

## Eating Quality Traits of Hanwoo *longissimus dorsi* Muscle as a Function of End-Point Cooking Temperature

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### Abstract

Interaction between carcass quality grade and end-point cooking temperature on eating quality of Hanwoo m. *longissimus* was investigated. Ten (10) of steers were sampled from a commercial population; carcasses with QG 1<sup>++</sup> (n=5) and QG 1 (n=5) were chosen. Samples were cooked by electric oven at 60 or 82°C and compared with uncooked control samples. The pH was not affected by cooking temperature but decreased the redness after cooking and steaks cooked at 60°C were more reddish than steaks cooked at 82°C in both QG groups. Higher cooking temperature greatly ( $p<0.05$ ) increased the cooking loss, but there was no significant interaction between cooking temperature and QG on the cooking loss. Moisture is negatively correlated with temperature in both QG while the proportionate relationship between crude fat and end-point temperature found in QG 1<sup>++</sup>. WBSF values were significantly ( $p<0.05$ ) high for QG 1, while that was significantly ( $p<0.05$ ) increased when the temperature continues to increase. The increasing quality grade of beef resulted in significant higher ( $p<0.01$ ) level of TBARS and cooking temperature increased TBARS content. Fatty acid composition was not altered by cooking at both temperatures and also the amount of fat intake was not changed. The current study indicates that eating quality of beef m. *longissimus* was greatly influenced by end-point temperature being interacted with QG. However, the amount and composition of fat were stable regardless of end-point temperatures. These results will provide a consumer reference to determine cooking conditions and intramuscular fat content.

**Keywords:** beef, quality grade (QG), the amount of fat intake, cooking temperature, eating quality

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### Introduction

Beef consumption in Korea has been growing steadily up to a little over 10 kg in 2013 (MAFRA, 2014), meanwhile the beef market increasingly demands more a tender and juicier meats, as other food groups and tender meat. Beef quality is a function of several factors such as tenderness, juiciness and flavor (Reddy *et al.*, 2014). Given the reason, manipulation and/or governing of these factors became a great issue in the beef industry and meat science. In a classic viewpoint of beef quality, intramuscular fat (IMF) has been suggested as a prime carcass traits determining eating quality by protecting protein denaturation during overcooking (Ba *et al.*, 2013; Miller, 1994). Furthermore, previous studies have demonstrated that fatty acid composition had a great effect on generation of aroma

compound and consequent flavor have been identified in cooked meat (Ba *et al.*, 2013; Elmore *et al.*, 2004). On the other hand, mostly from health point of view, several researchers have suggested that reduced fat in meat is necessary to maintain the health and to protect cancer (Corpet, 2011). As shown over the last decades, neo-consumers are increasingly interested in a healthy life and well-being, and they require more a balanced nutrition and diets. Under these social and cultural shifts, many consumers have started to question on the necessities of IMF in the meat tenderness (Ferguson, 2010).

Regardless of the issue of fat, there are the obvious evidences that meats are the prime source of minor minerals such as zinc, copper, selenium, and iron along with vitamin B and D among the food groups (Moloney *et al.*, 2001). McNell (2012) stated that in his review that lean beef could protect cardiovascular diseases, and that is largely available in the US retail market in the form of carcass fat-decreased through breeding, management and retail trimming.

Cooking or heating of meat is an essential procedure

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not only to ensure safety, but also essential to enhance the taste, color, and flavor of the meats (Tornberg, 2005). There are six categories of U.S. meat doneness according to internal temperature: very rare (55°C), rare (60°C), medium rare (63°C), medium (71°C), well done (77°C), and very well done (82°C) (AMSA, 1995) and these end-point temperatures results in diverse characteristics. Fast classic researches have focused on the effect of thermal conditions during cooking on texture (Bertola *et al.*, 1994), color (Martens *et al.*, 1982), cooking loss (Palka and Daun, 1999), water holding capacity (WHC) (Laakkonen *et al.*, 1970), Warner Bratzler shear force (WBSF) (Yancey *et al.*, 2011), fatty acid compositions (Smith *et al.*, 1989), structural changes (Tornberg, 2005), flavor (Bowers *et al.*, 1987) and nutritional quality (Alfaia *et al.*, 2010) of the cooked beef.

To our knowledge, there is not accessible data on the effects of end-point cooking temperatures on the changes in amount of intramuscular fat, fatty acid composition, and texture of meat quality for different carcass quality grade in Hanwoo *longissimus dorsi* (LD) muscle.

## Materials and Methods

### Sample preparation

The experimental design was composed of two QG (1<sup>++</sup> and 1) and three end-point cooking temperatures (0, 60 and 82°C; raw, rare and very well done) (AMSA, 1995). A total of ten steers was transported to a commercial slaughterhouse and were slaughtered by conventional procedures. After slaughter, the left side of carcasses was ribbed between the 13th rib and the 1st lumbar vertebra. All of the carcasses are graded by Korean carcass grading system (NLCF) and chilled for 24 h. The next day, the LD muscle was taken, vacuum packaged and transferred to the Muscle Biology and Meat Science Laboratory of the Chonbuk National University. All samples were vacuum-packaged and frozen at -40°C until further experiments; the frozen samples were thawed for 24 h at 0°C. Thawed muscles were sized to 2.54 cm thickness steaks and trimmed subcutaneous fat, then prepared steaks were assigned in the 2×3 factorial arrangements. Samples were put into pre-heated conventional oven (COV23H, TONGYANG Magic, Korea) at 240°C and cooked until internal temperature of the each steak was reached to designed temperature, and monitored the internal temperature using handheld digital thermometer (Testo 925, Germany) in real time. After cooking, the steak was immediately packaged to poly-bag and cooled for 30 min in cold

water.

### The pH and instrumental color determinations

The pH values were measured in duplicates using a glass probe pH meter (CH-8603, Mettler-Toledo, Switzerland). The pH values of the samples were measured by grinding a 1 g of sample in 9 mL distilled water for 10 s in a Homogenizer (T 25 digital ultra-turrax, IKA, Germany).

Each steak was sliced perpendicular to the cut surface, and the surface color (CIE *L\**, CIE *a\** and CIE *b\**) was measured after 30 min blooming at room temperature using a Konica Minolta Spectrophotometer (CM-2500d, Minolta, UK) using D65 illuminant.

### Cooking loss and Warner-Bratzler shear force (WBSF) values

The samples were placed in poly bags and cooked in a pre-heated water bath at 70°C for near about 1 h. The cooked samples were immediately cooled in 18°C running water for 30 min. The excess moisture was removed and then the cooking loss percentage was calculated using weights of before and after cooking.

After cooling, six of 0.5 inch diameter cores were taken parallel with the muscle fiber direction and WBSF of the cores was measured using an Instron (3342, Instron, USA) with a 40 kg load cell and a crosshead speed of 400 mm/min. The shear force value was the mean of each set of core samples and expressed as kilograms of force (kgf).

### Moisture and crude fat determinations

The moisture contents of raw and heated steaks were measured with Halogen moisture analyzer (HR73, Mettler Toledo, Switzerland). The minced samples (2.5 g each) were put in aluminum dish, and dried at 105°C.

The IMF was measured in triplicate via the Soxhlet method following Ji *et al.* (2010). Five grams of sample and 1.5 g of sea sand were put in the cylinder type paper and mixed together. The filter paper was dried in a dry oven at 102°C for 5 h and cooled in a desiccator for 30 min. After then, IMF extracted by petroleum ether at 100°C for 6 h and then petroleum was evaporated using a heating mantle and residual solvent was removed by heating the extract in a dry oven at 102°C for 1 h. IMF was calculated by percentage of extracting fat weight and sample weight. Furthermore, we calculated the amount of fat intake on the assumption that there is a possibility to happen enrichment phenomenon which caused by cooking loss during cooking. To achieve this value, how much the fat we intake from cooked beef, which applied different

end-point cooking temperature was determined considering IMF contents before heating and cooking loss. The amount of fat intake was expressed as g/100 g of raw meat and was calculated as follows.

$$\text{The amount of fat intake} = \text{Intramuscular fat \%} \times \{(100 - \text{cooking loss \%}) / 100\}$$

### Fatty acid composition

Fatty acid composition was determined by a method of Rule (1997). Heated steak was pulverized after lyophilization. 500 mg of powdered sample was placed into 20 mL headspace vial with silicon lined cap, and 2 mL of 14% borontrifluoride in methyl alcohol was added, and then the mixture was mixed every 5 min using a vortex for 2 h at the 80°C heating block. Methylated mixture was cooled at room temperature, and vortex-mixed with 3 mL of distilled water and 3 mL of hexane for 15 s. After mixing, the mixture was centrifuged at 1000 g for 5 min, and 1 mL of upper solution was taken to vial and kept on -20°C until analysis. The analysis of fatty acid composition was performed by a GC-FID system equipped with a flame ionization detector (6890N, Agilent Technologies, USA). Individual fatty acids were confirmed on the basis of retention time compared with a commercially available mixture of fatty acids (F.A.M.E. Mix C8-C24, Supelco, USA) and were expressed as percentage of the total fatty acids detected as fatty acid methyl esters.

### 2-Thiobarbituric acid reactive substances (TBARS) determinations

To investigate the effect of QG and end-point cooking temperatures on fat oxidative stability, TBARS was determined by a procedure of Buege and Aust (1978). Aliquots of sample (2.5 g) with 7.5 mL distilled water and 10 mL of TBA/TCA solution (0.29% thiobarbituric acid, 15% trichloroacetic acid) were homogenized at 11,000 rpm for 15 s and then 25 µL of butylated hydroxyanisole (BHA) was added to protect fat oxidation during the process. Homogenate was filled up to 30 mL with distilled water, and heated in 90°C water bath for 15 min. After heating, heated homogenate was immediately cooled in ice for 20 min, and centrifuged at 300 rpm for 10 min at 4°C. Absorbance of supernatant was measured at 531 nm using a UV spectrophotometer (Optizen 2120UV, Mecasys, Korea). TBARS was calculated by multiplying the absorbance and 5.88, and the results were expressed as mg of malonaldehyde (MA) equivalents per kg of meat.

### Statistical analysis

The effects of carcass quality grade and end-point cooking temperature were analyzed using SAS PROC GLM, and the least square means of the two main effects and interaction were presented. The difference in TBARS value as a function of carcass quality grade and end-point cooking temperature was compared using the Duncan's multiple range test at a level of significance of  $p < 0.05$ . Analysis was performed using the Statistic Analysis System package (2007).

## Results and Discussion

### Moisture and IMF of beef

The percentage of moisture, crude fat and the amount of fat intake (g/100 g raw meat) for raw and cooked LD muscles of Hanwoo beef as influenced by carcass quality grade (QG) and end-point cooking temperature are shown in Table 1. Although increasing the end-point cooking temperature of beef in oven led to a significant ( $p < 0.01$ ) loss of moisture content compared with the uncooked control samples, consequently to a significantly high IMF content in case of QG 1<sup>++</sup>, but not for QG 1. Moisture percentage of QG 1<sup>++</sup> were significantly ( $p < 0.01$ ) lower than QG 1 overall. Similar to our results, those of Jayasena *et al.* (2015) noted that the general rule that IMF content is inversely related to moisture content in meat. However, no apparent interaction between QG and end-point cooking temperature on moisture and IMF contents were observed.

IMF contents significantly ( $p < 0.05$ ) high in cooked beef in comparison with uncooked sample in QG 1 and 1<sup>++</sup> and which is attributed to the enriching effect of fat as moisture was lost with increasing cooking temperature. It was generally accepted that cooking was accompanied by moisture loss of the meat, and consequently nutrients increased (Badiani *et al.*, 2002). Although Legako *et al.* (2015) revealed that increased IMF content is associated with the continuous deposition of neutral lipid stored in the adipose tissues, whereas the polar lipid, serving as a structural component, remains at a fairly constant concentration.

As noted materials and method sections, we approximately calculated the changes in the amount of fat intake (g/100 g of raw beef) after heating using cooking loss and IMF contents. The amount of fat intake was not significantly different by end-point cooking temperature and this means that proportional significance ( $p < 0.01$ ) was only existed between the amount of fat intake and QG regardless of end-point cooking temperature. So the result indi-

**Table 1. Interaction between carcass quality grade and end-point cooking temperature on quality traits of Hanwoo *longissimus dorsi* muscles**

Traits	QG 1 <sup>1)</sup>			QG 1 <sup>++2)</sup>			SEM	F value		
	Raw	60°C	82°C	Raw	60°C	82°C		QG	Cook temp. <sup>3)</sup>	QG* Cook temp.
Moisture (%)	56.9	48.9	47.3	50.6	45.4	41.6	1.2	10.2**	11.8**	0.26
IMF (%)	19.2	27.3	27	30.4	35.4	36.3	1.4	23.6***	5.1*	0.21
Fat intake	19.2	22.6	20	30.4	29.3	27.2	1.2	21.6**	0.6	0.63
pH	5.62	5.54	5.67	5.49	5.52	5.54	0.1	3.4	0.2	1.46
CIE <i>L</i> *	41.2	52	26	41.3	52.5	31.5	2	1.2	54.0***	0.88
CIE <i>a</i> *	20.6	19.6	9.8	20.8	19.4	8.4	1.1	0.2	71.9***	0.32
CIE <i>b</i> *	16.2	20.2	10.1	16.6	20.1	11.1	0.8	0.7	110.1***	0.39
WBSF (kgf)	2.06	3.14	3.58	1.82	2.75	3.12	0.14	4.8*	25.1***	0.16
Cooking loss (%)	.	17.13	26.1	.	17.23	25.2	1.21	0.1	29.5***	0.1
TBARS mgMa/kg	0.32	0.37	0.53	0.32	0.54	0.64	0.5	8.15**	20.25***	3.81*
df <sup>4)</sup>	25-2									

<sup>1)</sup>QG1, carcass quality grade 1; <sup>2)</sup>QG1<sup>++</sup>, carcass quality grade 1<sup>++</sup>; <sup>3)</sup>Cooking temperature; <sup>4)</sup>df, degrees of freedom.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

cated that ‘the amount of fat intake from cooked beef’ depending on the IMF contents of raw materials (QG), but the end-point cooking temperature was irrelevant in this study. Marbling or IMF has positively influence on meat flavor, as fat level increases, desirable flavor of cooked meat increases in meat. When meat contains low levels of fat, the predominant flavors are associated with the lean, such as cooked beef lean, bloody, metallic, and brothy flavor while higher level of marbling associate with fatty and pleasant aroma (Elmore *et al.*, 2004). Moreover, IMF content affects juiciness by enhancing the WHC of meat, by lubricating the muscle fibers during cooking, by increasing the tenderness of meat, and thus the apparent sensation of juiciness (Lekago *et al.*, 2015; Yancey *et al.*, 2011).

#### The pH, instrumental color and cooking loss of meat

Means of pH and instrumental color as a function of QG and end-point cooking temperature are tabulated in Table 1. No significant effect existed between QG and end-point cooking temperature for pH and those values were in the range of 5.5-5.6. Even the pH was not differed between before and after heating in this study, which contrasts with results of Yang *et al.* (2012) who reported an increment of meat pH due to protein denaturation and fat oxidation during heating. However in general, high pH is closely related to the high water-holding capacity, tenderness and low shear force in raw meats.

Regarding the color of raw and cooked beef, there was no significant effect by QG. As expected, redness (CIE *a*\*) decreased after heating and steaks cooked at 82°C showed less red ( $p < 0.05$ ) than steaks cooked at 60°C of both QG.

Rare steaks were lighter CIE *L*\* and yellow CIE *b*\* than raw beef, whereas for the very well done steaks showed the lowest *L*\* and *b*\* values among them on both of QG. In addition, *L*\*, *a*\* and *b*\* dramatically decreased with increasing end-point cooking temperatures at 82°C, were observed, which agreed with the results of Bowers *et al.* (1987) who noted the same trends with ours and concluded that almost proteins in meat was completely denatured at 80°C. In addition, Yancey *et al.* (2011) reported that steaks cooked at 65.5°C were the reddest and as end-point temperature increased to 76.6°C, the internal color of steaks became less red, with greater hue angles (more brown) and lower chroma values (less total color). It was generally accepted that myoglobin and other heme-proteins can be attributed to the color of red meats (Lytras *et al.*, 1999). In particular, degradation of myoglobin as affected by heating brings out several color changes (Hunt *et al.*, 1999). Preliminary data presented by Martens *et al.* (1982) demonstrated that native myoglobin denatures in the 65-80°C range. Thus, we can assume that rare steaks looking similar trends with raw beef did not or incompletely happen myoglobin denaturation, but for very well done steaks it complete. Meanwhile, differences attributable to QG were not detected in *L*\* values, even on *a*\* and *b*\* values in both raw and cooked beef in this study.

The results presented that cooking loss was not affected by QG, and interaction between QG and end-point cooking temperature. In preliminary data presented by Kapitula *et al.* (2012) there was a very weak link between fat contents and cooking loss, which in line with ours. Meanwhile, we observed that changes in greater cooking loss tended to be linear with end-point cooking temperature (up to 82°C).

It was similar to a report written by Palka and Daun (1999) that cooking loss increased along with cooking temperature on bovine m. *semitendinosus*. Cooking loss was also associated with end-point cooking temperature, in agreement with Milligan *et al.* (1997), they cooked in a convection oven at 250°C to internal endpoint temperatures of 60, 70 and 80°C and revealed that cooking losses increased to 26.1%, 34.7% and 42.2%, respectively. Researchers mentioned as a reason for cooking loss was the diffusion of water through the meat and evaporation from the meat surface and through physical expulsion arise from constriction of muscle bundles (Offers and Knight, 1988). Previous researchers found that cooking loss from beef increased with heating temperature because of changes in water-holding capacity (Zayas and Naewbanij, 1986). Water-holding capacity of muscle tissue has been related to the extent of heat denaturation of myofibrillar proteins during thermal processing (Larick and Turner, 1992). With increasing cooking temperature, the denaturation of myosin and actin proteins caused structural changes of muscle and expelled the sarcoplasmic fluid from the muscle fibers, resulting in water losses from meat tissue (Bertola *et al.*, 1994). Thus low temperature cooking results in lower cooking loss compared with cooking at higher temperatures.

#### **Carcass quality grade and marbling relation on meat tenderness**

In this study, carcass quality grade positively affected to meat tenderness. The objective instrumental measurement of meat tenderness WBSF value was significantly ( $p < 0.05$ ) lower in cooked samples with QG 1<sup>++</sup> compare to QG 1 group. Obuz *et al.* (2004) also observed that USDA choice grade lower WBSF value than USDA select grade (relatively less marbling degree) at above 60°C. Most commonly, the cattle feeding system has focused on increasing IMF contents in Northeastern Asian countries such as South Korea and Japan. The principal reason for this tendency was because many beef consumers in these countries preferred high marbling beef due to unique flavor scores, sweet and fatty aroma, and a higher price is therefore paid for carcasses with more marbling (Matsuiishi *et al.*, 2001). Moreover, Park *et al.* (2000) suggested that there were high tenderness, juiciness and flavor scores in beef loins with high IMF contents of Hanwoo beef. Marbling in meat serves to enhance juiciness in indirect way. During cooking, melted fat apparently becomes *translocated* along bands of perimysial connective tissue. This uniform distribution of lipid throughout the muscle may act as a bar-

rier to moisture loss during cooking. Consequently, meat with some marbling shrinks less during cooking and remains juicier (Aberle *et al.*, 2001).

Furthermore heat caused tenderization of meat which is the most important factors in recognizing beef quality for consumers (Savell *et al.*, 1987). Interestingly, we also observed the WBSF value were significantly ( $p < 0.001$ ) increased with end-point cooking temperature from 60 and 82°C regardless of QG. It could be speculated that shear force was also affected by an end-point cooking temperature level, not to speak of relative IMF contents (QG). Parrish *et al.* (1973) have noted that the end-point temperature was a better modifier of tenderness and more important than marbling or maturity. In addition, Yancey *et al.* (2011) found that steaks cooked to 65.5°C had the lowest WBSF values in the 65.5 (medium-rare) to 76.6°C (medium-well) range of end-point temperature when different kinds of cooking methods were applied. The similar observation has been reported by Draudt (1972) who stated that the hardening of muscle fibers due to increased cooking temperature after an initial collagen shrinkage reaction.

The main structural proteins such as myofibrillar proteins (myosin and actin) and connective tissue protein (collagen) presented in meat play a prominent part of the texture of cooked meat (Brunton *et al.*, 2006). When meat placed in heat conditions, shrinking of muscle fibers and shortening of sarcomeres that be capable of causing less water binding ability were occurred, consequently expulsion water from the muscle (Bowers *et al.*, 1987). Another reason for fluid loss can be attributed to collagen shrinkage during cooking (Palka and Daun, 1999). It is widely accepted that denaturation and coagulation of sarcoplasmic proteins as well as above mentioned structural proteins by heating has a major influence on the resulting shear force (Obuz *et al.*, 2003). As reported by earlier researchers, all these proteins (myofibrillar, connective tissue and sarcoplasmic proteins) inclined to denature in the range of 40-73°C (myosin at 40-60°C; actin at 66-73°C; collagen at 65°C; sarcoplasmic proteins at about 65°C) (Laakkonen, 1973; Martens *et al.*, 1982). Bowers *et al.* (1987) referred to results that the shrinking of muscle fibers and shortening of sarcomeres existed only above 70°C.

Thus, the meat structure cooked at 60°C slightly changed as a reason for collagen denatured at 65°C as well as almost protein denaturation completed at 82°C, suggesting that shows relatively better tenderness appeared in lower temperature. In the meantime, QG 1<sup>++</sup> steaks as compared

with those QG 1 steaks tended to have lower shear force values at final internal temperature of both 60 and 82°C. These findings coincide with the finding of Miller (1994) who reported increased tenderness with higher IMF content due to prevent negative effects of overcooking on protein denaturation and decrease the strength of connective tissue. Although Aberle *et al.* (2001) noted that an extent of fat migration is uncertain, the cation is initiated by rising muscle temperature, solubilization of collagenous connective tissue provides channels through which melted fat may diffuse. Thus cooking action results in movement, and possibly emulsification, of fat with soluble protein (Aberle *et al.*, 2001).

### 2-thiobarbituric acid reactive substances (TBARS) assay

The TBARS values of raw and cooked Hanwoo beef steaks as influenced by QG and end-point cooking temperature is shown in Fig. 1. TBARS content one of the degradation products of lipid hydro peroxides and peroxides formed during the oxidation of polyunsaturated fatty acids (Gomes *et al.*, 2003) is widely used as an indicator of the degree of lipid oxidation and is considered an important quality index for meat. In our study TBARS value of raw beef was not significantly differed (0.32 and 0.33 mg MA/kg respectively) between QG (Table 1). However,

an increasing the marbling or quality grade of beef resulted in significant higher ( $p<0.01$ ) level of TBARS. As expected cooking temperature increased TBARS content; the lowest TBARS values were in raw steaks, then amounts significantly increased ( $p<0.001$ ) in samples cooked at 60°C and 80°C respectively, in beefs from both QG groups. It seems that low temperatures are known to inhibit the oxidation of lipids while high cooking temperatures increase the oxidation processes in meat. Fat oxidation is one of the most important transformations for food processing and consumption. Oxidation of lipids is commonly believed to occur during cooking and storage and the positive volatile flavors and aromas that are produced during cooking follow the same basic reaction pathways as oxidation during storage (Lekago *et al.*, 2015). Otherwise excessive lipid oxidation occurs in meat by heating also can cause many undesirable effects such as off-flavor development (Shahidi, 1994) and downgrades the nutritional value of fat (Alfaia *et al.*, 2010). However, TBARS values presented in this study were below than 1 mg malonaldehyde/kg meat, the critical limit of TBARS value (Tims and Watts, 1958).

### Fatty acid composition

The fatty acid composition in raw and cooked LD muscles of Hanwoo beef as influenced by QG and end-point

**Table 2. Effect of carcass quality grade and end-point cooking temperature combinations on fatty acid composition for raw and cooked beef of Hanwoo *longissimus dorsi* muscles (%)**

Fatty acids	QG 1 <sup>1)</sup>			QG 1 <sup>++2)</sup>			SEM	F value			
	Raw	60°C	82°C	Raw	60°C	82°C		QG	Cooking temperature	QG*Cooking temperature	
C8:0	0.01	0.01	0.01	0.01	0.01	0.01	0	0.03	0.10	1.0	
C10:0	0.11	0.09	0.09	0.08	0.11	0.11	0.01	0.05	0.22	1.45	
C12:0	0.14	0.15	0.15	0.14	0.16	0.18	0.01	0.5	0.84	0.51	
C14:0	4.2	4.37	3.87	4.83	5.22	5.02	0.16	8.84**	0.53	0.27	
C16:0	29.5	29.9	30.5	30.1	30.6	30.8	0.27	0.64	0.82	0.04	
C16:1	5.38	5.46	5.64	5.54	6.02	5.72	0.13	0.91	0.36	0.28	
C18:0	9.87	10.12	10	9.69	9.26	9.47	0.29	0.7	0.01	0.1	
C18:1	47.7	47.4	47.1	47.5	47.1	46.7	0.33	0.2	0.34	0.01	
C18:2	2.77	2.15	2.3	1.86	1.34	1.79	0.17	5.42*	1.07	0.14	
C18:3	0.11	0.1	0.11	0.09	0.09	0.09	0	6.95*	0.15	0.07	
C20:0	0.05	0.05	0.05	0.05	0.05	0.05	0	0.02	0.18	0.1	
C22:0	0.05	0.04	0.04	0.06	0.05	0.02	0.01	0.01	1.68	1.2	
C24:0	0.06	0.04	0.05	0.05	0.03	0.02	0	3.7	2.32	0.84	
SFA <sup>3)</sup>	44.0	44.8	44.8	44.9	45.5	45.7	1.2	0.68	0.23	0.01	
MUFA <sup>4)</sup>	53.1	52.9	52.6	53.1	53.1	52.4	1.1	0.01	0.12	0.03	
PUFA <sup>5)</sup>	2.88	2.25	2.41	1.95	1.43	1.88	0.4	5.68*	1.08	0.14	
PUFA/SFA	0.07	0.05	0.05	0.04	0.03	0.04	0.01	5.93*	1.06	0.12	
Df <sup>6)</sup>	2/25										

<sup>1)</sup>QG1, carcass quality grade 1; <sup>2)</sup>QG1<sup>++</sup>, carcass quality grade 1<sup>++</sup>; <sup>3)</sup>SFA, total saturated fatty acids; <sup>4)</sup>MUFA, total monounsaturated fatty acids; <sup>5)</sup>PUFA, total polyunsaturated fatty acids; <sup>6)</sup>df, degrees of freedom.

\* $p<0.05$ , \*\* $p<0.01$ .

cooking temperature are shown in Table 2. In this case, in decreasing order of percentage, the major FAs in IMF of raw and cooked beef were oleic (i.e., 23-26), palmitic (i.e., 29-30), stearic (i.e., 9-10) and palmitoleic (i.e., 5-6) acids. Just to mention a few significant differences by QG, in the case of the percentage of SFA myristic was greater ( $p < 0.01$ ) in QG 1<sup>++</sup> group than those of QG 1 (i.e., 4.83 and 4.2 respectively). On the other hand, the percentage of PUFA (linoleic and linolenic acids) of QG 1 group was significantly ( $p < 0.05$ ) higher than that of QG 1<sup>++</sup>. Specifically for linoleic acid in QG 1 group was higher than those of QG 1<sup>++</sup> (i.e., 2.77 and 1.86 in raw beef; 2.15 and 1.34 at 60°C; 2.3 and 1.79 at 82°C respectively). Similarly for linolenic acid of QG 1 group was higher than those of QG 1<sup>++</sup> (i.e., 0.11 and 0.09 in raw beef; 0.1 and 0.09 at 60°C; 0.11 and 0.09 at 82°C respectively). Unlike the initial expectations that applying the different internal temperature would change the fatty acid composition, the QG made the relatively higher difference than the internal temperature in our experimental conditions. These results are similar with previous reports, which no effects on the fatty acid composition of the total lipid of beef steak as influenced by cooking (Harris *et al.*, 1992; Smith *et al.*, 1989). Gerber *et al.* (2009) indicated that melting of fat during cooking, leading to a decline in the total of SFA, MUFA and PUFA (absolute values). In our study, no significant differences in the percentage of total SFA and MUFA as influenced by QG, end-point cooking temperature and their interaction. However total PUFA and PUFA/SFA ratios affected by QG ( $p < 0.05$ ). Researchers also mentioned that increased palatability may have resulted from the higher oleic acid and PUFA contents in Hanwoo beef (Jayasena *et al.*, 2015).

### Conclusion

The current dataset indicates that the end-point cooking temperature has limited effect on the amount of fat intake and also do not alter fatty acid composition. However, an evaluated cooking loss for the meats cooked at higher temperature increased toughness (i.e., higher shear force), with a great influence a less IMF group. These results will provide a consumer reference to determine cooking conditions and IMF content.

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