Utilization and Characteristics of Nakaniku using Low Temperature Steam Cooking

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The aim of this study is to promote the use of nakaniku, which is not eatable due to its hardness using low temperature steam cooking. We report the alteration of the tissue structure, umami components and taste of nakaniku during cooking. Histological observations of the material indicated that the muscle fibers shrunk and created gaps between the fibers when boiled, while there were fewer gaps in the materials cooked by baking or low temperature steaming.

IMP was found less in the steamed than baked samples, however, the amounts of AMP and free glutamic acid increased from steaming. Alteration in the size of the protein molecules was determined using SDS–PAGE gel. The differences in the heating methods altered the size and quantity of each protein observable in the gel pattern. A sensory evaluation indicated that low temperature steaming produced a good evaluation in the texture profiles, resulting in high total value score.

Key word: low temperature steam cooking, nakaniku, silverside beef, histological observation, nucleotides, sensory evaluation

Introduction

The nutritional value, physical properties and histological evaluation of various vegetables and meats cooked using low temperature steam have been reported1-4). Among these materials, mino, cattle's first stomach, which is often discarded due to its toughness after ordinary cooking, and silverside cuts of beef, taken from the hinder quarters, which are also rarely used either by pot-roasting or traditional boiling, are the subjects of this study. Both of them lack quality and commercial value as foods.

In this study, our objective is to promote the use of silverside beef using low temperature steaming as a cooked meat with an improved and acceptable taste. There are several studies on cooking meat under vacuum and at lower temperatures, i.e., around 75°C5-8), however, all of them deal with chicken meat or ordinary beef which are very popular for daily use. There is no report that has been published on a cooking method to make hard and fibrous meat tasty and eatable. We have developed a method for cooking such low quality materials that produces an appreciable change. We would like to focus on the histological and biochemical alteration of silverside beef during cooking.

Materials and methods

Materials: nakaniku, a part of silverside, was used for this study (Fig.1). Silverside beef is a muscle tissue actively used for physical movement of the animal and thus, the muscle fibers are so rough and hard that they are often discarded during main commercial processing. We purchased this beef from a butcher shop, thirty days after slaughter, with attention to quality that would be...
comparable each time. The material was cut at a right angle, against the muscle fibers alignment in 1.5 cm thick slices and it was equally separated into three portions. Each sample was 2 cm wide, and 30-40 grams in weight.

Preparation of the cooked samples: A portion of the meat sample was placed in a plastic bag (nylon-poly-L type No. 14, 200 x 300 mm) and then placed in an automatic vacuum-and-seal machine (Japan vacuum system, type KN–25) to prepare it for vacuum cooking. The other portion was heated without using a plastic bag. Heating was carried out at 70°C for 15 hours using a low temperature steaming apparatus (AIHO, ATS-10 A). This was determined after varying the heating temperature and cooking time to find the most suitable combination. Such a preliminary study is indispensable to compensate for deviation in the sample meat to obtain the best quality. Boiling was carried for one hour in a boiling pan containing about 0.6 liter of water and baking for 5 and 10 minutes in a frying pan.

Observation of muscle structure: Histological observations of the cells and tissues were carried out on the samples, that had been fixed in Bouin’s fixative and sectioned, followed by optical microscope observations with or without staining by Sudan III for the lipid material and hematoxylin-eosin for the nucleus and cytoplasm.

Analysis of samples: The ATP related compounds were determined by HPLC after preparation by Terasaki’s method. For the HPLC analysis, a VP-ODS column (φ4.6 mm x 250 mm) was used at 40°C. The adsorbed material was eluted with 100 mM phosphoric acid (pH 6.8 adjusted by triethylamine) : acetonitrile (mixture of 100 to 2), at the flow rate of 1.0 ml/min, and measured at 260 nm absorption. The glutamic acid was determined using an amino acid analyzer. The molecular size of the proteins was determined using SDS-PAGE gel electrophoresis. SDS-PAGE was performed with a gel containing 10% acrylamide. Oxidation of the lipid was detected by using the thiobarbituric acid method.

The analyses mentioned above were carried out on a solid portion of the meat after removal of the excluded juice, namely, the values shown in these experiments did not include the exudation.

Hygienic tests were carried out for Escherichia coli and its group, Staphylococcus aureus and Salmonella group bacteria using XM–G agar, TGSE agar and MLCB agar (Eiken), respectively.

The rupture property was measured by a creep-meter RE–3305 S (Yamaden Co.) using a No. 21 knife-type plunger.

The sensory evaluation was performed by 11 faculty members and students following a preference test using a 5-point scoring. The evaluated parameters are shown in Table 1.

### Results and Discussion

#### 1. Histological observation

Fig. 2 illustrates the appearance of the raw and cooked nakaniku. The meat shrunk due to heating, but the meat cooked using the vacuum low temperature steaming was

![Fig. 2 Appearance of nakaniku after heating](image)

A: Raw, B: Bake 5 minutes, C: Bake 10 minutes, D: Boil 1 hour, E: Low temperature steaming at 70°C for 15 hours, F: Vacuum low temperature steaming at 70°C for 15 hours.
much less affected. Table 2 shows the yield after four methods of cooking, such as "boiling" or "baking," "low temperature steaming," and "vacuum low temperature steaming." The yields of the low temperature steaming and vacuum low temperature steaming were similar to the baked sample despite the long heating period. We speculated that this was caused by the gentle protein denaturation and reduced dripping from the cooked meat.

Fig. 3a shows a longitudinal section of nakaniku. After heating, gaps were created between the fibers followed by shrinkage, thus the space between the fibers became evident. By boiling, the shrinkage was greater and the muscle fibers became thinner. On the other hand, baking, low temperature steaming, and vacuum low temperature steaming showed much less actual shrinkage without alteration of the fiber thickness. Fig. 3b shows cross section surfaces of the meat treated as described above. As shown in Figs. 3a, and b, heating induced shrinkage of the fibers causing a significant space between the fibers.

Table 2. Yield after heating

<table>
<thead>
<tr>
<th>Heating method</th>
<th>Yield (%) (Mean±SD)</th>
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<tbody>
<tr>
<td>Bake 5 minutes</td>
<td>80.5±5.5</td>
</tr>
<tr>
<td>Bake 10 minutes</td>
<td>68.9±3.5</td>
</tr>
<tr>
<td>Boil 1 hour</td>
<td>54.5±4.6</td>
</tr>
<tr>
<td>Low temperature steaming 70°C 15 hours</td>
<td>68.5±1.2</td>
</tr>
<tr>
<td>Vacuum low temperature Steaming 70°C 15 hours</td>
<td>76.8±2.8</td>
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</table>

* Percent of weight remaining after the heating versus raw sample.

Fig. 3a Histology of nakaniku without staining (longitudinal view)
A, B, C, D, E and F are the same as in Fig. 2
The scale bar is 100 μm (magnification : 15 × 40)

Fig. 3b Histology of nakaniku without staining (cross section surface)
A, B, C, D, E and F are the same as in Fig. 2
The scale bar is 100 μm (magnification : 15 × 40)
2. Analysis of samples

1) Difference in ATP related compounds

As shown in Fig. 6, the ATP related materials were reduced to various degrees following the heating. The reduction was significant when boiling, probably due to loosening in the boiling water and degradation of the meat due to heating. Small amounts of ATP and ADP were found in the baked tissue, but they were lost in the low temperature steaming and vacuum low temperature steaming. IMP, a component of umami, was found less after steaming than baking, however, the amount of AMP, the precursor of IMP, increased. Both adenine and ade-
nosine were not detected. Such differences might arise from the specificity of the enzymes involved in the metabolic pathways depending upon temperature and the time lapse of cooking. If AMP deaminase was active during the low temperature steam cooking, IMP would have increased in the meat.

2) Alteration of free glutamic acid

The effects of heating on the glutamic acid contents are shown in Fig. 7. After 10 minutes of baking, a reduction in the free glutamic acid content was observed in the meat. In the case of boiling, it was reduced to one-fifth that of the raw material. However, an increase in the free glutamic acid was detected during the low temperature steaming suggesting an increase in the umami. This illustrates one advantage of the low temperature cooking.

3) Molecular weight of protein(s) by heating

Alteration of the protein molecules in size was determined from the pattern obtained in the SDS–PAGE gel. Generally, protein molecules are reduced in size as the heating period increases. However, the difference in the heating method altered the rate and type of proteins observable in the gel patterns (Fig. 8). Namely, bands at 82.3 and 72.0-kDa (band 1, 2) were observed in the raw, low temperature steaming and vacuum low temperature steaming, however, they were absent in the baked and boiled ones. The band at 54.4-kDa (band 3) was weakly detectable in the baked and boiled samples, but quite visible with a dense band in the low temperature steaming and vacuum low temperature steaming samples. On the other hand, the bands at 47.7 and 23.1-kDa (band 4, 5) were dense in the baked and boiled ones, but were weak in the low temperature steaming and vacuum low temperature steaming samples. The density of the bands generally reflects the amount of protein. Thus, significant variations were indicated concerning the quantity and quality of the protein(s) based on the cooking methods.

It has been suggested that taste is affected by the amount and distribution of the fat and/or moisture contents in steamed meat, besides the reduction of the molecular size of the protein. We intend to carry out a further study to determine the reasons for the taste improvement together with the better texture.

3. Lipid oxidation in nakaniku tissue during heating

The lipid oxidation of tissue by the various heating methods is shown in Table 3, indicating an increase in the thiobarbituric acid (TBA) value during heating which suggests oxidation. For the vacuum low temperature steaming, a low TBA value suggests that oxidation rarely occurred, and a low value from boiling could be explained by the lack of oxygen in the boiling water. When boiling, the decreased TBA value may be caused by a loss into the boiling water.

<table>
<thead>
<tr>
<th>Table 3. Lipid oxidation of tissue by heating (n=5)</th>
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<tbody>
<tr>
<td>Heating method</td>
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<tr>
<td>Raw</td>
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* TBA value (measured by E532) based on gm. of raw material before heating
4. Hygienic tests

These results are shown in Figs. 9, 10 and 11. A bacterial contamination survey was carried out at the center of the meat samples by using food stamps. The tests were also carried out on samples left one day at room temperature after the cooking was completed.

*E. coli* and its group: *E. coli* and *E. coli* group bacteria were found in the raw sample, but not after cooking. One colony of *E. coli* was found in the 5 min. baked material, but none were found in all the other ones.

*Staphylococcus aureus*: Some colonies were found in the fresh meat, but not after any kind of cooking.

*Salmonella*: None of the samples showed colonies, therefore, it is reasonable to conclude that there was no *Salmonella* contamination.

The temperature used for the low temperature steaming may raise questions about microbial hygiene. Our study supports the safety of both the low temperature steaming and vacuum low temperature steaming against common bacteria.

5. Rupture property by creep-meter

Fig. 12 shows rupture stress-strain curves of the *nakaniku*.

The beginning of the rupture stress-strain curves showed a steep increase in the 10-minute baked and boiled samples, while that of the raw meat has a gentle and slow increase. The curve with the meat treated by low temperature steaming showed a median type of curve. Table 4 shows the rupture stress of the *nakaniku*.
after the various heating treatments. The rupture stress was the highest in the raw meat. The rupture stress-strain curve of the boiled sample indicated values lower than the other samples, as shown in Fig. 12. The low temperature steamed meat showed a curve slightly above that of the boiled one.

These results showed that low temperature steamed meat was tender and rather elastic.

6. Sensory evaluation

The boiled meat was loose and chewy, but was lacking in juiciness, as shown in Fig. 13. The degradation and loss of collagen due to heating created gaps between the muscle fiber bundles as shown in Fig. 3. The baked meat was juicy with a good appearance, but was hard. Cooking by vacuum low temperature steaming has been recommended in general, but in our case, the vacuum low temperature steamed meat produced a rather low evaluation on average, despite its juiciness and tenderness due to the formation of a scum on the cooked meat surface within the plastic bag. The low temperature steaming did not produce any scum on the surface and had a better evaluation in texture profiles, resulting in a high score in all the tests. This result agreed with the rupture stress values.

Based on these results, we would like to conclude the following: Nakaniku is a muscular tissue with low fat and is rich in protein. However, it is very tough when served using ordinary cooking methods. The baked meat was also tough, and boiling produces loose, separable and less palatable meat. Low temperature steaming is a superior cooking method for nakaniku that produces a tender and palatable meat.

The palatability of cooked nakaniku might arise from the composition and quantity of the protein, its hydrolysates and nucleotides, which are the products of an endogenous enzyme action. These components may influence the quality of the meat and its texture. The endogenous enzymes and their nature, as well as the protein composition of the meat will be the target of our future study.

In addition, the cooking methods mentioned in this paper are applicable to various food materials, currently discarded or seldom used, to produce a useable food at a low price.

Acknowledgment

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References

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低温スチーミング調理による中肉の性状と食味の向上

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筋肉質でかたく, 食用に不適な肉の利用を拡大することを目的に中肉を用いて低温スチーミングによる調理を行なった。本研究では中肉の低温スチーミング調理における組織構造, 旨味成分, 食味の変化について調べた。

組織学的には, 「茄で」では筋肉繊維が収縮し, 繊維間に間隔ができているが, 「焼き」や「低温スチーミング」では比較的形状が保たれていることが観察された。IMP は「低温スチーミング」の方が「焼き」より少ないが, AMP やグルタミン酸は増加していた。加熱によるたんぱく質の分子量変化を SDS-PAGE で観察すると, 構成するたんぱく質の大きさや量に差がみられた。官能検査では「低温スチーミング」は「焼き」と「茄で」の特長を合わせ持ったような高い評価が得られた。

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