on meat quality characteristics and fatty acid composition of *longissimus muscle* in different cattle breeds. **Livestock Production Science,** 94, 137-47.

O'Donovan, M., Minchin, W., Frank, B., David, K. & Laurence, S. 2009. **Adding value to cull cow beef.** [Online]. Available https://t-stor.teagasc.ie/bitstream/handle/11019/842/eopr-5395.pdf?sequence=1&is Allowed=y (15 June 2018).

Office of Agricultural Economics. 2010. **Reveals Techniques of fattening dairy cows culled for add value to farmers.** [Online]. Available http://www.mcot.net/site/content?id=4ff672360b01dabf3c015f64 (31 October 2016).

_____. 2015. **The agricultural situation and trends 2015.** [Online]. Available http://www.Foodfti.com/Files/Name/CONTENT829177504801.pdf (5 August 2017).

_____. 2016a. **Agricultural Statistics of Thailand.** Farm gate price of livestock and products, 2007-2016. [Online]. Available http:// www.oae.go.th/download/download_journal/2560/yearbook59.pdf (14 August 2017).

_____. 2016b. **Agricultural Statistics of Thailand.** Number of dairy-cow on 1st January and quantity of fresh milk by region and province, 2014-2016. [Online]. Available http://www.oae.go.th/down load/download_journal /2560/yearbook59.pdf (31 October 2016).

_____. 2017. **Important agricultural commodity situation and trends.** [Online]. Available http://www.oae.go.th/download/document_tendency/ agri_situation2560.pdf (30 July 2017).

Okumura, T., Saito, K., Nade, T., Misumi, S., Masuda, Y., Sakuma, H., Nakayama, S., Fujita, K. & Kawamura, T. 2007. Effect of intramuscular fat on the sensory characteristics of M. longissimus dorsi in Japanese Black steers as judged by a trained analytical panal. **Asian-Aust J. Anim. Sci.,** 20, 577–581.

Oler, A., Głowinska, B. & Młynek, K. 2015. Slaughter and carcass characteristics, chemical composition and physical properties of *longissimus lumborum* muscle of heifers as related to marbling class. **Arch. Anim. Breed.,** 58, 145–150.

Opatpatanakit, Y., Sethakul, J., Tuntivisoottikul, K. & Chongcharoen, M. 2004. Return of high quality meat production from crossbred Charolais. pp. 307-314. In **Proceedings of 42nd Kasetsart University Annual Conference**: Animals, Veterinary Medicine, 3-6 February 2004, Bangkok.

Opatpatanakit, Y., Sethakul, J., Tuntivisoottikul, K. & Prom-in, W. 2007. Factors Affecting on Carcass Quality of Feedlot Steers under Production System of Kam-phaengsaen Beef Cooperative. pp. 171-178. In **Proceedings of 42nd Kasetsart University Annual Conference**: Animals, Veterinary Medicine 3-6 February 2004, Bangkok.

Opatpatanakit, Y., Jutarat, S., Kunya, T. & Prom-in, W. 2007. Factors Affecting on Carcass Quality of Feedlot Steers under Production System of Kamphaeng-saen Beef Cooperative. pp 171-178. **In Proceedings of 45th Kasetsart University Annual Conference:** Animals and Veterinary Medicine.

O'Quinn, T. G., Brooks, J. C., Polkinghorne, R. J., Garmyn, A. J., Johnson, B. J., Starkey, J. D., Rathmann, R. J. & Miller, M. F. 2012. Consumer assessment of beef strip loin steaks of varying fat levels. **Journal of Animal Science,** 90(2), 626–634.

O'Quinn, T. G. 2012. **Identifying preferences for specific beef flavor characteristics.** Doctoral Dissertation. Colorada State University.

Ozawa, S., Mitsuhashi, T., Mitsumoto, M., Mastsumoto, S., Itoh, N., Itagaki, K., Kohno, Y. & Dohgo, T. 2000. The characteristics of muscle fiber types of longissimus thoracis muscle and their influences on the quantity and quality of meat from Japanese Black steers. **Meat Sci.,** 54, 65-70.

Pacheco, R. F., Mayer, A. R., Marcos, V., A. B., Pötter, L., Cattelam, J., Callegaro, Á. M., Pizzuti, L. A. D, Brondani, I. L., Filho, D. C. A. & Pacheco, P. S. 2015. Qualitative characteristics of meat from cull cows of different genotypes and age class slaughter under different finishing systems: a meta-analytic approach. **An Acad Bras Cienc.,** 87(2), 1083-1093

Page, J. K., Wulf, D. M. & Schwotzer, T. R. 2001. A survey of beef muscle color and pH. **J. Anim. Sci.,** 79, 678–687.

Perez-Alvarez, J. A., Sendra-Nadal, E., Sanchez-Zapata, E. J. & Viuda- Martos, M. 2010. Poultry flavor: general aspects and applications. pp. 339-357. In I. Guerrero, L. & Hui, Y. H. (Eds.). **Handbook of polutry sciences and technology: secondary processing (Vol. 2).** New Jersey: John Wiley & Sons.

Pfuhl, R., Bellmann, O., Kühn, C., Teuscher, F., Ender, K. & Wegner, J. 2007. Beef versus dairy cattle: a comparison of feed conversion, carcass composition, and meat quality. **Archiv Tierzucht Journal,** 50, 59-70.

Poojang, A., Opatpatanakit, Y. & Sethakul, J. 2009. **Productive performance and carcass quality of fattening cull dairy cow fed with pineapple or corn by-product silage as a roughage source.** Proceeding of the 1st Meat Science

Technology 17-18 December 2009. Meat Technology Research Network center, King Mongkut's Institute of Technology Ladkrabang, Bangkok.

_____. 2010. Productive performance and carcass quality of fattening cull dairy cow fed with pineapple or corn by-product silage as a roughage source. **Journal of Agricultural Technology King Mongkut's,** 28(2), 43-51.

Pritchard, R. H. & Burg, P.T. 1993. Feedlot performance and carcass traits of cull cows fed for slaughter. **BEEF REPORT, Cattle,** 93-20, 101-107.

Prukshasri, P. 2005. **Kampaengsaen Beef Breed.** Nonthaburi: Nee-on Book Media.

Pujeang, A., Opatpatannkit, Y. & Settakul, J. 2009. Productive performance, carcass, and meat quality of fattening culled dairy cows fed with pineapple or corn By-product silage as a roughage source. **King Mongkut's Agricultural Journal,** 28(2), 43-51.

Ralf, P., Bellmann, O., Kühn, C., Teuscher, F., Ender, K. & Wegner, J. 2007. Beef versus dairy cattle: a comparison of feed conversion, carcass composition, and meat quality. **Arch. Tierz., Dummerstorf,** 50(1), 59-70.

Realini, C. E., Duckett, S. K., Brito, G. W., Dalla Rizza, M. & Mattos, D. De. 2004. Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. **Meat Science,** 66, 567–577.

Renerre, M. 1990. Review: Factors involved in the discoloration of beef meat. **International Journal of Food Science and Technology,** 25, 613-630.

Robbins, K., Jensen, J., Ryan, K. J., Homco-Ryan, C., McKeith, F. K. & Brewer, M. S. 2003. Consumers attitude towards beef and acceptability of enhanced beef. **Meat Science,** 65, 721-729.

Roncalés, P., Geesink, G. H., Van Laack, R. L. J. M., Jaime, I., Beltrán, J. A., Barnier, V. M. H. & Smulders, F. J. M. 1995. Meat tenderisation: Enzymatic mechanisms. pp. 311-332. In Ouali, A., Demeyer, D. I. & Smulders, F. J. M. (Eds.). **Expression of tissue proteinases and regulation of protein degradations related to meat quality.** Netherlands: ECCEAMST.

Ryoichi, S., Degychi, T. & Nagata, Y. 1993. Effectiveness of the filter paper press methods for determining the water holding capacity of meat. **Fleichwirtsch,** 73, 1399-1400.

Sato, M., Nakamura, T., Numata, M., Kuwahara, K., Homma, S., Sato, A. & Fujimaki, M. 1995. Study on factors related to beef quality on the flavor and umami taste of Japanese Black cattle branded beef. **Journal of Animal Science and Technology,** 66, 274-282.

Savell, J. W., Branson, R. E., Cross, H. R., Stiffler, D. M., Wise, J. W., Griffin, D. B. & Smith, G. C. 1987. National consumer retail beef study: Palatability evaluations of beef loin steaks that differed in marbling. **J. Food Sci.,** 52, 517–519, 532.

Sawyer, J. E., Mathis, C. P. & Davis, B. 2004. Effects of feeding strategy and age on live animal performance, carcass characteristics, and economics of short-term feeding programs for culled beef cows. **J. Anim. Sci.,** 82, 3646-3653.

Schaefer, D. M. 2005. Yield and quality of Holstein beef. pp. 323-333. In Tigner, R. & Lehmkuhler, J. (ed). **Proc. Managing Quality Holstein Steers.** Madison, WI.: Wis. Agric. Service Assoc.

Schnell, T. D., Belk, K. E., Tatum, J. D., Miller, R. K. & Smith, G. C. 1997. Performance, carcass, and palatability traits for cull cows fed high-energy concentrate diets for 0, 14, 28, 42, or 56 days. **Journal of Animal Science,** 75, 1195-1202.

Scollan, N. 2003. **Strategies for optimising the fatty acid composition of beef.** [Online]. Available https://www.aber.ac.uk/en/media/departmental/ibers/pdf/innova tions/03/ 03ch7.pdf (2 August 2017).

Scollan, N., Hocquette, J. F., Nuernberg, K., Dannenberger, D., Richardson, I. & Moloney, A. 2006. Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. **Meat Science,** 74, 17-33.

Seah, J., Gay, G., Su, J., Tai, E. S., Yuan, J. M., Koh, W. P. & van Dam, R. 2017. Consumption of Red Meat, but Not Cooking Oils High in Polyunsaturated Fat, Is Associated with Higher Arachidonic Acid Status in Singapore Chinese Adults. **Nutrients,** 9(2), 101.

Segert, A., Lengerken, G. V. & Fahr, R. D. 1996. Deposition und Mobilisation von Körperfett bei Milchrindern während der Aufzucht und der 1. Laktation. **Arch. Tierz. Dummerstorf,** 39: 557-569.

Sethakul, J. 2010. Production system and ageing period on meat quality of Thai native and crossbred beef. **King mongkul's agricultural journal,** 28(2), (supplement).

Sethakul, J. 2012. The zoologist should know the chain of production of quality beef. **Khon Kaen Agricultural Journal,** 40(2), 55-59.

Sethakul, J. & Lengnoodum, K. 2012. **Dairy Beef...Beef Replaces Beef Quality. Beef** Business Newsletter Publication. Office of Beef Business Newsletter. Meat Technology Research Network Center. King Mongkut's Institute of Technology Ladkrabang. Bangkok. (Pamphlet)(In Thai).

Sethakul, J. & Noidad, S. 2013. The quality of dairy beef in domestics. **The TRF Beef Business Newsletter,** 6(3), 9-12.

Shackelford, S. D., Wheeler, T. L. & Meade, M. K. 2001. Consumer impressions of tender select beef. **J Anim Sci.,** 79, 2605-2614.

Shemeis, A. R., Liboriussen, T., Bech, A. B. & Abdallah, O. Y. 1994. Changes in carcass and meat quality traits of Danish Friesian cull cows with the increase of their age and body condition. **Meat Science,** 37(2), 161–167.

Shutirak, J. 2017. **Effects of aging on meat quality of beef.** [Online]. Available http://www. natres.psu.ac.th/animal/doc/seminar2-2559/%E0%B8%9C%E0%B8%A5%E0%B8%82%E0%B8%AD%E0%B8%87%E0%B8%81%E0%B8%B2%E0%B8%A3%E0%B8%9A%E0%B9%88%E0%B8%A1%E0%B8%95%E0%B9%88%E0%B8%AD%E0%B8%84%E0%B8%B8%E0%B8%93%E0%B8%A0%E0%B8%B2%E0%B8%9E%E0%B9%80%E0%B8%99%E0%B8%B7%E0%B9%89%E0%B8%AD%E0%B9%82%E0%B8%84.pdf (31 June 2018).

Sink, J. D. 1979. Factors influencing the flavour of muscle foods. **J Food Sci.,** 44, 1–5.

Sinpitakkul, P. 2011. **Factors affecting marbling of Thai-French beef.** Thesis. King Mongkut's Institute of Technology Ladkrabang.

Slover, H., Elainelanza,R. H., Thompson, J. R., CAROL, S. D. & GEORGE, V. M. 1987. Lipids in raw and cooked beef. **Journal of Food composition and analysis**, 1, 26-37.

Smith, G. C., Savell, J. W., Cross, H. R., Carpenter, Z. L., Murphey, C. E., Davis, G. W., Abraham, H. C., Parrish, F. C. & Berry, B. W. 1987. Relationship of USDA quality grades to palatability of cooked beef. **J. Food Qual.,** 10, 269–286.

Smith, G. C, Dutson, T. R., Hostetler, R. L. & Carpenter, Z. L. 1976. Fatness, rate of chilling and tenderness of lamb. **Journal of Food,** 41, 748-756.

Smith, S. B., Gill, C. A., Lunt, D. K. & Brooks, M. A. 2009. Regulation of fat and fatty acid composition in beef cattle. **Asian-Australasian Journal of Animal Sciences,** 22(9), 1225-1233.

Soncin, S., Chiesa, L. M., Cantoni, C. & Biondi, P. A. 2007. Preliminary study of the volatile fraction on the raw meat of pork, duck and goose. **Journal of Food Composition and Analysis,** 20(5), 436-439.

Spanier, A. M. & Miller, J. A. 1993. Role of Proteins and Peptides in Meat Flavor. pp.78-97. In Spanier, A. M., Okai, H. & Tamura, M. (eds). **Food Flavor and Safety.** ACS Symposium Series No. 528. Am. Chem. Soc. Washington, D.C.

Spanier, A. M., Flores, M., McMillin, K. W. & Bidner, T. D. 1997. The effect of post mortem aging on meat flavor quality in Brangus beef. Correlation of treatments, sensory, instrumental and chemical descriptors. **Journal of Food Chemistry,** 59, 531-538.

Steven, R. R. & Cassie, S. A. 2005. **Comparison of dairy versus beef steers.** [Online]. Available https://pdfs.semanticscholar.org/0927/32f3eac62352cff3b451b08 c11a2 3947cc6d.pdf (15 June 2018).

Stetzer, A. J., Cadwallader, K., Singh, T. K., Mckeith, F. K. & Brewer, M. S. 2008. Effect of enhancement and ageing on flavor and volatile compounds in various beef muscles. **Meat Science,** 79(1), 13-19.

Stetzer, A. J., Tucker, E., McKeith, F. K. & Brewer, M. S. 2006. Quality changes in various beef muscles enhanced prior to aging. II. Complexus, Serratus ventralis, Vastus lateralis, Vastus medialis and *Longissimus dorsi* muscles. **Journal of Food Science.** In submission.

Stelwagen, J., Sol, J. & Dijkhuizen, A. A. 1984. A three year herd health and management program on thirty Dutch dairy farms. **Veterinary Quarterly,** 6(3), 149-157.

St. John, L. C., Young, C. R., Knabe, D. A., Schelling, G. T., Grundy, S. M. & Smith, S. B. 1987. Fatty acid profiles and sensory and carcass traits of tissues from steers and swine fed an elevated monounsaturated fat diet. **Journal of Animal Science,** 64, 1441-1447.

Sukjai, W., Opatpatannkit, Y. & Supphakitchanon, T. 2012. Carcass and meat quality of culled dairy cows with different slaughter weight and age. **Khon Kaen Agriculture Journal,** 40, 18-24.

Sung, S. M., Seong P. N. & Jin, Y. J. 2015. Evaluation of Meat Color and Physiochemical Characteristics in Forequarter Muscles of Holstein Steers. **Korean J. Food Sci. An.** 35(5), 646-652.

Suzuki, T. 2015. **Feeding management of dairy steers. I dairy beef production system and it supply chain in Asia.** Dusit Thai Pattaya Hotel, 26 October 2015, Thailand.

Tan, B. & Ding, X. L. 2004. Meat (beef) flavor compounds: A review. **China Food Additives,** (6), 73–79.

Tatum, D. 2007. **Beef Grading.** [Online]. Available http://www.beefresearch.org/CMDocs/Beef Research/Beef%20Grading.pdf. (9 August 2017).

Therkildsen, M., Stolzenbach, S. & Byrne, D. V. 2011. Sensory profiling of textural properties of meat from dairy cows exposed to a compensatory finishing strategy. **Meat Science,** 87, 73–80.

Thonney, M. L., Perry, T. C., Armbruster, G., Beermann, D. H. & Fox, D. G. 1991. Comparison of steaks from Holstein and Simmental x Angus steers. **Journal of Animal Science,** 69, 4866-4870.

Thonney, T., Perry, C., Armbruster, G., Beermann, D. H. & Fox, D. G. 1991. Comparison of steaks from Holstein and Simmental x Angus steers. **J Anim Sci.,** 69, 4866-4870.

Touraille, C. & Girardm, J. P. 1985. Revue des factures ante et post-mortem influenc ant la flaveur de la viande at celle des produitscarne's Bull. **Tech Centre de Re-cherches Zootechniques et Veterinaires TheixINRA,** 60, 83-97.

UEDA, Y., Akira, W., Mikito, H., Hiroyuki, S., Shiro, K. & Mitsuru, S. 2007. Effects of intramuscular fat deposition on the beef traits of Japanese Black steers (Wagyu). **Animal Science Journal,** 78, 189–194.

USDA. 1997. **United States Standards for Grades of Carcass Beef.** Washington, DC.: Agric. Marketing Serv.

Varela, A. 2002. **Estudio de las variables que afectan a la produccion del tipo 'Cebon'.** Doctoral Thesis. University of Santiago de Compostela.

Vestergaard, M., Madsen, N. T., Bligaard, H. B., Bredahl, L., Rasmussen, P. T. & Andersen, H. R. 2007. Consequences of two or four months of finishing feeding of culled dry dairy cows on carcass characteristics and technological and sensory meat quality. **Meat Science,** 76, 635–643.

Verbeke, W. & Viaene, J. 1999. Beliefs, attitude and behavior towards fresh meat consumption in Belgium: empirical evidence from a consumer survey. **Food Quality and Preference,** 10, 437-445.

Wang, X., Zhu, L., Han, Y., Xu, L., Jin, J., Cai, Y. & Wang, H. 2017. Analysis of volatile compounds between raw and cooked beef by HS-SPME-GC-MS. **Journal of Food Processing and Preservation,** 42(2), 1-8.

Wasserman, A. E. & Spinelli, A. M. 1972. Effect of some water-soluble components on aroma of heated adipose tissue. **J. Agric. Food Chem.,** 20(2), 171–174.

Waritthitham, C., Lambertz, H., Langholz, J., Wicke, M. & Gauly, M. 2010. Muscle Fiber Characteristics and Their Relationship to Water Holding Capacity of Longissimus dorsi Muscle in Brahman and Charolais Crossbred Bulls Asian-Aust. **Journal of Animal Science,** 23(5), 665 – 671.

Warris, P. D. 2000. **Meat Science. An Introductory Text.** New York: CABI Pub. Inc.

Werner, K. J., Carrick, D. & Micheal, D. 2004. **Encyclopedia of Meat Science Volume 1.** Oxford, UK: Elsevier Ltd.

Wegner, J., Albrecht, E., Fiedler, I., Teuscher, F., Papstein, H. J. & Ender, K. 2000. Growth- and breed-related changes of muscle fiber characteristics in cattle. **Journal of Animal Science,** 78(6), 1485–1496.

Warren, H. E., Scollan, N. D., Enser, M., Hughes, S. I., Richardson, R. I. & Wood, J. D. 2008. Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. I: Animal performance, carcass quality and muscle fatty acid composition. **Meat Science,** 78, 256-269.

Weglarz, A. 2010. Quality of beef from Polish Holstein-Friesian bulls as related to weight a slaughter. **Annals of Animal Science Journal,** 10(4), 467-476.

Westerling, D. B. & Hedrick, H. B. 1979. Fatty acid composition of bovine lipids as influenced by diet, gender, and anatomical location and relationship to sensory characteristics. **Journal of Animal Science,** 48, 1343–1348.

Wheeler, T. L., Cundiff, L. V., Koch, R. M. & Crouse, J. D. 1996. Characterization of biological types of cattle (cycle IV): carcass traits and *Longissimus* palatability. **Journal of Animal Science,** 74, 1023–1035.

Prom-in, W. 2005. **Carcass quality and meat quality under Kumpangsan production cooperation system.** Thesis. King Mongkut's Institute of Technology Ladkrabang, Bangkok.

Wiyabot, T. 2014. A study of beef quality and consumer preference test on beef breeds in Nakhon-Sawan province. **Khon Kaen Agr. J.** 42(1), 312-316. (in Thai).

Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., Sheard, P. R. & Enser, M. 2003. Effects of fatty acids on meat quality: a review. **Meat Science,** 66, 21-32.

Wood, J. D. & Richardson, R. I. 2004. **Factors affecting flavour in beef.** [Online]. Available http://beefandlamb.ahdb.org.uk/wp-content/uploads/2013/04/beef_flavour_ report.pdf (31 June 2018).

Woerner, D. R. 2010. **Beef from market cows.** [Online]. Available https://fyi.uwex.edu/ wbic/files/2011/04/Beef-from-Market-Cows.pdf (24 July 2018).

Wulf, D. M., O'Connor, S. F., Tatum, J. D. & Smith, G. C. 1997. Using objective measures of muscle color to predict beef *longissimus* tenderness. **Journal of Animal Science,** 75(3), 684-692.

Yamasaki, Y. & Maekawa, K. 1978. A peptide with delicious taste. **J. Ag. Biol. Chem.,** 42, 1761-1765.

Yancey, E. J., Dikeman, M. E., Hachmeister, K. A., Chambers, E. & Milliken, IV. G. A. 2005. Flavor characterization of top blade, top sirloin, and tenderloin steaks as affected by pH, maturity, and marbling. **Journal of Animal Science,** 831, 2618-2623.

Yetim, H., Muller, W. D., Dogan, M. & Klettner, P. G. 2006. Using fluid whey in comminuted meat products: Effects on textural properties of frankfurter sausages. **Journal of Muscle Foods,** 17(3), 354–366.

Zembayashi, M., Nishimura, K., Lunt, D. K. & Smith, S. B. 1995. Effect of breed type and sex on the fatty acid composition of subcutaneous and intramuscular lipids of finishing steers and heifers. **Journal of Animal Science,** 73, 3325-3332.

APPENDIX

Appendix A

Hedonic Test

Table Appendix 1 Hedonic Test Beef Sample

Hedonic Test

Beef Sample

Name.....Gender.....Age.....Date.....

Use the number scale below to mark number that you liked or disliked about beef

1 = Disliked Extremely 2 = Dislike Very Much 3 = Dislike Moderately

4 = Dislike Slightly 5 = Neither Like nor Disliked 6 = Like slightly

7 = like moderately 8 = like Very Much 9 = like Extremely

Attribute	Code	
	145	098
Color		
Appearance		
Flavor		
Texture		
Overall acceptability		

Appendix B

Sensory Attributes, Reference and Definition Used to Evaluate Beef

Table Appendix 2 Sensory attributes, reference and definitions used to evaluate beef

Attribute	Score	Reference	Definitions
		Texture	
Juiciness	0	Banana	Moistness of the cooked muscles during
	7.5	Cucumber	mastication
	15	Watermelon	
Denseness	0	Whipped topping	The force required to compress a
	7.5	Sausage	substance between the molar teeth (for
	15	Fruit jelly	solids) or between the tongue and palate
			(for semi-solids) to a given deformation or
			to penetration.
Cohesiveness	0	Corn muffin	The extent to which a material can be
	7.5	Candy chews	deformed before it ruptures
	15	Chewing gum	
Fibrousness	0	Corn muffin	Number and thickness of fibres perceived
	7.5	Fried Mushroom's	during chewing
		Stipe	
	15	Crushed dried squid	
		Flavor	
Milky/like-fat	0	Water	Amount of milky flavor from fresh milk
	7.5	50 ml/L Milk	(Meji) identity in the sample
	15	500 ml/L Milk	
Salty	0	Water	Amount of salty flavor from Maggi sauce
	7.5	50 ml/L Maggi sauce	identity in the sample
	15	250 ml/L Maggi	
		sauce	
Browned/Grilled	0	Water	Amount of hotdog-Bar grilled flavor
	7.5	Hotdog-Bar (5g)	identity in the sample
	15	Hotdog-Bar (20g)	
Beefy/Brothy	0	Water	Aromatic associated with cooked beef
	7.5	625 ml/L Beef soup	muscle. beefy/brothy
	15	1000 ml/l Beef soup	(7.5=25ml/40ml, 15=40 ml)

Table Appendix 2 (Continued)

		Taste	
Umami	0	Water	Taste on the tongue associated with
	7.5	0.243 ml/L MSG	monosodium glutamate
	15	2.187 ml/L MSG	
Sweetness	0	Water	Taste on the tongue associated with
	7.5	3.6 ml/L Sugar	sucrose
	15	4.2 ml/L Sugar	
Oily	0	Water	Taste on the tongue associated with
	7.5	whipped cream	whipped cream and unsalted butter
	15	unsalted butter	
		Color (meat color))	
Color	0	White	- White-gray-black consider the upper beef
	7.5	gray, yellow, pink	edge
	15	black, brown ,red	- White-pink-red, white-yellow-brown for consider the center of the meat.

Appendix C

Master Sheet of Sensory Evaluation

1

Master Sheet (Set 1)

Date_Mondy_12/9/59___

Name_____Age_____Sex___

Texture

1) Attribute__Juiciness_____

0 7.5 15

2) Attribute__Denseness_____

0 7.5 15

3) Attribute__Cohesiveness_____

0 7.5 15

4) Attribute__Fibrousness_____

0 7.5 15

Flavor

5) Attribute___ Browned/grilled _____

0 7.5 15

6) Attribute____ Beefy/brothy_____

0 7.5 15

7) Attribute___ Milky/fat-like_____

0 7.5 15

Figure Appendix 1 Master Sheet of Sensory Evaluation

2

8) Attribute____Salty/Briny_____

Taste

9) Attribute___Umami _____

10) Attribute___Sweet_____

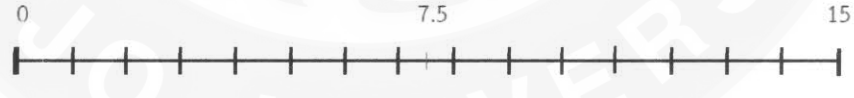
11) Attribute___Oily_____

Color

12) Attribute__Black Color_____

13) Attribute__Brown Color____

14) Attribute__Red Color_____



Note:

.....

.....

.....

Thanks you ^_^

Figure Appendix 1 (Continued)

Appendix D

Curriculum Vitae

CURRICULUM VITAE

Name Miss Jarunan Chainam

Date of Birth 1 October 1984

Education

2018 Doctor of Philosophy in Animal Science
Maejo University, Chiang Mai Province, Thailand

2010 Master of degree in Animal Science
National Ilan University, Yilan, Taiwan

2007 Bachelor of degree in Animal Science (Dairy Science)
Maejo University, Chiang Mai province, Thailand