Effect of the Granular Size of Ground Meat on the Sensory Distinction and Physical Properties of Meat Patties

Etsuko IMAI, Fumiyo HAYAKAWA,* Keiko HATAE,* Atsuko SHIMADA* and Masaharu AIUCHI**

The University of The Air, Chiba 260, Japan
* School of Human Life and Environment Science, Ochanomizu University, Bunkyo-ku, Tokyo 112, Japan
** Snow Brand Milk Products Co. Ltd., Kawagoe, Saitama 350, Japan

The effect of granular size on the physical properties and sensory distinction of samples was examined by preparing patties from three kinds of ground meat, i.e., beef, pork, and chicken, which had been passed through one of five plates with orifice diameters of 2.4, 3.4, 4.8, 6.8 and 9.6 mm.

Measurements of the granular size of the raw meat grains and those of the meat grains after cooking indicated a contraction ratio due to cooking in the order of beef>pork>chicken. In addition, it was easiest with beef to distinguish the granular size of patties prepared from meat passed through different orifice diameters, and chicken was found to be the most adhesive.

The juice in thawed meat patties with a large granular size was retained to a greater extent in cooked meat patties than that with a small granular size. There was also a difference in juice retention among the kinds of meat, that is, this being greater in the order of chicken>pork>beef. The shearing-breaking strain and cohesiveness of the cooked meat patties was significantly increased with increasing orifice diameter, beef showing the greatest changes in values from different orifice diameters. This suggests that the physical properties of beef ground through different orifice diameters are easier to distinguish than those of pork and chicken.

The results of the sensory evaluation show that the coarseness of the meat, hardness, elasticity, and nikuryukan (size and amount of meat-like granules) were distinguishable to some extent with each kind of meat patties prepared by using different orifice diameters. It is also shown that there was difference in distinguishability according to the kind of meat, i.e., beef≥pork≥chicken. We thus verified the distinguishability by size measurements of the meat grains and physical measurements of the cooked meat patties.

Nikuryukan, which is a sensory index of meat granular size, is shown to be 98% predictable by two physical properties, namely the ratio of dripping of a meat patty before and after cooking, and the water-holding capacity of a thawed meat patty. The granular size was distinguishable when the volume ratio of the meat grains was larger than 1.2–1.5.

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Keywords: ground meat, granular size, sensory evaluation, physical property.

INTRODUCTION

The meat patty is now one of the most popular foods in Japan, especially among young people. It is also recognized as one of the fastest-growing foods in the food market. This market contains many varieties of frozen and retorted food products, and in 1991, 58,818 tons of frozen hamburger steaks were manufactured in Japan.

It has been pointed out that the taste, flavor, and texture are important factors in determining the tastiness of a meat patty.1) Endo et al.2) have reported that the features of meat patties on the market could be expressed by five classifications to evaluate their texture, these being fibrous, oily, elastic, soft, and ‘tsubu-tsubu’ or granular. Izutsu et al.3) have shown that the most important sensory properties in the texture of meat patties were fleshiness (a geometrical characteristic) and resistance to biting (a rheological charac-
teristic), the former including 'fibrousness' and 'ni-
kuryukan' (size and amount of meat-like granules),
which has a meaning similar to 'tsubu-tsubu' by
Endo et al.2) In an attempt to evaluate the texture
of meat patties by objective methods, Wani et al.4)
have reported that the characteristics of the meat
grains in patties (granular size and distribution of
meat grains) were important.

Although the granular size of the ground meat
seems to have the greatest influence on the tastiness
of meat patties, there has been no investigation on
the effect of the granular size on the texture felt by
people. Most studies on meat patties have consid-
ered the influence of supplementary raw mater-
ials5)-9) or of freezing storage.10)- 14) In relation to
restructured steak, on study has been reported on
the flaking conditions and granular size of ground
meat,15) and another showed that the sensory panel-
ists had the greatest liking for steak with a 6-mm
flake size (supplemented with 0.75% NaCl).16) However, restructured steak is not a 'ground meat'
dish, but rather a 'lump meat' dish.

With these previous investigations in mind, the
effect of the granular size of ground meat on texture
was examined. Emphasis was placed on the textur-
al evaluation with respect to the distinguishability
of granular size, and on the physical properties of
meat patties prepared from ground meat of various
granular sizes.

**MATERIALS AND METHODS**

**Materials**
The following materials comprised the types of
meat used for these investigations.

1. Beef: Approx. 30 kg of internal round meat
was taken from 4 male Holsteins bred for 580 days
at the Yukijirushi test farm (Kawasaki, Miyagi
prefecture), and was used after 4 days of ripening
at 0°C and 3 days of ripening at St.

2. Pork: Approx. 30 kg of internal and external
ham was taken from 10 male and 10 female large
Yorkshires, Landraces, and Durocs bred for 190
days at the Hanamaki Kanegasaki stock farm
(Kanegasaki, Tawanawa, Iwate prefecture), and was
used after 1 day of ripening at 2-3°C and 4 days of
ripening at 5°C.

3. Chicken: Approx. 30 kg of white meat was
taken from approx. 100 male broilers and New
Fuji birds bred for 65 days at Kono poultry farm
(Tokorozawa, Saitama prefecture), and was used
after 4 days of ripening at 5°C.

**Preparation of the samples**
The fat and sinews in the meat were removed by
hand with a knife to obtain approx. 6-7 kg of each
type of meat, which was then cut into approx. 5-cm
cubes before passing through a meat grinder
(Career Kogyo, GM-DX model, 82-mm external
plate). The orifice diameters of the plates included
those commonly used, and all orifice diameters were
set to give an interval of 2 times the area (or 1.4
times the diameter). Thus, the five orifice diam-
ters selected were 2.4, 3.4, 4.8, 6.8, and 9.6 mm. In
the subsequent description, meat ground with each
orifice diameter will be called A, B, C, D, and E,
respectively. The meat temperature was approx.
3-6°C and 4-7°C before and after grinding, and all
the grinding conditions were the most suitable. The
ground meat was individually measured into 80-g
lumps and pushed by hand into oval-shaped molds
for cutting by a meat patty shaping machine
(Yamanaka Seikeiki model 60) to give a 91.0-mm
major axis, 65.5-mm minor axis, and 13-mm thick-
ness). Approximately 80 sample was prepared
from each A-E ground meat and immediately placed
in an air-draught freezer (Toyo Seisakusho, Touke-
tsu Jikkensouchi, -35°C internal temperature and 5
m/s air velocity) to quick-freeze the patties down
to -30°C. Each sample took 20-25 min to freeze
completely. Each frozen sample was then individu-
ally placed in a boil-in-pack (made of polyethylene,
nylon and polyvinylidene chloride), sealed under
vacuum with an automatic vacuum-packing machi-
ne (Tosie Electric, Tospack V-301G), and then
stored in a freezer at -30°C.

For each test, a frozen sample in its boil-in-pack
was cooked in boiling water, a thermocouple insert-
ed into the center of each frozen sample recording
the temperature change during cooking. The fro-
zen samples were cooked in the boiling water bath
until their internal temperature reached 80°C, all the
cooked samples for our tests being obtained by
using this procedure. The cooking times for the
beef, pork, and chicken samples were 10, 11 and 12
min, respectively.

**Approximate analysis of the meat used**
A frozen sample was thawed for approx. 24 h in
the chilling compartment (0±2°C) of a refrigerator
(Matsushita Electric, NR-337CG), all the thawed
samples for our tests being obtained by using this
procedure. The thawed sample was then chopped
for 20 s with a food cutter (Toshiba, CQ-30), and the
water content (heat-drying method under atmo-
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spheric pressure at 135°C for 3 h), crude proteins (micro-Kjeldahl method), crude fats (Bligh-Dyer method), and crude ash (direct mineralization method) were each determined.

Measurement of the granular size of the ground meat

An image processing unit (PIAS, LA-555) using Gazo Keisan software and color-image processing unit (Mitanishoji, IMC-512V8) using SPECTRUM software were used to measure the granular size of about 100 meat samples. The parameters measured with the image processing unit were the area, degree of circularity \((4\pi \times \text{area}/\text{circumferential length}^2)\), the lengths of the long axis and short axis, the ratio of the long and short axes, the volume (assuming an elliptical form), the maximum length, and average width.

Measurements were taken of 4 types of ground meat.

1. Raw meat grains immediately after grinding, the grains being separated from each other with a pair of tweezers.

2. Meat grains from cooked samples, the grains being separated from each other with a pair of tweezers. Sample types A and B were omitted because it was hard to separate these meat grains from each other.

3. Meat grains cooked after separating from thawed samples, the grains of thawed samples being separated from each other with a pair of tweezers, lain in a colander, and cooked by steam with a large quantity of hot water. The cooking time is defined as the time required for the internal temperature of a meat grain to reach 80°C. These times for the samples were B, 1.5 min; C, 2 min; D, 3 min; and E, 5 min. Sample type A was omitted because the meat grains from the thawed samples were too adhesive to separate from each other.

4. Meat grains from cooked samples after mixing and air-drying, 50 ml of distilled water being added to 10 g of a cooked sample, mixed for 20 s with 35 V which arranged by a transfomer (Koizumi NMX-0701 electric mixer), filtered, and air-dried overnight.

Measurement of the physical properties

Measurement of the physical properties was conducted 8 times for each sample, and the mean values calculated.

1. Ratio of the patty thickness after and before cooking

The thickness of the central region of a sample was measured with slide calipers before and after cooking. The ratio of thickness after cooking to that before cooking was calculated (the term will hereinafter be abbreviated to the thickness ratio).

2. Ratio of the dripping weight to frozen sample weight

The weight of a frozen sample was measured, and the dripping weight was measured immediately after cooking. The ratio of dripping weight to the frozen sample weight was calculated (the term will hereinafter be abbreviated to the dripping ratio).

3. Water-holding capacity of a thawed sample

Approx. 7 g of a thawed sample was precisely measured into centrifugation tubes, centrifuged at 16,000 rpm (28,000 g) for 30 min, and the supernatant was removed. The ratio of the weight of the precipitate after centrifugation to the frozen sample weight before centrifugation was calculated as the water-holding capacity of a thawed sample (the term will hereinafter be abbreviated to water-holding capacity).

4. WBS value

Immediately after cooking, a cooked sample was cut into pieces of 1 (length) \(\times\) 2 (breadth) \(\times\) 1 (height) cm\(^3\), covered with wrapping film, and stored in a thermostatic chamber at 20°C for 1 h. The WBS value was then determined with a Warner-Bratzler shearing test machine (ZENKEN, Warner-Bratzler meat shear, model 3000).

5. Textural property values (hardness and cohesiveness)

Immediately after cooking, a cooked sample was cut into pieces of 2 (length) \(\times\) 2 (breadth) \(\times\) 1 (height) cm\(^3\), covered with wrapping film, and stored in a thermostatic chamber at 20°C for 1 h. The hardness and cohesiveness were then determined with a texturometer (Zenken GT-2X, plane dish plate, lucite plunger of 18 mm dia., 5 mm clearance).

6. Breaking property values (breaking-strain, breaking-strength, and apparent modulus of elasticity obtained from shearing and punching tests)

Immediately after cooking, a cooked sample was cut into pieces of 2.5 (length) \(\times\) 2.5 (breadth) \(\times\) 1.0 (height) cm\(^3\), covered with wrapping film, and stored in a thermostatic chamber at 20°C for 1 h. Using a rheoner (Yamaden RE-3305), a shearing test (20 kg load sensor, back edge of a spare cutter knife (0.4 mm width) as the plunger, No. 102 48 mm in diameter plunger guide, and 0.5 mm/s sample plate speed) and punching test (20 kg load sensor, cylindrical
No. 5 plunger, 5 mm in diameter, No. 103 plunger guide 48 mm in diameter, 10 mm hole diameter, and 0.5 mm/s sample plate speed) were carried out to determine the breaking-strain, breaking-strength, and apparent modulus of elasticity of each sample.

**Sensory evaluation**
A distinction test was carried out according to the method of Scheffe's paired comparison modified by Haga. Each of five samples was compared with every other sample making a total of 10 comparisons. Twenty-four panelists (10 x 24 = 240 comparisons) evaluated the samples. Half of the panelists were served with the samples in the order of A before B, for instance, and the other half of the panelists were served in the order of B before A. The panelists were, however, allowed to taste the two samples repeatedly in turn, and the order of tasting was not monitored.

In the studies Izutsu et al., Wani et al., and Yano, the items evaluated were the appearance (coarseness of the meat section [fine—coarse]), texture (hardness [soft—hard], elasticity [not detected—detected], nikuryukan [not detected—detected], juiciness [not detected—detected]) and taste (strength of umami [weak—strong]). For each item, the panelists evaluated the sample on their right in seven grades from -3 to +3, when the sample on their left was regarded as grade 0.

A cooked sample was immediately taken from its boil-in pack and cut into 4 pieces (about 15 g each) by the edge of a microtome for the sensory evaluation. A pair of samples was placed in the same direction on a white plate of 15 cm in diameter, and it was confirmed that it took less than 3 min to serve the cooked samples to each panelist. The internal temperature of the samples for the sensory evaluation was about 65°C when served to the panelists.

The sensory evaluation was conducted under white light in individual sensory evaluation booths in the periods from 10 a.m. and 11 a.m., and from 2 p.m. to 4 p.m.

The panelists (aged 22-28 years) were members of the Cookery Science Laboratory at Ochanomizu University.

**Statistical treatment**
Statistica/Mac was used to calculate and analyze the statistical data.

**RESULTS AND DISCUSSION**

**Approximate analysis of the meat used**
The results of the approximate analysis of the beef, pork, and chicken are shown in Table 1.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Beef</th>
<th>Pork</th>
<th>Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>73.3</td>
<td>73.7</td>
<td>72.7</td>
</tr>
<tr>
<td>Protein</td>
<td>21.9</td>
<td>20.1</td>
<td>23.2</td>
</tr>
<tr>
<td>Lipid</td>
<td>3.5</td>
<td>2.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Ash</td>
<td>1.2</td>
<td>1.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

These three kinds of meat had approx. 73% water content, 20-23% crude proteins, 1-3.5% crude fats, and approx. 1% ash. Although chicken had a somewhat lower content of crude fats and higher content of crude proteins than the other two kinds of meat, the differences were very small and could be neglected.

**Granular size of the ground meat**
1. **Granular size of the raw meat immediately after grinding**
The granular size of the raw meat immediately after grinding is shown in Table 2. The average width of a sample was distributed in the range of 2.1-7.8 mm, all of which tended to be a little less than the orifice diameter used. The maximum length was in the range of 7.8-18.7 mm, which increased with increasing orifice diameter. On the contrary, however, the ratio of maximum length to average width became smaller as the orifice diameter increased. Therefore, the degree of circularization of a grain increased with increasing orifice diameter. Grain volume was in the range of 33-1,095 mm³. Among the three kinds of meat, chicken tended to have significantly smaller values for average width, maximum length, and volume for the B-D samples than beef or pork.

2. **Granular size of meat grains separated from cooked samples, and those cooked after separating from thawed samples**
In order to know the ultimate granular size of meat grains in the cooked samples, the meat grains were separated after cooking. However, it was impossible to determine the A and B samples because it was hard to separate these meat grains from each other. To provide reference data, meat grains in a thawed sample were separated from each other in the raw state, and were cooked prior to determining their granular size. It was, however, still impossible to separate the meat grains in sample A. The results of these measurements are
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Table 2. Granular sizes of the raw meat immediately after grinding

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meat</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Average width (mm)</td>
<td>beef</td>
<td>2.1&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>2.1&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>chicken</td>
<td>2.1&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maximum length (mm)</td>
<td>beef</td>
<td>7.8&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>9.7&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>chicken</td>
<td>9.5&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>Volume (mm³)</td>
<td>beef</td>
<td>33&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>42&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>chicken</td>
<td>44&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td>Circularity&lt;sup&gt;y&lt;/sup&gt;</td>
<td>beef</td>
<td>0.67&lt;sup&gt;xy&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>0.53&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>chicken</td>
<td>0.55&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>–<sup>x</sup> Means in the same row with different letters are significantly different at p < 0.05. <sup>–<sup>y</sup> Means in the same column with different letters are significantly different at p < 0.05. <sup>f</sup> = 4 x area/circumferential length.<sup>2</sup> A-E: Meat was ground in a meat mincer equipped with plates of various orifice diameters: A, 2.4 mm; B, 3.4 mm; C, 4.8 mm; D, 6.8 mm; E, 9.6 mm.

Table 3. Granular size of the cooked ground meat prepared by different methods

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meat</th>
<th>Ground meat separated from cooked patties</th>
<th>Ground meat cooked after separating from raw patties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>Average width (mm)</td>
<td>beef</td>
<td>2.9&lt;sup&gt;x&lt;/sup&gt;</td>
<td>4.4&lt;sup&gt;xy&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>3.6&lt;sup&gt;y&lt;/sup&gt;</td>
<td>4.8&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>chicken</td>
<td>3.6&lt;sup&gt;y&lt;/sup&gt;</td>
<td>4.7&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maximum length (mm)</td>
<td>beef</td>
<td>7.7&lt;sup&gt;x&lt;/sup&gt;</td>
<td>11.6&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>9.5&lt;sup&gt;y&lt;/sup&gt;</td>
<td>13.3&lt;sup&gt;xy&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>chicken</td>
<td>9.3&lt;sup&gt;y&lt;/sup&gt;</td>
<td>12.5&lt;sup&gt;xy&lt;/sup&gt;</td>
</tr>
<tr>
<td>Volume (mm³)</td>
<td>beef</td>
<td>85&lt;sup&gt;x&lt;/sup&gt;</td>
<td>236&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>141&lt;sup&gt;x&lt;/sup&gt;</td>
<td>253&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>chicken</td>
<td>142&lt;sup&gt;x&lt;/sup&gt;</td>
<td>306&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>x</sup>–<sup>y</sup> Means in the same row each preparation method with different letters are significantly different at p < 0.05. <sup>x</sup>–<sup>y</sup> Means in the same column with different letters are significantly different at p < 0.05. B-E: Refer to Table 2.

shown in Table 3.

Sample C-E, when separated from the cooked patties, had an average width of 2.9-5.4 mm, maximum length of 7.7-14.2 mm, and volume of 85-483 mm³. In respect of the differences between samples A, B, C, D and E, volume E/C, for instance, was 5.0, 3.4 and 3.2 for beef, pork and chicken, respectively, showing that beef had larger volume differences between samples A, B, C, D and E than the other two kinds of meat. Beef had the smallest values for average width, maximum length, and volume. The contraction ratio of meat grains during cooking was
calculated from the granular size of the raw meat in Table 2. Beef had the greatest contraction ratio of 29-36% in average width, 27-36% in maximum length, and 58-61% in volume, while chicken had the smallest contraction ratio of 5-24%, 7-20%, and 14-34%, respectively.

The reference data for samples B-E, which were cooked after separating the grains from thawed samples, were in the range of 2.7-6.0 mm in average width, 7.7-13.7 mm in maximum length, and 61-482 mm³ in volume. Beef had the largest E/B volume difference ratio of 7.9, followed by 6.3 for pork, and 5.7 for chicken. In addition, beef had the largest contraction ratio during cooking when using the data in Table 2 (this contraction ratio was 14-23% in average width, 15-28% in maximum length, and 40-56% in volume), while chicken had the smallest contraction ratios (0-22%, 0-14%, and 0-45%, respectively).

These results suggest that the granular size distinction between A, B, C, D and E was easiest for beef and most difficult for chicken.

The degree of circularity was 0.62-0.70 for the meat grains separated from the cooked samples, and 0.64-0.73 for the meat grains cooked after separating from the thawed samples, although no significant trend was apparent.

3. Granular size from cooked samples after mixing and air-drying

Cooked samples were disrupted in a mixer running under slight load, and the granular size of the broken meat pieces was determined. This data was used as an index to indicate how easily the samples would be broken into pieces while being chewed in the mouth. The volume data are shown in Table 4.

The volume after mixing each cooked sample and air-drying was in the range of 14-124 mm³, which tended to increase as the granular sizes became larger from A to E. For example, the E/A volume difference ratio was 4.9 for beef, 4.7 for pork, and 3.5 for chicken. It was assumed that chicken would have a smaller granular size difference while being chewed in the mouth among samples A-E than beef or pork. Moreover, in any size from A to E, the volume of broken meat pieces of chicken was larger than that of beef or pork, which suggest that chicken had the strongest adhesive force of the meat grains tested.

Physical properties of the samples

Table 5 shows the correlation coefficients of the 11 measured parameters. The correlation coefficients of table show wide variation from -0.016 to 0.957 between them. High correlation was not apparent between the water-holding capacity and any other measured parameter. Based on these results and considering the degree of correlation, the reproducability of experimental data, ease of measurement, etc., four measured parameters were selected to express the physical properties of cooked samples in a relatively independent way: the dripping ratio, breaking strain in the shearing test, cohesiveness, and water-holding capacity. Tables 6 and 7 list the measurements of these four parameters and the results of the analysis of variance.

The dripping ratio was 17-27%, which significantly increased as the granular size increased from sample A to E. There was a high negative correlation between the dripping ratio and the thickness ratio (Table 5), which significantly decreased as the granular size increased from sample A to E. In addition, the water-holding capacity was in the range of 74-80%, which significantly increased with increasing granular size. These results show that a smaller granular size made it more difficult to retain meat juice in the raw meat because more tissue was
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Table 5. Correlation coefficients among eleven measured variables for the cooked meat patty

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dripping</td>
<td>2</td>
<td>-0.937</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHC</td>
<td>3</td>
<td>-0.016</td>
<td>0.164</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain of S</td>
<td>4</td>
<td>-0.498</td>
<td>0.367</td>
<td>0.701</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength of S</td>
<td>5</td>
<td>-0.738</td>
<td>0.658</td>
<td>0.482</td>
<td>0.822</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulus of S</td>
<td>6</td>
<td>-0.740</td>
<td>0.612</td>
<td>0.451</td>
<td>0.792</td>
<td>0.950</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Strain of P</td>
<td>7</td>
<td>-0.492</td>
<td>0.373</td>
<td>0.714</td>
<td>0.906</td>
<td>0.826</td>
<td>0.825</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength of P</td>
<td>8</td>
<td>-0.572</td>
<td>0.448</td>
<td>0.704</td>
<td>0.869</td>
<td>0.837</td>
<td>0.846</td>
<td>0.957</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>9</td>
<td>-0.957</td>
<td>0.906</td>
<td>0.094</td>
<td>0.486</td>
<td>0.808</td>
<td>0.776</td>
<td>0.532</td>
<td>0.612</td>
<td></td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>10</td>
<td>-0.588</td>
<td>0.661</td>
<td>0.269</td>
<td>0.658</td>
<td>0.799</td>
<td>0.660</td>
<td>0.574</td>
<td>0.582</td>
<td>0.663</td>
</tr>
<tr>
<td>WBS</td>
<td>11</td>
<td>-0.906</td>
<td>0.865</td>
<td>0.213</td>
<td>0.632</td>
<td>0.895</td>
<td>0.830</td>
<td>0.674</td>
<td>0.728</td>
<td>0.957</td>
</tr>
</tbody>
</table>

* Ratio of the thickness after and before cooking. b Dripping ratio for the cooked meat patty. c Water released from the raw meat patty by centrifugation. d Breaking strain of the shearing test. e Breaking strength of the shearing test. f Apparent modulus of elasticity of the punching test. g Breaking strain of the punching test. h Breaking strength of the punching test. p (15, 0.001) = 0.760, p (15, 0.01) = 0.641, p (15, 0.05) = 0.514.

destroyed, whereas the meat juice was retained in the cooked meat because of the larger adherable area among the meat grains. This possibly caused the samples to be thicker.

Among the three kinds of meat, beef had the greatest dripping ratio, followed by pork, and then chicken. Chicken had the greatest water-holding capacity and thickness ratio, followed by pork, and then beef. Consequently, the degree of juice outflow from the meat differed according to the type, juice being retained to a higher degree in the order of chicken, pork, and beef, both in the raw and cooked states. This possibly helped to increase the thickness of the samples, although this factor was not examined in this study. Moreover, when the dripping ratio was greater (beef > pork > chicken), the cooked meat grains had a higher contraction ratio and smaller volume. This corresponds to Table 3, which shows the meat grain volume when separated from the cooked samples (beef < pork < chicken). The low dripping ratio for chicken suggests that chicken was made more adhesive by cooking. This supports the granular size measurements (Table 4) for cooked samples after mixing and air-drying.

The breaking strain measured in the shearing test significantly increased as the granular sizes became larger from sample A to E. There was no significant difference among the three kinds of meat. At the rate of increase of breaking strain for samples A, B, C, D and E, however, differed according to the meat kind, beef having the largest value.

Cohesiveness was in the range of 0.53–0.60, which significantly increased as the granular sizes became larger from sample A to E, and was significantly greater in pork than in chicken. As with the case of the breaking strain measured in the shearing test, beef had a markedly larger rate of increase of cohesiveness for samples A, B, C, D and E than the other two kinds of meat.

The results of the cohesiveness and the breaking strain measured in the shearing test indicate that differences in the physical properties of samples A, B, C, D and E of beef would be easier to distinguish sensorily than with the other two kinds of meat.

Sensory distinction of properties

1. Results of the sensory evaluation on property distinction

The results of the sensory evaluation to distinguish cooked samples, using a modified version of Scheffe's method, are shown in Fig. 1. The average scores evaluated for A–E were plotted on a line, under which yardstick Y (the least significant difference) is shown. If the length between any two samples is greater than the length of Y, there is a significant difference at p < 0.05 between the samples.

An evaluation by appearance could distinguish that the meat section was coarser in the order of A,
B, C, D and E with each of the three kinds of meat. However, there were no significant differences between D and E for beef and pork, and between A and B, C and D, D and E, and C and E for chicken. Moreover, when compared with beef and pork, chicken had smaller differences in coarseness among samples A, B, C, D and E. This possibly indicates that chicken has more-adhesive meat.

<table>
<thead>
<tr>
<th>Meat</th>
<th>Dripping* (%)</th>
<th>WHC* (%)</th>
<th>Breakingc strain</th>
<th>Cohesiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>21.8±1.7</td>
<td>73.8±1.4</td>
<td>0.38±0.15</td>
<td>0.53±0.02</td>
</tr>
<tr>
<td>B</td>
<td>23.2±1.1</td>
<td>75.1±0.8</td>
<td>0.52±0.13</td>
<td>0.55±0.03</td>
</tr>
<tr>
<td>C</td>
<td>25.2±1.8</td>
<td>76.5±2.0</td>
<td>0.50±0.18</td>
<td>0.60±0.03</td>
</tr>
<tr>
<td>D</td>
<td>27.1±1.8</td>
<td>76.9±1.8</td>
<td>0.64±0.24</td>
<td>0.59±0.04</td>
</tr>
<tr>
<td>E</td>
<td>27.0±1.5</td>
<td>77.6±1.3</td>
<td>0.80±0.24</td>
<td>0.61±0.03</td>
</tr>
<tr>
<td>Pork</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>20.1±0.9</td>
<td>74.6±1.0</td>
<td>0.52±0.04</td>
<td>0.58±0.02</td>
</tr>
<tr>
<td>B</td>
<td>21.7±1.1</td>
<td>75.3±0.6</td>
<td>0.58±0.09</td>
<td>0.58±0.04</td>
</tr>
<tr>
<td>C</td>
<td>23.7±1.1</td>
<td>76.8±1.7</td>
<td>0.61±0.07</td>
<td>0.58±0.04</td>
</tr>
<tr>
<td>D</td>
<td>24.5±1.4</td>
<td>77.6±0.7</td>
<td>0.67±0.08</td>
<td>0.60±0.02</td>
</tr>
<tr>
<td>E</td>
<td>26.3±1.4</td>
<td>78.0±1.6</td>
<td>0.70±0.09</td>
<td>0.60±0.04</td>
</tr>
<tr>
<td>Chicken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>17.6±1.0</td>
<td>78.0±2.2</td>
<td>0.50±0.09</td>
<td>0.56±0.02</td>
</tr>
<tr>
<td>B</td>
<td>17.7±1.6</td>
<td>78.3±1.3</td>
<td>0.57±0.10</td>
<td>0.56±0.02</td>
</tr>
<tr>
<td>C</td>
<td>19.8±1.1</td>
<td>78.6±1.7</td>
<td>0.64±0.18</td>
<td>0.56±0.03</td>
</tr>
<tr>
<td>D</td>
<td>20.3±1.0</td>
<td>78.7±1.5</td>
<td>0.64±0.11</td>
<td>0.56±0.02</td>
</tr>
<tr>
<td>E</td>
<td>20.3±1.5</td>
<td>80.4±2.1</td>
<td>0.75±0.15</td>
<td>0.58±0.02</td>
</tr>
</tbody>
</table>

* Dripping ratio for the cooked meat patty.  
* Water released from the raw meat patty by centrifugation.  
* Breaking strain of the shearing test.  
A-E: Refer to Table 2.

Table 7. Analysis of variance for four physical properties of cooked meat patties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Factor</th>
<th>( p&lt;0.05 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dripping*</td>
<td>meat</td>
<td>*** beef&gt;pork&gt;chicken</td>
</tr>
<tr>
<td></td>
<td>size</td>
<td>*** A&lt;B&lt;C=D, A&gt;B&lt;C=E</td>
</tr>
<tr>
<td></td>
<td>interaction</td>
<td>**</td>
</tr>
<tr>
<td>WHC*</td>
<td>meat</td>
<td>*** chicken&gt;pork=beef</td>
</tr>
<tr>
<td></td>
<td>size</td>
<td>*** A&lt;C=E, A&gt;B&lt;D=E</td>
</tr>
<tr>
<td></td>
<td>interaction</td>
<td>n.s.</td>
</tr>
<tr>
<td>Breaking strain of shearing test</td>
<td>meat</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>size</td>
<td>*** A&lt;B&lt;D&lt;E, A&lt;C=E</td>
</tr>
<tr>
<td></td>
<td>interaction</td>
<td>n.s.</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>meat</td>
<td>** pork&gt;beef=chicken</td>
</tr>
<tr>
<td></td>
<td>size</td>
<td>*** A&lt;C&lt;E, A&gt;B&lt;D=E</td>
</tr>
<tr>
<td></td>
<td>interaction</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* Dripping ratio for the cooked ground meat patties.  
* Water released from the raw ground meat patties by centrifugation.  
A-E: Refer to Table 2.  
** \( p<0.01 \).  
*** \( p<0.001 \).
Effect of the Granular Size of Ground Meat on Meat Patties

grains than beef or pork, which agrees with the results of Table 4 (meat pieces from cooked samples after mixing and air-drying) and of Table 6 (dripping ratio).

Hardness also increased in the order of A, B, C, D and E, but it was impossible to significantly distinguish any hardness difference between samples D and E of beef, between A and B and between D and E of pork, and between A and B and between C and D of chicken. The hardness differences among A, B, C, D and E were greatest for beef, followed by pork and then by chicken.

Elasticity also increased in the order of A, B, C, D and E. It was possible to significantly distinguish between any pair of samples A, B, C, D and E for beef, but it was impossible to distinguish any difference between A and B, B and C, and D and E for pork, and between A and B, B and C, C and D, and D and E for chicken. The variation of elasticity among samples A, B, C, D and E was greatest for beef, and was almost the same for pork and chicken.

The granular size of a meat patty influences the perceived texture of the meat when a sample is eaten. The sensory evaluation of the texture of meat grains used ‘nikuryukan’ as the index. Nikuryukan increased in the order of A, B, C, D and E with all of the three kinds of meat, although there were no significant differences between A and B and between D and E for beef, between D and E for pork, and between A and B and between C and D for chicken. Beef and pork had a similar differences in A, B, C, D and E, while chicken had the smallest differences.

Juiciness tended to decrease as the granular size increased from sample A to E. This was partially distinguishable with pork, but it was not significantly distinguishable with beef and chicken. The values of dripping ratio (Table 6) show 0-6.2% differences in A, B, C, D and E for each of the three kinds of meat, but the difference was too small for sensory recognition.

No significant differences in the strength of umami taste were distinguishable among samples A, B, C, D and E of any of the three kinds of meat.

The distinguishability test thus clarified that the coarseness of the meat texture, its hardness, elasticity, and nikuryukan could be distinguished to some extent between samples of different granular size in each of the three kinds of meat. The differences in samples A, B, C, D and E were more distinguishable in the order of beef ≥ pork ≥ chicken, although there
were some exceptions. These results correlate with the granular size differences among samples A, B, C, D and E (Tables 3 and 4) being in the order beef > pork > chicken, and with beef having the largest variation in cohesiveness and breaking strain measured in the shearing test among samples A, B, C, D and E (Table 6).

2. Principal component analysis of the sensory evaluation on property

The sensory results of the property of samples with different grain sizes was evaluated by six variables for each kind of meat, and the average evaluation being given to each variable as shown in Fig. 1. The average scores were used to produce a smaller number of general characteristics (principal components) to conduct a principal component analysis of all the data with fewer variables. The principal component analysis was started with 15 cases (n) =3 kinds of meat × 5 grain sizes and 6 variables (p=6) in the variance-covariance matrix (V). The eigenvalue proportion and the factor loading of each principal component are shown in Table 8.

The principal component analysis showed one principal component with an eigenvalue proportion of 97.6%. The factor loading, which shows the correlation between the first principal component and its original individual variables, was highly positive for the coarseness of the meat section, hardness, elasticity, and nikuryukan, and highly negative for juiciness. The second principal component, umami, had a high positive factor loading, and juiciness also had a positive factor loading to some extent, although the second principal component had a small eigenvalue proportion of 1.6%. These results and those in Fig. 1 show that the first principal component was largely dependent on the meat grain size. In other words, the coarseness of the meat section, hardness, elasticity, and nikuryukan were greatly influenced by the grain size and increased with increasing grain size. Juiciness tended to decrease with increasing grain size, and was influenced by factors other than the grain size. Umami was found to be a sensory property unconnected with the grain size or with any other variable. Consequently, the evaluation illustrated in Fig. 1 could be verified in an objective way.

Relationships among nikuryukan, physical property values, and meat granular size

1. Multiple regression analysis of nikuryukan and physical property values

In order to identify the physical properties which clearly influenced the sensory evaluation of nikuryukan, a multiple regression analysis was carried out by using the physical property values as predictor variables and nikuryukan as the criterion variable.

The four variables in Table 6 were used as physical property values, and the analysis was conducted with the results shown in Table 9.

The effect of two variables was not significant, and the remaining predictor variables were the dripping ratio and water-holding capacity. Both contributed greatly to nikuryukan, and it was clarified that 98% of nikuryukan could be predicted by only these two variables.

2. Degree of distinction of the meat grains

Nikuryukan was distinguishable between all pairs of sample sizes, except between A and B and between D and E for beef, between D and E for pork, and between A and B and between C and D for chicken. To investigate the necessary difference between granular sizes that would enable nikuryukan to be distinguished, an examination was made of the granular size measurements of cooked meat grains shown in Tables 3 and 4. A ratio of around 1.2-1.5 in the granular size of two ground samples proved to be the limit for distinguishing nikuryukan by granular size, although there was some scattering of data.

CONCLUSIONS

The effect of the granular size of ground meat on the physical properties and sensory distinction was examined for meat patties prepared from 3 kinds of ground meat (beef, pork and chicken) which had

<table>
<thead>
<tr>
<th>Table 8. Eigenvalues and factor loading obtained from the principal component analysis of sensory properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor loading</td>
</tr>
<tr>
<td>Coarseness</td>
</tr>
<tr>
<td>Hardness</td>
</tr>
<tr>
<td>Elasticity</td>
</tr>
<tr>
<td>&quot;Nikuryukan&quot;</td>
</tr>
<tr>
<td>Juiciness</td>
</tr>
<tr>
<td>Umami</td>
</tr>
<tr>
<td>Eigenvalue</td>
</tr>
<tr>
<td>Proportion (%)</td>
</tr>
<tr>
<td>Cumulative proportion (%)</td>
</tr>
</tbody>
</table>
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Table 9. Values obtained from the multiple regression analysis of "nikuryukan" and physical properties

<table>
<thead>
<tr>
<th>Physical property</th>
<th>Partial regression coefficient</th>
<th>Standard partial regression coefficient</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dripping</td>
<td>0.185</td>
<td>0.733</td>
<td>17.7</td>
<td>***</td>
</tr>
<tr>
<td>WHC</td>
<td>0.357</td>
<td>0.796</td>
<td>19.2</td>
<td>***</td>
</tr>
<tr>
<td>Breaking strain</td>
<td></td>
<td></td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>Cohesiveness</td>
<td></td>
<td></td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-31.686</td>
<td>-</td>
<td>-21.3</td>
<td>***</td>
</tr>
<tr>
<td>Proportion ((R^2))</td>
<td>0.980</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a Dripping ratio of the cooked meat patty. b Water released from the raw meat patty by centrifugation. c Breaking strain of the shearing test. *** p < 0.001.

been passed through 5 sizes of plate with orifice diameters of 2.4, 3.4, 4.8 and 9.6 mm to respectively obtain samples A, B, C, D and E. The physical properties were then measured and sensory evaluation carried out.

1. The granular size of the raw meat immediately after grinding was significantly smaller with chicken than with beef and pork, while the contraction ratio of the meat grains due to cooking was in the order of beef > pork > chicken. The size of meat grains separated from cooked samples was significantly smaller with beef than with chicken and pork. The variation in granular size of samples A, B, C, D and E of cooked meat was in the order of beef > pork > chicken, which suggests that it is easiest to distinguish the granular size of beef samples.

When the cooked patty samples were disrupted under a slight load, the chicken meat pieces were larger than the beef and pork pieces, which suggests the higher adhesiveness of chicken.

2. A correlation analysis was carried out on 11 measured physical property values, and four variables were selected as being relatively independent: the ratio of the weight of dripping to the weight of the frozen sample, the water-holding capacity of a thawed sample, the breaking strain in the shearing test, and the cohesiveness. The dripping ratio and the water-holding capacity of a thawed sample significantly increased as the granular size increased from A to E. With small granular size, it is thought to have been more difficult to retain the juices in raw meat because more tissue is destroyed by grinding, but it was easier to retain the remaining meat juice while cooked because of the larger adherable area. In both the thawed and cooked samples, juice was most readily released from the meat in the order of beef > pork > chicken. This corresponds to the order for the contraction ratio of meat grains during cooking, and supports the notion that chicken is highly adhesive. The cohesiveness and breaking strain measured in the shearing test also significantly increased as the granular size increased from A to E. In particular, beef had a greater variation of values among samples A-E when compared with chicken and pork. This leads to the assumption that the physical properties of beef are easier to distinguish.

3. The sensory evaluation showed that the coarseness of the meat section, hardness, elasticity, and nikuryukan could be distinguished to some extent between samples A, B, C, D and E of cooked meat was in the order of beef > pork > chicken, which suggests that it is easiest to distinguish the granular size of beef samples. When the cooked patty samples were disrupted under a slight load, the chicken meat pieces were larger than the beef and pork pieces, which suggests the higher adhesiveness of chicken.

4. The multiple regression analysis showed that nikuryukan, one of the indices indicating the sensing of meat granular size, was 98% predictable by only the values for the dripping ratio and the water-holding capacity of a thawed sample. It appears that a 1.2–1.5 ratio of the grain sizes of two different samples was the boundary condition for deciding whether or not granular size was distinguishable.
The authors are very grateful to Professor Toshiro Haga of Science University of Tokyo for his kind and valuable guidance in the statistical treatment of the sensory evaluation.

REFERENCES


ハンバーグ様栃き肉試料の食感の識別および
物性に及ぼす栃き肉粒度の影響

今井悦子，早川文代*，細江敏子*，
島田淳子*，相内雅治**
（放送大学，* お茶の水女子大学生活科学部，** 雪印乳業技術研究所）

平成6年1月31日受理

5種類の目皿（細孔の直径2.4, 3.4, 4.8, 6.8および9.6mm）を通した栃き肉（牛、豚お
よび鶏の3種類）を用いてハンバーグ様試料を製造し、試料の官能的識別および物性に及ぼす
粒度の影響を検討した。

生肉粒、加熱後の肉粒の粒度を測定した結果、加熱による肉粒の収縮率は牛肉＞豚肉＞鶏肉
であった。さらに粒度測定から、牛肉、目皿の直径が異なる試料間の粒度の識別がもっとも
しやすく、また鶏肉は結果性がもっとも高いことが示唆された。

試料中の水分の保ちやすさは、解凍試料では目皿の直径が大きい試料の方で、加熱試料では小
さい試料の方であり、さらに鶏肉＞豚肉＞牛肉という肉種による差があった。剪断破断歪みお
よび凝集性は、目皿の直径が大きい試料ほど有意に大きく、また牛は他の肉種よりも、目皿の
直径が異なる試料間での変化率が大きかった。これより、牛肉の物性は、目皿の直径が異なる
試料間で識別しやすいことが示唆された。

官能検査の結果、目皿の直径が異なる試料間で、切り口の粗さ、硬さ、弾性および肉粒感
は3種の肉ともにある程度識別できたが、識別のしやすさには肉種による差があり、牛肉＞豚
肉＞鶏肉であることが分かった。この結果より、肉粒の粒度測定および物性測定による示唆が
裏づけられた。

肉の粒度を官能的に捉える指標の1つである肉粒感は、肉汁の流出率および解凍試料の保水
力の2つの物性で98%予測できることができた。また、2つの肉粒の体積の比が1.2～
1.5以上になると粒度の識別ができたと考えられた。

キーワード：栃き肉、粒度、官能検査、物性。