Components Contributing to the Improvement of Meat Taste during Storage

Toshihide Nishimura, Mee Ra Rhue, Akihiro Okitani* and Hiromichi Kato

Department of Agricultural Chemistry, The University of Tokyo,
Bunkyo-ku, Tokyo 113, Japan
*Department of Animal Products Science and Technology,
Nippon Veterinary and Zootechnical College,
Musashino-shi 180, Japan

Received April 25, 1988

The changes in both taste and taste components of beef, pork, and chicken during storage were examined.

The brothy taste intensity of pork and chicken was significantly stronger after conditioning than before. On the other hand, for beef, there was no significant difference in the brothy taste intensity before or after conditioning. The analysis of major taste components showed that the levels of free amino acids in all meats were higher after conditioning than before. The differences in the levels of free amino acids before versus after conditioning were large in pork and chicken and very small in beef. Oligopeptide levels were lower in beef after conditioning than before, but they were higher in pork and chicken after conditioning than before. These results corresponded to results of the sensory evaluation studies described above, indicating that free amino acids and oligopeptides contributed to the improvement of meat taste during storage.

Flavor is one of the important qualities of meat. Although it has been thought that a period of postmortem aging of meat improves its flavor, consistent results have not been obtained.1-9) This seems to be because the flavor of meat is a result of complex sensations arising from two distinct responses, taste and aroma. There have been few studies to distinguish between taste and aroma in meat. Taste in flavor elements is elicited mainly by water-soluble components. Over a period of postmortem aging, meat shows a gradual change in levels of various chemical components, including free amino acids (FAA),10-18) adenosine 5'-triphosphate (ATP) metabolites,5,19-22) sugars23,24) and organic acids.24,25)

In this manner, although there are many studies on chemical components in raw meat, the components responsible for the improvement of the taste of meat have not been identified. Chemical components not only in raw meat but also cooked meat should be measured to identify the component(s) responsible for the improvement of meat taste, because these components in raw meat seem to be reduced by the amino-carbonyl reaction with sugar during heating. Furthermore, there have not been many reports that these components in beef, pork and chicken were measured exactly under the same conditions.

In this work, we noted taste in meat flavor and examined the changes of taste during the storage of beef, pork, and chicken. Then, we measured the level of water-soluble components in raw meats and heated soup of meats before and after conditioning, and clarified the relationship between taste intensity and the levels of taste components, to identify the component(s) responsible for the improvement of meat taste during storage.

MATERIALS AND METHODS

1. Reagents. Xanthine, inosine 5'-monophosphate...
(IMP), and adenosine 5'-diphosphate (ADP) were purchased from Sigma Chemical Co. Inosine and hypoxanthine were from Daiichi Chemical Co. and Wako Chemical Co., respectively. Adenosine 5'-monophosphate (AMP) was obtained from Yamasa Syoyu Co., ATP was from Kohjin Co. and lactic acid was from Nakarai Chemical Co. Bovine serum albumin (BSA) was purchased from Boehringer Mannheim GmbH. All other chemicals used were reagent grade.

2. Materials. We used, as samples before conditioning, four bovine rounds stored for 4 days at 4°C after slaughter, four porcine muscles (longissimus dorsi) stored for 1 day after slaughter, and four chicken muscles (pectoralis superficialis) stored for 0 day after slaughter. We used, as samples after conditioning, each meat stored at 4°C for 12, 6, and 2 days after slaughter, respectively, for beef, pork, and chicken.

3. Sensory evaluation.

1) Preparation of heated soups for sensory evaluation. Soups were prepared from each meat to remove the effects of texture on sensory evaluation. An equal weight of water was added to the minced meat, and the preparation was homogenized. The homogenate was heated in boiling water for 20 min, and then centrifuged to obtain the meat soups. The NaCl concentration and the pH of each soup were adjusted to 0.5 ~ 0.6% and 6 ± 0.05, respectively.

2) Sensory evaluation. Panelists judged the relative strength of the brothy taste between before and after conditioning meat.

4. Chemical analyses. We analyzed FAA, ATP metabolites, anserine (Ans), carnosine (Car), oligopeptides, and lactic acid in an acid-soluble fraction obtained via addition of trichloroacetic acid solution (final conc. 5%). We analyzed FAA, Ans and Car with a Hitachi amino acid analyzer Model 835, ATP metabolites were analyzed by high performance liquid chromatography (HPLC) using an ion exchange column (Hitachi 3013N) at 70°C with linear gradients from 6% CH₃CN-0.02 m NH₄Cl-0.01 m KH₂PO₄-0.01 m K₂HPO₄ at 0 min to 6% CH₃CN-0.3 m NH₄Cl-0.05 m KH₂PO₄-0.05 m K₂HPO₄ at 30 min. The level of oligopeptides was measured by the method of Lowry et al. using BSA as the standard. Lactic acid was prepared from meat extracts by ion exchange columns, Dowex 50 and Dowex 2, and analyzed by HPLC using an ion exchange column (Shodex Ionpac KC-811). All chemical values are means for 4 individuals.

RESULTS AND DISCUSSION

1. Improvement of brothy taste during conditioning

As shown in Table I, the sensory evaluation of the brothy taste intensity of meat before and after conditioning showed that the brothy taste intensity of pork and chicken was significantly stronger after conditioning than before. On the other hand, for beef, there was no significant difference in the brothy taste intensity before or after conditioning. Smith et al. reported that aging beef 11 days at 1°C was associated with significant increases in pleasant flavor. Caul and Paul et al. observed that aging beef improved its flavor. But Field et al. and Minks and Stringer reported that aging beef for 5 ~ 19 days at 2°C did not improve its flavor. Thus consistent results have not been obtained. Our result can not be directly compared with these results, because flavor, which was studied by these authors, includes both taste and aroma. However, because our result at least showed that aging beef did not improve its taste, improvement of flavor in beef during storage may depend primarily on aroma. On the other hand, Harrison et al. and Bennett et al. observed that aging pork did not improve its flavor. One of the causes of the discrepancy with our result may be that we conducted sensory evaluation for only the taste of pork. Terasaki et al. reported that chicken flavor was more pleasant at 8 hr than immediately after slaughter. Our result was in good accord with their result.

<table>
<thead>
<tr>
<th>Meat</th>
<th>Before additional storage</th>
<th>After additional storage</th>
<th>$n$</th>
<th>Difference$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>12</td>
<td>4</td>
<td>16</td>
<td>NS</td>
</tr>
<tr>
<td>Pork</td>
<td>2</td>
<td>14</td>
<td>16</td>
<td>*</td>
</tr>
<tr>
<td>Chicken</td>
<td>8</td>
<td>23</td>
<td>31</td>
<td>*</td>
</tr>
</tbody>
</table>

$^a$ NS, not significant.

* Significantly different ($p<0.05$).
2. Changes of taste components in meat before and after conditioning

1) Free amino acids. Table II shows the changes in the levels of FAA during the storage of beef, pork, and chicken. In beef, FAA except for Gin and β-Ala, increased during storage; the increases in Ala, Tau, Leu, Ser, Val and Glu were especially large. Parrish et al. reported that aging beef for 4 days at 2°C was accompanied by large increases in Ala, Val, Glu and Lys. Field et al. reported that large increases in Val, Thr+Ser, Glu, Leu, and Lys were obtained by aging beef for 5 days at 2°C. With the exception of the increase in Lys, these results were in accord with results from this study. In pork, free amino acids, with the exception of Tau, increased; the increases of Glu, Ala, Ser, Leu and Gly were especially large. Bowers reported that Ala, Ser, Thr, and Glu were greatly increased by aging pork loin for 7 days at 2°C. Their results—that Ala, Glu and Ser were the major amino acids increasing during storage—were in good accord with our results from this study. In chicken, all FAA increased; the increases of Ala, Ser, Glu, Tau, and Leu were particularly notable. Niewiarowicz et al. reported that large increases in Ala, Ser, Glu, and Leu could be obtained by aging chicken breast muscle for 6 days at 4°C. Their results were in accord with the results of this study. The extent of increase of FAA was smallest in beef and largest in chicken. The increment of Glu was also lowest in beef and highest in chicken. These results seemed to be due to the fact that the total activity of aminopeptidase and its hydrolytic activity toward glutamic acid-β-naphthylamide (Glu-NA) were lowest in beef and highest in chicken (Nishimura et al., in preparation).

We measured the levels of FAA in heated soups, which were examined by sensory evaluation, of beef, pork, and chicken before and

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Beef 4</th>
<th>Beef 12</th>
<th>Pork 1</th>
<th>Pork 6</th>
<th>Chicken 0</th>
<th>Chicken 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asp</td>
<td>0.09</td>
<td>0.15</td>
<td>0.06</td>
<td>0.07</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>Thr</td>
<td>0.42</td>
<td>0.58</td>
<td>0.16</td>
<td>0.28</td>
<td>0.43</td>
<td>0.15</td>
</tr>
<tr>
<td>Ser</td>
<td>0.65</td>
<td>0.93</td>
<td>0.28</td>
<td>0.28</td>
<td>0.60</td>
<td>0.32</td>
</tr>
<tr>
<td>Gin</td>
<td>4.23</td>
<td>3.98</td>
<td>-0.25</td>
<td>1.29</td>
<td>1.30</td>
<td>0.01</td>
</tr>
<tr>
<td>Gly</td>
<td>1.38</td>
<td>1.52</td>
<td>0.14</td>
<td>1.94</td>
<td>1.46</td>
<td>0.27</td>
</tr>
<tr>
<td>Ala</td>
<td>3.59</td>
<td>4.28</td>
<td>0.69</td>
<td>2.03</td>
<td>2.41</td>
<td>0.38</td>
</tr>
<tr>
<td>Val</td>
<td>0.49</td>
<td>0.75</td>
<td>0.26</td>
<td>0.40</td>
<td>0.56</td>
<td>0.16</td>
</tr>
<tr>
<td>Cys</td>
<td>0.03</td>
<td>0.06</td>
<td>0.03</td>
<td>0.01</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Met</td>
<td>0.19</td>
<td>0.39</td>
<td>0.20</td>
<td>0.09</td>
<td>0.28</td>
<td>0.19</td>
</tr>
<tr>
<td>Ile</td>
<td>0.33</td>
<td>0.52</td>
<td>0.19</td>
<td>0.23</td>
<td>0.37</td>
<td>0.14</td>
</tr>
<tr>
<td>Leu</td>
<td>0.57</td>
<td>0.95</td>
<td>0.38</td>
<td>0.36</td>
<td>0.65</td>
<td>0.29</td>
</tr>
<tr>
<td>Tyr</td>
<td>0.23</td>
<td>0.39</td>
<td>0.16</td>
<td>0.15</td>
<td>0.30</td>
<td>0.15</td>
</tr>
<tr>
<td>Phe</td>
<td>0.25</td>
<td>0.43</td>
<td>0.18</td>
<td>0.15</td>
<td>0.30</td>
<td>0.15</td>
</tr>
<tr>
<td>β-Ala</td>
<td>0.22</td>
<td>0.21</td>
<td>-0.01</td>
<td>0.29</td>
<td>0.31</td>
<td>0.02</td>
</tr>
<tr>
<td>Lys</td>
<td>0.60</td>
<td>0.77</td>
<td>0.17</td>
<td>0.26</td>
<td>0.43</td>
<td>0.17</td>
</tr>
<tr>
<td>His</td>
<td>0.24</td>
<td>0.33</td>
<td>0.09</td>
<td>0.12</td>
<td>0.18</td>
<td>0.06</td>
</tr>
<tr>
<td>Arg</td>
<td>0.43</td>
<td>0.53</td>
<td>0.10</td>
<td>0.15</td>
<td>0.34</td>
<td>0.19</td>
</tr>
<tr>
<td>Asn</td>
<td>0.23</td>
<td>0.34</td>
<td>0.11</td>
<td>0.14</td>
<td>0.32</td>
<td>0.18</td>
</tr>
<tr>
<td>Pro</td>
<td>0.34</td>
<td>0.36</td>
<td>0.02</td>
<td>0.30</td>
<td>0.35</td>
<td>0.05</td>
</tr>
<tr>
<td>Tau</td>
<td>3.09</td>
<td>3.68</td>
<td>0.59</td>
<td>2.57</td>
<td>2.38</td>
<td>-0.19</td>
</tr>
<tr>
<td>Total</td>
<td>18.01</td>
<td>21.81</td>
<td>3.80</td>
<td>10.60</td>
<td>13.77</td>
<td>3.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.35</td>
<td>15.90</td>
<td>6.55</td>
</tr>
</tbody>
</table>

a μmol/g meat.
b Time postmortem (days).
Fig. 1. Free Amino Acid Content of Heated Soup of Beef, Pork and Chicken before and after Additional Storage.

(■), before additional storage; (■■■■), after additional storage.

*, significantly different (p<0.05); —, standard error; numbers in parentheses, time postmortem (days).

### Table III. Changes in the Levels of ATP Metabolites during the Storage of Beef, Pork and Chicken

<table>
<thead>
<tr>
<th>ATP metabolite</th>
<th>Beef</th>
<th></th>
<th></th>
<th></th>
<th>Pork</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Chicken</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 b</td>
<td>12 Increment</td>
<td>1 6 Increment</td>
<td>0 2 Increment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADP</td>
<td>0.45</td>
<td>0.44</td>
<td>−0.01</td>
<td>0.45</td>
<td>0.42</td>
<td>−0.03</td>
<td>0.29</td>
<td>0.36</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AMP</td>
<td>0.06</td>
<td>0.01</td>
<td>−0.05</td>
<td>0.02</td>
<td>0.01</td>
<td>−0.01</td>
<td>0.03</td>
<td>0.00</td>
<td>−0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMP</td>
<td>2.30</td>
<td>2.03</td>
<td>−0.27</td>
<td>6.63</td>
<td>5.75</td>
<td>−0.88</td>
<td>7.24</td>
<td>5.89</td>
<td>−1.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inosine</td>
<td>1.93</td>
<td>2.09</td>
<td>0.16</td>
<td>2.49</td>
<td>3.20</td>
<td>0.71</td>
<td>2.09</td>
<td>3.48</td>
<td>1.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoxanthine</td>
<td>1.48</td>
<td>2.82</td>
<td>1.34</td>
<td>0.41</td>
<td>0.82</td>
<td>0.42</td>
<td>0.09</td>
<td>0.60</td>
<td>0.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xanthine</td>
<td>0.17</td>
<td>0.37</td>
<td>0.20</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a μmol/g meat.
b Time postmortem (days).

ND, not detected.

After meat conditioning. As shown in Fig. 1, the levels of almost all FAA in meat soup were higher after conditioning than before. The differences in the levels of FAA before versus after conditioning were largest in chicken and smallest in beef. In raw meat, these differences were larger in beef than in pork. This suggests that the level of free amino acids in beef after
conditioning was decreased by heating. FAA, which were significantly larger in heated soup of meat after conditioning than before, were Asp and Tyr in beef, Asp, Ser, Glu, Met, Ile, Leu, Tyr, Phe, Arg, Asn and Pro in pork, and Asp, Ser, Glu, Gln, Val, Cys, Met, Ile, Leu, Tyr, Phe, His, Arg, Asn and Pro in chicken. These results corresponded to the higher brothy taste intensity in pork and chicken after meat conditioning as compared to before conditioning. This correspondence suggests that the increase in FAA contributed to the improvement of meat taste after conditioning.

2) ATP metabolites. As shown in Table III, we investigated the changes in levels of ATP metabolites during storage of beef, pork and chicken. ATP was not detected in all meats. ADP was reduced in beef and pork, but was increased in chicken. In all meats, AMP and IMP decreased, but inosine and hypoxanthine increased. Only in beef was xanthine detected. The IMP content of beef was lowest. A large part of IMP seemed to be converted into inosine. Tsai et al.22) reported that the ATP content of pork muscle at 3 hr after slaughter was 0.16 μmol/g muscle. The IMP content reached 5.48 μmol/g muscle at 3 hr after slaughter and decreased gradually as the postmortem period lengthened, but levels of inosine and hypoxanthine increased gradually after slaughter. Terasaki et al.5) reported that the IMP content of chicken breast muscle reached a maximum at 8 hr after slaughter and then decreased gradually. These results were in good accord with the results in this study.

Figure 2 shows the level of ATP metabolites in heated soup of meat before and after conditioning. AMP, IMP, inosine and hypoxanthine were detected in beef, pork, and chicken. In all meats, the contents of inosine and hypoxanthine were larger after conditioning than before. However, we considered they did not contribute to the improvement of taste during storage, because they were reported to have no effect on taste.27) The IMP content was lower in soup prepared from conditioned meat that in soup prepared from meat before conditioning, indicating that IMP was not a

![Fig. 2. ATP Metabolites Content of Heated Soup of Beef, Pork and Chicken before and after Additional Storage.](image)

**Table IV. Changes in the Levels of Ans<sup>a</sup> and Car during the Storage of Beef, Pork and Chicken**

<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>Pork</th>
<th>Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12</td>
<td>Increment</td>
</tr>
<tr>
<td>Ans</td>
<td>3.27</td>
<td>3.54</td>
<td>0.27</td>
</tr>
<tr>
<td>Car</td>
<td>19.11</td>
<td>20.59</td>
<td>1.48</td>
</tr>
</tbody>
</table>

<sup>a</sup> μmol/g meat.

<sup>b</sup> Time postmortem (days).
particularly important component contributing to the improvement of meat taste. However, because Yamaguchi\(^{28}\) reported a synergistic phenomenon between IMP and glutamic acid, the importance of IMP in meat taste should be investigated in detail.

3) Peptides. We examined the changes in the levels of anserine (Ans) and carnosine (Car) during the storage of beef, pork and chicken. As shown in Table IV, Ans increased a little in all meats and its content is largest in chicken both before and after conditioning. On the other hand, Car increased a little in beef and pork and decreased in chicken. Since carnosinase was reported to be present in rat muscle,\(^{29}\) this enzyme in chicken seemed to degrade Car during the storage.

Figure 3 shows that the levels of Ans and Car in heated soups of all meats were higher before conditioning than after. Especially, both Ans and Car in chicken and Car in pork were significantly higher before conditioning than after. These results did not correspond to the higher brothy taste intensity in pork and chicken after conditioning as compared to before conditioning. This suggests that Ans and Car did not contribute to the improvement of meat taste during storage, although they were reported to have some buffer action.\(^{30}\)

We examined the changes in oligopeptide levels occurring during the storage of beef, pork and chicken. As shown in Table V, oligopeptides increased in all meats during storage. In pork and chicken, there were significant differences in peptide levels of these meats before versus after conditioning. On the other hand, there were no significant differences in peptide levels of beef before versus after conditioning.

![Graph showing changes in anserine (Ans) and carnosine (Car) content of heated soups of beef, pork, and chicken before and after additional storage.](image)

**Figure 3.** Anserine (Ans) and Carnosine (Car) Content of Heated Soup of Beef, Pork and Chicken before and after Additional Storage.

**Table V.** Changes in the Levels of Peptides\(^ a\) during the Storage of Beef, Pork and Chicken

<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>Pork</th>
<th>Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peptides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4(^ b)</td>
<td>2.08</td>
<td>2.40</td>
<td>1.95</td>
</tr>
<tr>
<td>12</td>
<td>2.51</td>
<td>3.05</td>
<td>2.33</td>
</tr>
<tr>
<td>Increment</td>
<td>0.43</td>
<td>0.65</td>
<td>0.38</td>
</tr>
</tbody>
</table>

\( a\) mg BSA eq./g meat.

\( b\) Time postmortem (days).
Improvement of Meat Taste during Storage

Table VI. Changes in the Levels of Lactic Acid during the Storage of Beef, Pork and Chicken

<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>Pork</th>
<th>Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactic acid</td>
<td>4.71</td>
<td>5.82</td>
<td>5.32</td>
</tr>
<tr>
<td>Increment</td>
<td>4.10</td>
<td>5.19</td>
<td>4.55</td>
</tr>
<tr>
<td></td>
<td>-0.61</td>
<td>-0.63</td>
<td>-0.77</td>
</tr>
</tbody>
</table>

*a mg/g meat.

*b Time postmortem (days).

Fig. 5. Lactic Acid Content of Heated Soup of Beef, Pork and Chicken before and after Additional Storage.

Lactic acid was analyzed by HPLC. ( ), before additional storage; ( ), after additional storage. I—I, standard error; numbers in parentheses, time postmortem (days).

hand, there were no significant differences in peptide levels in beef before versus after conditioning. Thus far, there has been only one report on this. Suzuki et al.31) observed that the peptide level after the storage of rabbit skeletal muscle reached three times that before the storage.

Figure 4 shows the levels of oligopeptides in the heated soup of meat before and after conditioning. In beef, peptide levels were lower in the soup prepared from meat after conditioning than that before conditioning, but in pork and chicken peptide levels were higher in the soup prepared from meat after conditioning than that before conditioning. Because these results corresponded to results of our sensory evaluation studies described above, it appeared that oligopeptides at least partially contributed to the improvement in meat taste during storage. Yamasaki et al.32,33) have isolated an octapeptide with a delicious taste from beef treated with papain. Although we did not examine the structure of the peptides in meats, it would be of particular interest to clarify their structure and their contribution to meat taste. The peptide levels in all samples increased by heating. This appears to be caused by the action of endopeptidases on proteins at the start of heating.

4) Lactic acid. As shown in Table VI, lactic acid decreased slightly in all meats during the storage. The lactic acid level after the conditioning was highest in pork (5.19 mg/g meat) and lowest in beef (4.10 mg/g meat). Bodwell et al.25) observed that the lactic acid level in beef reached the maximum value, 7.4 mg/g meat, at 2 days after slaughter and did not change later. Gunther and Schweiger24) also reported that the lactic acid level in beef or pork was constant at 2 or 1 day(s) after slaughter, respectively. These results were not in accord with the results in our study. This discrepancy seems to be caused by the difference of storage time. Then Terasaki et al.5) observed that the lactic acid level in chicken reached the maximum value, 6.75 mg/g muscle, within 1 day after slaughter and was reduced gradually to 5.47 mg/g muscle at 3 days after slaughter.
This result was in good accord with our results.

Figure 5 shows that the levels of lactic acid were larger in heated soup of all meats after conditioning than before. Because these results did not correspond to results of our sensory evaluation studies described above, it appeared that lactic acid did not contribute to the improvement in meat taste during storage.

REFERENCES