Rheological Properties of Emulsion-Type Sausage Prepared from Deer Meat

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Rheological properties of an emulsion-type sausage prepared from deer meat and pork fat were compared with those of experimental pork sausages and of commercial sausages. Deer meat sausage showed a softer texture than the experimental pork sausage. Three-dimensional structure, one of the characteristic structures of emulsion-type sausages, was clearly observed even in deer meat sausages by scanning electron microscopy, although the structure of deer meat sausages was slightly coarser than that of the experimental pork sausages. However, rheological parameters of deer sausages obtained in the present study were in the range of normal values observed for sausages sold in the market. The characteristics in color of deer meat sausage were darker than those of the experimental pork sausages, so that the color of deer meat sausage was similar to that of typical dried sausage such as salami in the market. Therefore, the present results indicate that emulsion-type sausage using deer meat will be acceptable by consumers with no problem.

Key words: Deer meat, Sausage, Product texture, Rheology

1. INTRODUCTION

In Japan, the numbers of inhabitants of wild deer have recently been increased, so that some of them usually have spoiled and are still spoiling agricultural products in crop fields by eating. The loss of damaged agricultural products has also been increased. Therefore, some of them, especially of male deer, are permitted to hunt during a few weeks in the winter season in order to control the population of wild deer. Unfortunately, however, the consumption of deer meat has been done only by a limited numbers of people such as hunters and people who like to have gourmet meals. In addition, only a few kinds of deer meat products, such as dried meat and "Sigure-ni (sweetened cooked deer meat)", are sold as attractions for visitors in secluded places in the mountains in Japan. Therefore, the expansion of the consumption of deer meat and its products are anticipated. In New Zealand, on the other hand, a number of red deer are raised in farms, and it is known that the numbers of red deer are increased to almost equal numbers of dairy cows [1, 2]. Most of those red deer are sold as raw steak meat but not as meat products.

There have been a few reports regarding the chemical composition of deer meat and deer fat[3, 4], so that the chemical properties of deer meat have considerably been unveiled. Unfortunately, however, almost no research has been made in the field of deer meat processing so far. The objectives of this study were to attempt to prepare an emulsion-type
sausage composed of deer meat and pork fat, and to investigate rheological properties of the resulting sausages, and compare the rheological properties of deer meat sausage and those of experimental pork sausages and of sausages sold in the market.

2. MATERIALS AND METHODS

2.1. Preparation of emulsion-type sausage

Deer meat (leg meat) was dissected out from deer carcass hunted in Kyushu University Forest (Shiiba-Mura, Miyazaki, Japan) and was stored at -80°C for 2 days. Then, the deer meat and pork fat were cut into a small cubes (approximately 3 cm in diameter), and was subjected to dry curing with a curing mixture (2.0 % sodium chloride, 0.3 % polyphosphate mixture (SH-50; Poly-Phos Chemical Ltd.), 150 ppm sodium nitrite, 550 ppm sodium ascorbate and 1.5 % sugar) for 3 days at 5°C. Then, five parts of the cured deer meat and two parts of pork fat were mixed with 20% (wt./wt. of meat) ice-water, 5% (wt./wt. of meat) starch, 0.4 % (wt./wt. of meat) gelatin, 0.5% (wt./wt. of meat spice mixture (0.14% white pepper, 0.02% of marjoram leaves, 0.08% of ginger, 0.04% of garlic, 0.03 % of allspice, 0.03% of nutmeg, 0.16 % of bouillon and 0.004 % of basil)) and 0.1% sodium glutamate in a food cutter and was cut for 4 min. The emulsified sausage mixture was staffed in a collagen casing (30 mm in diameter), followed by weighing. After leaving the resulting raw sausage in the smokehouse for a while, it was subjected to smoking (approximately 50°C for 30 min) and cooking (75°C for 30 min at the center of the sausages) in order. After cooling, droplets of water on the surfaces of the sausages were wiped out, the weight of each sausage was measured. Cooking loss during smoking and cooking was estimated by subtracting the final weight of the sausage from the initial weight (the weight before cooking). Experimental pork sausage was prepared by the same procedure described above, except that pork meat (leg meat) was used instead of deer meat.

2.2. Color and rheology

Deer sausage, experimental pork sausages, all-pork sausages (Fukudome Ham, Co. Ltd., Hiroshima, Japan) and fish sausages (Maruha, Ltd., Tokyo, Japan) purchased at a grocery store were cut into pieces having the shape of column (1.5 cm in height). The color (L*, a* and b*) of the pieces of those sausages was measured with a color meter (Nippon Denshoku Kogyo Ltd., ND-1001DP).

Physical properties of the pieces of the four kinds of sausages were evaluated with a Rheomer (RE 2-33005, Yamaden Ltd.) using a cylindrical plunger (12mm in diameter) with a constant rate of biting of the plunger to 80% pressing[5]. Rheological parameters (hardness, cohesiveness and gumminess) were calculated from charts of the biting of the plunger, according to the analytical procedure of Bourne[6].

2.3. Extractability and composition of muscle proteins and pH value

Deer meat stored at 0°C for 3 days after slaughter and pork meat (purchased from a wholesaler) before curing were cut into small pieces (2g). Half of each 2g meat sample was homogenized with a polytron (Kinematica Ltd., Switzerland) in 4 ml of 40 mM Tris-HCl (pH 7.2), followed by centrifugation (10, 000 X g for 20 min). The resulting supernatant was filtered through two layers of gauze. The filtrate was used as sarcoplasmic protein fraction. The remaining half of the meat samples was subjected to homogenization with a polytron in Weber-Edsall solution[7], centrifugation and filtration as described above. The resulting filtrate was used as salt-soluble protein fraction. Protein concentration of each fraction was determined by Biuret method[8] using bovine serum albumin as a standard. Protein composition of the two fractions was examined by SDS-PAGE[9] using a gradient gel of 7.5 - 20% acrylamide. The pH values of deer meat and pork meat were determined after homogenizing 5g of those meat with 25 ml distilled water.

2.4. Scanning electron microscopy (SEM)

Specimens of the sausages for SEM were prepared according to the method of Haga et al.[10]. Then, microstructure of the emulsion-type deer meat sausage and experimental pork sausage were observed by SEM, after spraying gold on the surface of the specimens (S-2050, Hitachi Ltd.).

2.5. Determination of myoglobin in deer meat and pork meat

Myoglobin content in deer meat and pork meat was determined by the procedure of Sakata and Nagata[11].

2.6. Statistical analysis

Data were expressed as means ± SD. Statistical differences of data sets were analyzed using one-way ANOVA and differences between groups was assessed by using Bonferroni's Multiple Comparison Test or, if applicable, by Mann-Whitney's U Test using commercially available statistics software (Stat123, Shinkou-koueki-isyo Publishing Limited, Japan).
Rheological properties of emulsion-type sausage prepared from deer meat

A

Fig. 1. Extractability of proteins from each meat (A) and SDS-PAGE patterns of deer and pork meat protein (B).

(A) The extractability of each muscle protein (mg of extracted protein/g muscle) was determined as described in Materials and Methods. Each column indicates the mean and SD (n=5). Statistical difference between groups was analyzed by Mann-Whitney's U Test. (*P<0.05).

(B) SDS-PAGE patterns of water-soluble proteins extracted from each meat.

- Lane 1, Myoglobin (17 kDa)
- Lane 2, Myosin B (rabbit skeletal muscle)
- Lane 3, Sarcoplasmic proteins of pork meat
- Lane 4, Sarcoplasmic proteins of deer meat
- Lane 5, Salt-soluble proteins of pork meat
- Lane 6, Salt-soluble proteins of deer meat

3. RESULTS AND DISCUSSION

3.1 Extractability of muscle proteins and their composition

It is generally recognized that myofibrillar proteins play very important roles in developing and improving binding property and water-holding capacity of processed meat products: myosin and actin molecules solubilized into cytosol from muscle cells during curing usually joint to form gels, so-called three dimensional networks containing water and fat droplets in the cracks of the networks, during the gelation process of cooking. Thus, the formation of three dimensional networks is a very important reaction in improving water-holding capacity of sausage meat during processing. Even in the case of the emulsion-type sausage containing deer meat as a protein source, it is easily considered that the principle reaction underlying sausage processing is the same as that of pork meat. Therefore, the extractability of muscle proteins of deer meat and their composition were compared with those of pork meat. As shown in Fig. 1A, the extractabilities of the two muscle protein fractions of pork meat were slightly greater than that of deer meat. SDS-PAGE pattern of myofibrillar protein fraction of deer meat was almost the same as that of pork meat.

Table 1. Physical properties of meat products

<table>
<thead>
<tr>
<th>Objective parameters</th>
<th>deer sausage</th>
<th>Pork sausage</th>
<th>Commercial Pork sausage (1)</th>
<th>Commercial fish sausage (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firmness (× 10^5 N/m²)</td>
<td>1.49 ± 0.32a</td>
<td>1.91 ± 0.17b</td>
<td>1.68 ± 0.31ab</td>
<td>1.79 ± 0.07ab</td>
</tr>
<tr>
<td>Cohesiveness (m² / m²)</td>
<td>0.42 ± 0.03nd</td>
<td>0.38 ± 0.01b</td>
<td>0.37 ± 0.04abc</td>
<td>0.42 ± 0.00d</td>
</tr>
<tr>
<td>Gumminess (× 10³ N / m²)</td>
<td>0.60 ± 0.16ec</td>
<td>0.73 ± 0.07ab</td>
<td>0.61 ± 0.09c</td>
<td>0.76 ± 0.03ed</td>
</tr>
</tbody>
</table>

Within each row, means having the same superscripts do not differ at p < 0.05.

(1) Bologna sausage (FUKUTOME HAM, Ltd.) (2) Fish sausage (MARUHA, Ltd.)
However, there was a difference in the electrophoretogram of sarcoplasmic proteins fraction, i.e., a band of 17 kDa (corresponding to myoglobin) was stained more strongly in deer meat than in pork meat (Fig. 1B). The pHs of deer meat and pork meat before curing were 5.87 and 5.70, respectively. These pH values were ideal for making emulsion-type sausages.

3.2. Rheological properties of meat products

The results for rheological properties of meat products in the present study were summarized in Table 1. Firmness of deer meat sausage (Resistant force against the plunger when the plunger was penetrated into the pieces of the sausage) was significantly lower than that of experimental pork sausage. However, the difference in the firmness between deer meat sausage and commercial sausages was not statistically significant. Cohesiveness (an indicator of internal binding force) of the deer meat sausage as well as commercial fish sausage was significantly higher than that of the experimental pork sausage. Gumminess, one of the secondary parameters calculated from both of firmness and cohesiveness, of deer meat sausage was appreciably lower than that of the experimental pork sausage and commercial fish sausage. These results indicated that deer meat sausage probably gave us softer touch than other sausages did. Cooking loss, a good indicator of water-holding capacity and binding property of raw meat, of deer meat sausage was apparently lower than that of the experimental pork sausage (Fig. 2), indicating that most of meat particles in the sausage properly bind each other to make three-dimensional network. The result of the cooking loss of deer meat sausage also coincides with that of cohesiveness.

In general, rheological properties of gelled foods are highly dependent on three-dimensional structure of the foods. In the case of deer meat sausage, three-dimensional structure was also clearly observed by SEM (Fig. 3). In comparing the microstructure of deer meat sausage and that of the experimental pork sausage, the diameter of each stick composing the three-dimensional structure of deer meat sausage was considerably smaller than that of the experimental pork sausage. Also, the gel of deer meat sausage was composed of coarser networks than that of the experimental pork sausage. Therefore, high softness in the texture of deer meat sausage described above was probably due to those characteristics of the network structure of the deer meat sausage. In Japan, average body size of wild deer varies from about 150 kg of "Ezo-sika" in Hokkaido Island to about 50 kg of 'Nihonjika (Cervus nippon)' in Kyushu Island, i.e., body size of wild deer is decreased from north to south in Japan. The deer

![Fig. 2. Cooking loss of meat products.](image)

Cooking loss was estimated by subtracting the final weight of the sausage from the initial weight (the weight before cooking). Each column indicates the mean and SD (n=5). Statistical difference between groups was analyzed by Mann-Whitney's U Test. (*P<0.05).

![Fig. 3. Microstructure of meat products.](image)

Microscopic magnification (X 10,000)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Deer sausage</th>
<th>Pork sausage</th>
<th>Commercial Pork sausage (1)</th>
<th>Commercial fish sausage (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L* (Lightness)</td>
<td>51.75 ± 0.93a</td>
<td>67.70 ± 0.96b</td>
<td>69.60 ± 0.12e</td>
<td>69.72 ± 0.50c</td>
</tr>
<tr>
<td>a* (Redness)</td>
<td>16.27 ± 1.51a</td>
<td>10.10 ± 0.10b</td>
<td>18.30 ± 0.50c</td>
<td>10.89 ± 0.31e</td>
</tr>
<tr>
<td>b* (Yellowness)</td>
<td>13.74 ± 0.68a</td>
<td>12.36 ± 0.50b</td>
<td>13.07 ± 0.43c</td>
<td>4.36 ± 0.33e</td>
</tr>
</tbody>
</table>

In each row, means having the same superscripts do not differ at p < 0.01.

1) Bologna sausage (FUKUDOME HAM, Ltd.) 2) Fish sausage (MARUHA, Ltd.)
used in the present study were of Kyushu Island, so that body weight of the deer used in the present study was approximately 50 kg and the season we hunted was in late autumn, immediately before or early in the breeding season. The body size of deer and the season we hunt may be one of the reasons of the softer texture of the deer sausage.

In our preliminary sensory test (data not shown), texture of the meat products evaluated by eating corresponded to the rheological properties of the meat products in the present study. An off-flavor specific for deer meat was diminished after the preparation of sausages from deer meat according to our preparation method and the combination of spices. In fact, most of the panelists cared nothing for its flavor.

3.3. Color of meat products

The color of deer meat sausage was slightly darker than that of experimental pork sausage, so that L* value of deer meat sausage was significantly lower than that of the experimental pork sausage, and a* and b* values of the former were also significantly higher than those of the latter. However, those parameters of the former were lower than those of the commercial pork sausage except b* value (Table 2). This may be due to the contribution of a color additive (Cochineal) to the color of the commercial pork sausage. In addition, H* value, an indicator of the profoundness of redness, of the former showed an intermediate value between H* value of the experimental pork sausage and that of fish sausage (Data not shown). These results indicate that the characteristics in color of deer meat sausage are due to higher content of myoglobin (%) in raw deer meat (deer meat; 0.63, pork meat; 0.29). As a matter of fact, each color parameter of deer meat sausage is quite similar to that of dried sausages such as salami.[12].

In summarizing the results in the present study, deer meat sausage showed a softer texture than the experimental pork sausage did. However, the rheological parameters obtained in the present study were in the range of normal values usually observed for sausages sold in the market. Also, the deer meat sausage did not produce the off-flavor problem. Therefore, the present results indicate that emulsion-type sausage using deer meat will be acceptable by consumers.

REFERENCES