1. INTRODUCTION

Beef from Japanese black cattle has long been the most famous and preferred meat in Japan (Okita et al., 1999; Koizumi et al., 2000). On the other hand, the lean meat of Holstein cattle is preferred by people who desire a healthy diet (Iida et al., 1999). The experience of many chefs has shown that the palatability of these types of beef is affected by the chosen cooking method.

There have also been some studies of culinary beef and some knowledge has already been accumulated. Schock et al. (1970) reported that tenderness, flavor and overall acceptability in cooked pieces of beef semimembranosus muscle were not affected by the different cooking methods such as deep-fat fried, oven-roasted, oven-braised and pressure-braised. Batcher & Deary (1975) and Morgan et al. (1991) have shown that the tenderness and sensory ratings for roasted beef were higher than those for broiled or grilled beef. Morgan et al. (1991) also found that the reason for the increased tenderness obtained with this cooking method was related to the collagen solubilized during thermal processing and the higher moisture content obtained by the longer cooking time. Goodson et al. (2002) investigated the factors affecting consumers’ evaluations of steaks, and showed that flavor was the most significant sensory factor that correlated with overall appeal. Adhikari et al. (2004) reported that medium-rare grilling was a highly suitable cooking method, because it yielded more juiciness and flavor in beef than roasting or
braising. As for the heating temperature, Lorenzen et al. (2005) clarified the end-point temperature (55–82 ℃) in a sensory and instrumental flavor profile of beefsteaks. They mentioned that consumers found no differences in the flavors of the steaks, and that steaks cooked at lower temperatures (55–60 ℃) were preferred because of their tenderness and juiciness. Although there are some reports on cooked beef by conventional methods, there are few reports which investigated tenderness and flavor using same part of muscle.

Low temperature long time (LTLT) cooking has also been in detail investigated and improved (Laakkonen, E. et al. 1970, Vaudagna, S.R. et al. 2002, Obuz et al. 2003, Ko, S. et al. 2011, Christensen, L. et al. 2012). These reports have shown that LTLT cooking makes meats tender and reduces fat content. This method is now become widely used in mass cooking. In a different study, Fulton and Davis (1983), Joseph and Joycelyn (1986) compared microwave and conventionally heated samples, and found that microwave heating produced less firmness because more collagen was solubilized from the meat samples than with conventional heating methods.

From these reports, tenderness, juiciness and flavor are recognized as playing an important role in the palatability of beef. And it is reported that meat quality and palatability are also affected by the factors such as sex, age of beef, period of ageing, and a part of muscle. However, there have been few reports analyzing both characteristics such as texture and taste in beef cooked with different methods using same part of muscle.

Therefore, the purpose of this study is to clarify such characteristics as the taste and texture of beef cooked by different cooking methods using Holstein loin (rib roast). Furthermore, the relationship between sensory analyses and instrumental properties is discussed.

2. MATERIALS AND METHODS

(1) Beef meat samples

Loin meat (the right side of the Longissimus thoracis, approximately 25 cm long and weighing 5 kg) was taken from the carcass of a male Holstein (19 months old and bred in Hokkaido, Japan) and stored at 0 ℃ for 14 days after slaughter. These meat samples were randomized and used equally with five cooking methods (Figure 1). Measurements were carried out using meat from eight Holstein steers.

Figure 1. Preparation of experimental samples for cooking and analyses from block meat

(2) Cooking methods

Five commonly used methods for cooking loin meat were chosen by American meat cookbook (Aidells, B &Kelly, D., 1998), namely grilling (hot plate; Zojirushi, Japan) and oven roasting (Electrolux Convection Ovens AR 170S, Sweden. Plate size 300 W × 500 D (mm)), and poaching (4,700 kcal/h), vacuum-packed low-temperature cooking and microwaving (Harman combination range, DR508E GMO-S 1300, 1350 W, 50–60 Hz, 415 W × 365 D × 265 H (mm), Japan).

When the internal core temperature of a meat sample reached 60 ℃ heating was stopped with all five cooking methods (shown in Figure 2). The heat of meat sample in all cooking was started from 10 ℃. This condition gave a high sensory evaluation test score and most tender in the instrumental score in a pre-test (from medium-rare to medium well-done 60–75 ℃, shown in Figure 3). Therefore, we set a common internal temperature of 60 ℃, which we monitored with thermometer (ANRITSU COMPACT THERMOLOGGER AM-8010K TYPE K, Φ 1.0 mm). With the grilling method (GR), the meat was cooked on a hotplate for 1 minutes at 200 ℃, overturned, and then it was further cooked for 1 minutes and 30 seconds (internal core temperature 60 ℃). With the roasting method (RO), the internal core temperature of the meat reached 60 ℃ (target temperature measured by thermometer penetrated into meat core) after about 30±5 min in an oven set at 180 ℃. With the poaching method (PO), the meat was poached in boiling water at 100 ℃ (1.5L, Φ 180 mm) for 18 minutes (internal core temperature 60 ℃). With the vacuum–packed low-temperature water bath cooking method (VPLT), the meat was braised in a water bath (Advantec LD–220, Japan) at 60 ℃ for 6 hours after being vacuum–packed in a CUTE
(3) Sensory analysis
Analyses were performed on the meat samples cooked using the methods described above. A piece of the cooked meat (size: \(3 \times 4 \times 1 \text{ cm}^3\)) was served within ten minutes of cooking and at a temperature of 40 °C. Nine panelists (students and staff in the cookery science lab at JWU, 22–24 years old) were trained in repeated threshold tests and the evaluation of various grades of beef. The semantic differential method was used when the panelists evaluated the differences in tenderness, juiciness, fattiness, odor desirability, intensity of umami taste and overall judgment for a total of forty–three samples (the total of valid responses). To standardize the evaluation, the panelists were trained using the lean meat in younger cattle (5 months old) as “tender one” and the lean meat in older cattle (6 and 9 years old) as “tough one”. In terms of odor, meaty and savory odors were evaluated as “desirable”, and the odor produced by lipid oxidation as “undesirable”, using a standard whereby the savory odor of well–roasted meat was considered “desirable” and the odor of steamed meat was considered “undesirable” using by same meat in this study. The umami intensity was evaluated using MSG (0.05 g/dl) as standard. The evaluations were expressed on an eight–point scale (1 to 8).

Each panelist used a nose clip to eliminate the odor factor when evaluating umami intensity. Panelist evaluated five meat samples at the same time, and repeated from five to eight times in other days.

(4) Texture measurement
A piece of beef sample (size: \(3 \times 4 \times 1 \text{ cm}^3\)) was prepared to measure its breaking properties, and a Rheometer–RE33005s (Yamaden Co., Japan) was employed. The breaking stress and breaking energy of each sample cooked using different methods were measured 11 to 20 times using a 0.1 mm knife–type plunger (area of the edge in contact with the sample: 3 mm²), perpendicular to fibers. Ninety nine percent of the sample was broken with a head speed of 1 mm/sec and a pressing load of 200 N. Samples for texture measurement were the same part as those used in sensory evaluation.

(5) Chemical analysis
1) Measurements of moisture and fat content
The moisture content was calculated from the difference in the weights of meats between before and after heating
at 105 ℃ for 90 min. The 1.29±0.2 g of meat was taken from the center of cooked meat. After the moisture content had been measured, the crude fat in remaining meat was measured by Soxhlet extraction, according to the AOAC method (1990). The data were expressed as a relative percentage to the content in the sample before treatment.

2) Free amino acids

Ten grams of cooked meat in central part was homogenized with 25 ml of distilled water for 1 min in chipped ice in order to reduce protease activities The homogenate was centrifuged at 11,500 g for 10 min at 4 ℃, and the supernatant was collected. The supernatant was then percolated through a filter paper (Advantec 5B; Toyo, Japan). After the proteins had been removed from this filtrate by adding trichloro-acetic acid (5 % final conc.) and the filtrate centrifuged as described above, the supernatant was passed through a membrane filter (0.45 μm, Advantec, Toyo, Japan) and analyzed for free amino acids with an amino acid analyzer (JASCO LC-NET II / ADC Analyzer).

3) 5′-inosinic acid (5′-IMP)

The method reported by Suzuki et al. (1994) was used in the following experiment. Ten grams of cooked minced meat was homogenized with 25 ml of 1 M HClO₄ supplied by BAMIX (BM0101, Switzerland) for 1 min. After the homogenate had been centrifuged at 11,500 g for 10 min at 4 ℃, the supernatant was passed through a filter paper (Advantec 5B; Toyo, Japan). Its pH was adjusted to 6.5–6.8 with 1 M or 5 M KOH and 1 M HCl and it was left overnight at 4 ℃. The supernatant was then passed through a membrane filter (0.45 μm, Advantec, Toyo, Japan) and diluted tenfold with distilled water to determine 5′-IMP by employing HPLC (Shimadzu SPD-10AV : UV-VIS, Detector LC-10AD, Japan), with a column (Senshu Pak PEGASIL-B ODS 4.6 φ×250 mm, Japan) equilibrated with 20 mM phosphoric acid/22 mM diethyl amino ethanol. The flow rate was 1.0 ml/min, and IMP was detected at 250 nm.

(6) Statistical analysis

Statistical analyses of sensory, and instrumental data were performed using SPSS PASW Statistics18 for the analysis of variance with Tukey’s HSD.

3. RESULTS

(1) Changes in moisture and fat content of beef cooked by different methods

The changes in the weight of beef cooked using different methods are shown as cooking loss in Table 1. GR and RO resulted in the least cooking loss of beef, followed by PO and VPLT. MW was the highest cooking loss of beef of all methods.

The relative moisture loss and fat content of beef cooked with different methods is also shown in Table 1. The relative moisture loss after cooking against raw meat with the VPLT was lowest, whereas that of beef cooked by PO and MW was highest. The fat content of the meat samples was lowest in beef cooked by VPLT. The relatively high moisture and fat content in the grilled and roasted beef contributed to the low cooking loss value for this beef.
(2) Texture properties of beef cooked by different methods

1) Sensory characteristics of texture of meats cooked by different methods

Sensory analyses related to tenderness, juiciness and fattiness showed that different cooking methods resulted in beef with different characteristics (Figure 4). Grilled and roasted beef attained the highest score for juiciness and fattiness. Beef cooked by PO and MW gained consistently lower scores for tenderness, juiciness and fattiness. Beef cooked by VPLT had the greatest tenderness.

2) Breaking properties of beef cooked by different methods

The breaking properties of beef cooked with the five different cooking methods were measured (Figure 5). There was no significant difference in the breaking stress score with any of the cooking methods. As regards breaking energy, MW had the highest value, and the values for GR were the lowest. The structure of muscle fiber in beef cooked by the MW seemed to be tougher by heating process.

(3) Flavor properties of beef cooked by different methods

1) Sensory characteristics of flavor of meats cooked by different methods

The results of sensory analyses related to desirable odor and umami intensity are shown in Figure 6. MW and VPLT produced a lower value for odor. The grilled and roasted beef exhibited a high score in odor, umami intensity and overall judgment.
2) Amounts of umami compounds in meat cooked by different methods

2)-1 Amount of free amino acids

The beef cooked by PO exhibited the lowest quantity of free amino acids among all the methods (Table 2). On the other hand, beef cooked with VPLT contained the highest quantity of these acids. Because the temperature and time used in VPLT was 60 ℃ and 6 hours, respectively, some amino acids could be released in the meat samples through the action of enzymes during heating (Ishii, K., et al. 1995).

Gln and Ala were the dominant free amino acids regardless of the cooking method. The Glu and Asp content levels that elicited umami were 1.49 and 0.51 µ mol /g in grilled beef, 1.32 and 0.44 µ mol /g, in roasted beef. There were no significant differences in content of Glu and Asp between cooking methods. Some differences in the Thr, Gln, Val, Leu and Tyr content were recognized in beef samples cooked using different methods. These differences seemed to be caused by the different in cooking time. Thr, Val, Leu and Tyr content increased by cooked longer time in VPLT, on the other hand Gln content decreased.

2)-2 Umami intensity, umami compounds in beef cooked by different methods

It was shown that umami intensity in meat is mainly caused by the synergistic effect by umami compounds such as 5'-inosine mono phosphate (5'-IMP), glutamic acid (Glu) and aspartic acid (Asp) (Nishimura, T., et al. 1988. Nishimura, T., 1998.). Other amino acids were also shown to contribute to umami by the synergistic effect with 5'-IMP and Glu/Asp (Tanaka et al. 1969). In the present work, the amounts of 5'-IMP and glutamic acid in beef cooked with the five methods were measured and then the umami intensity was calculated with the formula (Yamaguchi et al.1971) (Table 3.), because there is no information on the contribution factor of other amino acids in this formula.

The amounts of 5'-IMP and glutamic acid (Glu) in grilled beef were the highest of all the meat samples. The calculated umami intensity was high for all the meat samples. The samples seemed to contain sufficient amounts of 5'-IMP and glutamic acid to elicit umami by synergistic effect of both umami compounds. There was about 1 to 3.8 µ mol/g of 5'-IMP, which was much higher than its threshold value of 0.64 µ mol/g, although the glutamic acid was below its threshold value of 1.77 µ mol/g.

| Table 2. Free amino acid content in beef cooked by five different methods (µ mol/g meat) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Asp             | GR 0.51         | RO 0.44         | PO 0.44         | VPLT 0.59       | MW 0.72         |
| Thr             | 0.81 b          | 0.79 b          | 0.65 a          | 1.34 b          | 0.71 b          |
| Ser             | 1.03 b          | 1.03 b          | 0.81 a          | 1.64 b          | 0.89 ab         |
| Asn             | 0.33            | 0.30            | 0.22            | 0.37            | 0.27            |
| Glu             | 1.49            | 1.32            | 1.10            | 1.36            | 0.87            |
| Gln             | 6.91 c          | 5.14 c          | 4.67 a          | 2.54 a          | 4.80 b          |
| Gly             | 1.37 a          | 1.31 a          | 1.08 a          | 1.73 c          | 1.17 b          |
| Ala             | 5.54            | 4.76            | 4.27            | 5.34            | 5.50            |
| Val             | 1.23 b          | 1.33 b          | 0.93 a          | 2.22 b          | 1.00 ab         |
| Met             | 0.40 b          | 0.52 b          | 0.32 a          | 0.85 b          | 0.39 b          |
| Ile             | 0.43 a          | 0.89 a          | 0.73 a          | 1.60 b          | 0.68 a          |
| leu             | 1.04 b          | 1.71 a          | 0.86 a          | 2.40 c          | 1.19 b          |
| Tyr             | 0.28 a          | 0.72 a          | 0.29 a          | 0.98 c          | 0.53 b          |
| Phe             | 0.58            | 0.78            | 0.48            | 1.04            | 0.47            |
| Orn             | 0.69            | 0.48            | 0.61            | 0.61            | 0.34            |
| His             | 0.44            | 0.37            | 0.41            | 0.48            | 0.39            |
| Arg             | 1.56            | 1.46            | 1.72            | 1.77            | 2.01            |
| Pro             | 0.74            | 0.55            | 1.17            | 1.13            | 0.52            |
| Total           | 25.38 b         | 23.89 b         | 20.77 a         | 27.99 b         | 22.45 b         |

Each value was the mean calculated using data for eight samples.
Different capital letters in the same item indicate significant differences; p<0.01
Different lowercase letters in the same item indicate significant differences; p<0.05
Table 3. Quantity of umami compounds and umami intensity of beef cooked by five different methods

<table>
<thead>
<tr>
<th>Cooking method</th>
<th>GR</th>
<th>RO</th>
<th>PO</th>
<th>VPLT</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>5'–IMP</td>
<td>3.75</td>
<td>3.27</td>
<td>1.28</td>
<td>3.00</td>
<td>2.93</td>
</tr>
<tr>
<td>±S.D</td>
<td>±1.05</td>
<td>±0.76</td>
<td>±0.05</td>
<td>±0.79</td>
<td>±0.93</td>
</tr>
<tr>
<td>Glu</td>
<td>1.49</td>
<td>1.32</td>
<td>1.10</td>
<td>1.36</td>
<td>0.87</td>
</tr>
<tr>
<td>±S.D</td>
<td>±0.40</td>
<td>±0.52</td>
<td>±0.45</td>
<td>±0.68</td>
<td>±0.29</td>
</tr>
<tr>
<td>Umami Intensity*</td>
<td>3.49</td>
<td>2.66</td>
<td>0.89</td>
<td>2.55</td>
<td>1.63</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences; p<0.01

Umami intensity was calculated by the following formula:
\[ y = u + 1218 \times v \]

\( y \): umami intensity, \( u \): Glu content (%), \( v \): IMP content (%)

\( \mu \) mol/g (Komata 1996). Aspartic acid was considerably below its threshold value (6.45 \( \mu \) mol/g) compared with the above umami compounds. Therefore, the quantity of umami compounds appeared to be sufficient to generate umami intensity in all the meat samples.

4. DISCUSSION

In this study, we investigated the characteristics such as texture and flavor of the center part in beef cooked by different methods. The characteristics of the cooking methods for Holstein loin beef were discussed below based on all the above results.

The sensory value of beef cooked by GR and RO was high because of its high levels of juiciness and strong umami intensity. Furthermore, beef cooked by these methods had a more desirable odor. The higher juiciness and fattiness scores of grilled and roasted beef seemed to result from the higher fat content and lower cooking loss. Adhikari et al. (2004) have also found that the juiciness of meat in a sensory evaluation is affected by both moisture content and fat content.

The lower cooking loss in grilled and roasted beef seemed to result in a strong umami intensity from the umami compounds and free amino acids in beef, because a strong umami intensity in meat was known to be mainly caused by synergistic effect of umami compounds such as Glu, Asp, 5’–IMP and other free amino acids (Nishimura, T., et al. 1988. Nishimura, T., 1998., Tanaka et al. 1969). Furthermore, the strong meaty aroma produced by GR and RO at high temperature could mask undesirable aromas, which seemed to lead to a high score as regards the odor of grilled and roasted beef in sensory evaluations.

Although the temperature of the central part in meats cooked by all cooking methods was the same, the differences in meat quality seemed to be caused by the differences in cooking time. The meat heated at over 70 °C for long time was reported to make perimysial collagen shrunk and myofibrils more rigid (Locker et al. 1977). Meat cooked by GR was almost rare and most tender in all meats. This might be caused by short cooking time, because the strong heat in GR gave high temperature over 100 °C to meat and took short time to get 60 °C in the center of beef. On the other hand, it took longer time in RO, because its cooking by radiant heat in convective heat transfer gave weaker heat and lower temperature to meat than GR. However, RO might lead to cook more tender meat than PO and MW, because collagen net in meat did not seem to be tensioned by the effect of radiant heat. The beef cooked by PO was tougher than that by GR, because PO heated directly meat at about 100 °C in water and took longer time in than GR.

VPLT produced tender beef with a strong umami intensity, however this beef scored worse in terms of aroma. Tenderness appears to be realized by preventing the meat fibers and membranes from shrinking at high temperature. Morgan et al. (1991) and Obuz et al. (2003) also reported that a longer cooking time increases the opportunity for the solubilization of collagen during thermal processing, resulting in higher cooking losses. Locker et al. (1977) reported that the heating beef at over 70 °C made the meat tough, and that at 60 °C made myofibrils shrunk easily and collagen tightened gradually. The strong umami intensity in beef achieved with VPLT seemed to be caused by the high quantity of free amino acids. Ishii et al. (1995) have shown that VPLT increases the free amino acids and peptides during heating as a result of the action of proteases such as endopeptidases and aminopeptidases. Therefore, free amino acids and peptides seem to increase during initial heating until 60 degrees Celsius. And the difference in these compounds is thought to contribute the difference in taste of beef cooked by different methods. In this paper, the contribution of other amino acids except for Glu to umami intensity of cooked beef by different methods was not investigated. This is a next problem to be resolved.

MW is very popular because it is a convenient and short-time cooking method. However, this method produced beef with less tenderness, juiciness and umami intensity.
intensity, and a less desirable aroma. It was found that MW resulted in a high temperature for part of the meat, with the meat fiber suddenly shrinking and an increase in cooking loss. Joseph et al. (1986) reported that MW made beef tenderer than poaching in cutting parallel to fiber. They showed that the former cooking method produced more solubilized collagen than the latter. This discrepancy with our result seemed to be caused by the differences in part of muscles, and direction of cutting. That is, the sample of Joseph et al was cut at parallel to the meat fiber, while our sample at perpendicular. Fulton and Davis (1983) have shown the tenderness of meat cooked by MW was same as that of roasted meat. This tender meat was seemed to be obtained because of MW cooking with heavy plastic wrap. In this work, the MW method produced as less juiciness than conventional oven methods, because meat was cooked by MW without wrap.

In this study, the characteristics of cooking methods used for Holstein loin beef were investigated by using the same part of muscle, and it was shown that different cooking methods produced beef with different characteristics. Specifically, the cooking loss influenced both the texture and umami intensity with dry heat methods. Further studies are needed to investigate the interaction between umami intensity and fat content.

5. CONCLUSION

To clarify the characteristics of cooking methods used for Holstein loin beef were investigated by using the same part of muscle, and it was shown that different cooking methods produced beef with different characteristics.

Grilled and roasted beef with a higher fat content and less cooking loss resulted in greater juiciness and higher sensory values. The beef cooked by PO obtained a medium score for all attributes. VPLT produced tender beef with a strong umami intensity, but produced a lower value for odor. Although MW is very popular and quick, it produced poorer results than conventional methods. Specifically, the cooking loss influenced both the texture and umami intensity with dry heat methods.

6. Acknowledgments

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7. References


異なる加熱方法による牛肉ロース芯の食感および食味特性

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本研究は、ホルスタイン種牛肉のロースを異なる加熱方法、すなわち焼成と蒸し焼き、煮熟、真空低温、マイクロ波の各方法で、内部中心温度 60 度に達するまで加熱した後、ロース芯を用いて官能評価と機器測定により食感および味の違いを検討した。ロース芯の加熱損失は、焼成、蒸し焼き加熱で最も小さく、マイクロ波で最も大きかった。調理後の肉の水分含量は真空低温加熱で最も多く、マイクロ波で最も少なかった。調理後の脂質含量は、真空低温で加熱した肉で低い値を示した。破断測定における破断エネルギーはマイクロ波加熱で高値であった。調理後の総アミノ酸含量は真空低温加熱で調理された肉において、最も高い値を示した。官能評価では、焼成および蒸し焼き加熱の肉で多汁性が高く、香りが良く、うま味も強いと評価された。真空低温加熱の肉はやわらかく、うま味が強いか、香りが良くないと評価された。マイクロ波加熱はどの項目においても低い評価値を示した。

以上の結果から、異なる加熱方法によるホルスタイン種牛のロース芯の官能評価特性の差異は、加熱損失、水分含量、うま味成分含量並びに破断エネルギーの差によってもたらされることが明らかとなった。

キーワード：牛肉、調理法、官能評価、食感、食味、うま味強度