Influence of Sodium Substitution with Potassium on Microbial and Organoleptic Spoilage Patterns in Sliced Vacuum-Packed Pasteurized Pork Loin

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ABSTRACT

Sliced, cured, cooked and smoked pork loin was produced with sodium chloride or a mixture of sodium and potassium chloride, with each preparation of pork loin having the same water activity (0.967-0.968). The pork loins were sliced, vacuum packaged and stored at 2, 5 and 10°C. Microbial spoilage was determined using selective and nonselective media to enumerate total aerobic bacteria, lactics, Brochothrix thermosphacta, gram-negative bacteria and yeasts. Spoilage was also determined using sensory evaluation. Generally, the influence of sodium substitution on microorganisms was minimal. Organoleptic scores were similar for the two preparations of pork loin, hence no adverse effect of sodium substitution was observed.

In the last decade there has been increasing interest in reducing the level of sodium chloride in meat products. Studies have been done on the technological problems of substituting part of the sodium with other cations (75). However, there have been only a few reports concerning the microbiological aspects of sodium replacement. For example, in a study of sodium replacement with other cations in a meat emulsion, only lactobacilli grew but they developed irrespective of which chloride salt was used (76). The fermentative activity of Lactobacillus plantarum, i.e., the ability to decrease pH in a meat emulsion, was inhibited by KCl compared to NaCl (70). Studies of experimental raw sausages produced with NaCl, KCl, MgCl₂ or CaCl₂, with replacement being based on equal ionic strength, revealed no effect on aerobic plate counts (77). When nitrite was added, however, bacterial numbers were higher with KCl and MgCl₂ than with NaCl and CaCl₂.

An earlier study revealed sodium replacement with KCl had a minimal effect on microbial spoilage patterns, but greater inhibition was observed with divalent cations (9). However, inhibition of microbial growth was less in meat emulsions than in broth cultures. The effect of KCl on Brochothrix thermosphacta, Serratia liquefaciens and L. plantarum in meat emulsions was negligible.

There have not been any reports concerning the effect of sodium replacement in processed meat products produced under commercial conditions. The purpose of this investigation was to study the effect of a partial replacement of sodium chloride with potassium chloride on the spoilage microflora of meat. Potassium chloride was selected because it has the smallest effect of cations other than sodium on the sensory properties of meat products (6).

MATERIALS AND METHODS

Two batches of cured, cooked and smoked pork loin were produced at a meat factory. The pork loins were multi-stitch pumped with a pickle. The NaCl brine was composed of water (35 kg), nitrite-salt (mixture of sodium chloride and ca. 0.5% sodium nitrite) (5 kg), sodium chloride (2.5 kg), sodium tripolyphosphate (0.72 kg) and glucose (0.15 kg). The NaCl/KCl brine had a similar composition, with the exception that the 2.5 kg of sodium chloride was substituted with potassium chloride (4.41 kg). The amount of KCl needed to obtain an equivalent water activity in the two batches (aw 0.968) was calculated with tables of water activities and concentrations (12).

Each batch consisted of four pork loins and was pumped with the brine to approximately a 17% increase in weight. The cured pork loins were held for 2 d at 5°C for equilibration, stuffed in casings, and held for 1 d more before pasteurization and smoking in a steam cabinet to a center temperature of 70°C. After cooling, the casings were removed and the pork loins sliced and vacuum packaged at a commercial manufacturer (eight slices per package). The packaging film had an oxygen permeability of ca. 60ml/m²/24 h/1 atm at 25°C and 75% R.H.

Microbiological analyses

The content of a package (65 g) was aseptically removed and
added to a stomacher bag with 150 ml of salt-peptone water (0.1% Bacto peptone and 0.85% NaCl). The meat and diluent were macerated by a Stomacher for 1 min. The slurry was serially diluted in peptone water and plated onto: plate count agar (PCA, Difco) and all purpose medium with tween (APT, Difco) for aerobic bacteria counts, Rogosa agar (Merck) for lactic acid bacteria counts, streptomycin thallous acetate actidione agar for B. thermosphacta counts, desoxycholate hydrogen sulfide lactose agar (Merck) for gram-negative bacteria counts and APT with 100 ppm oxytetracycline for yeast counts. Microbiological assays were done on triplicate samples.

Chemical analyses

The meat slurry used for microbiological assays was also used for pH measurements. Moisture was determined by drying to constant weight at 104°C (1). Chloride content was determined by the Volhard method (2). Water activity was determined by Novasina equipment (Novasina AG, Switzerland) in a constant temperature chamber at 25 ± 0.2°C. The instrument was calibrated with different salt solutions of known water activity.

Sensory analyses

Sensory analyses were done using a trained panel, consisting of six to eight panelists who were experienced in the sensory analyses of meat products. The sensory evaluations were done in a specially constructed room having individual booths. The slices of pork loin were presented in containers with covers individually coded with random numbers. Evaluation of odor and overall acceptability was done using an eleven-point scale (+5, ideal; 0, neither good nor bad; -5, extremely undesirable). A decrease to a score of -2 on the hedonic scale was used to indicate the time when the pork loin was no longer acceptable.

Statistical analyses

Data from each panel session were analyzed for differences between Na and Na/K samples at each temperature by an analyses of variance (14). Mean values of log10 microbial numbers were also analysed by analyses of variance.

RESULTS AND DISCUSSION

Microbial numbers during storage at 2, 5 and 10°C and organoleptic scores are shown in Tables 1 and 2, respectively. Water activity of the two preparations of pork loins, were similar i.e., aw for the NaCl batch and aw for the mixed salt batch. Moisture contents were 66.9 and 67.1%, respectively. Chloride content in the NaCl batch was 1.8% which was equivalent to 3.0% NaCl. Initial microbial numbers were quite low (approx. 10^2 CFU/g) and the number of B. thermosphacta, gram-negative bacteria, and yeast were all below the level of detection (Table 1).

The growth pattern of aerobic bacteria as determined on PCA and APT was similar for the two treatments (P<0.05) at all temperatures. Growth was rapid in both preparations of pork loin, reaching 10^7 CFU/g or more within 3 wk at 2°C and 2 wk at 5 and 10°C. For packages at 2°C, bacterial counts observed on PCA and APT were quite similar, at 5 and 10°C the counts were higher on APT than on PCA during the later part of storage. Rogosa agar was used as selective medium for enumeration of lactic acid bacteria. These bacteria developed relatively slowly at 2°C. After 4 wk of storage, numbers remained below 10^7 CFU/g. At the higher temperatures, these numbers were reached within 2 wk.

*B. thermosphacta* developed at all temperatures, but numbers were below 10^7 CFU/g. On four occasions, numbers were higher in the NaCl batch than in

| TABLE 1. Microbial numbers during storage of sliced and vacuum-packed cured, cooked pork loin produced with NaCl or mixture of NaCl and KCl. |
|---|---|---|---|---|
| Medium | Days | 2°C | 5°C | 10°C |
| PCA | 0 | 1.6 1.9 | 1.6 1.9 | 1.6 1.9 |
| 3 | 1.7 1.9 | 3.3 3.1 |
| 7 | 4.6 4.9 | 6.8 6.7 |
| 14 | 7.3 8.1 | 8.3 8.4 |
| 21 | 7.6 7.6 | 8.3 8.4 |
| 28 | 7.6 8.0 | 8.3 - |
| ROG | 0 | 0.7 0.8 | 0.8 0.7 | 0.7 0.8 |
| 3 | 1.1 1.2 | 3.1 3.2 |
| 7 | 4.1 4.1 | 5.6 6.1 |
| 14 | 7.2 8.0 | 8.4 8.4 |
| 21 | 6.2 7.6 | 8.0 7.6 |
| 28 | 8.6 8.2 | - |
| STAA | 0 | <0.6 <0.6 | <0.6 <0.6 | <0.6 <0.6 |
| 3 | 2.3 1.5 | 3.1 2.4 |
| 7 | 3.8e 3.8f | 5.7 5.7 |
| 14 | 6.3 6.3 | 5.9 5.9 |
| 21 | 6.2 6.2 | 6.7 6.3 |
| 28 | 5.3 5.3 | - |
| DHL | 0 | <0.6 <0.6 | <0.6 <0.6 | <0.6 <0.6 |
| 3 | 0.6 0.7 | 1.2 1.5 |
| 7 | 4.5 4.9 | 4.5 4.9 |
| 14 | 4.7 5.2 | 6.7e 8.7f |
| 21 | 4.3 4.9 | 8.3 8.3 |
| 28 | 4.3 4.9 | 5.1 - |
| APT | 0 | 2.1 2.2 | 2.2 2.2 | 2.1 2.2 |
| 3 | 2.0 1.7 | 3.1 2.4 |
| 7 | 4.3 4.0 | 6.6 6.8 |
| 14 | 8.5 8.1 | 9.0 9.5 |
| 21 | 7.8 8.0 | 8.4 8.6 |
| 28 | 8.7 8.2 | - |
| APTO | 0 | <0.6 <0.6 | <0.6 <0.6 | <0.6 <0.6 |
| 3 | - - | - - |
| 7 | - - | 3.4 4.0 |
| 14 | <1.6 - | - 3.2 |
| 21 | <1.6 <1.6 | 3.9 3.9 |
| 28 | <1.6 <1.6 | 3.4 - |

3PCA, plate count agar; ROG, Rogosa agar; STAA, streptomycin thallous acetate actidione agar; DHL, desoxycholate hydrogen sulfide lactose agar; APTO, APT with oxytetracycline.
4N, NaCl.
5N/K, mixture of NaCl and KCl.
6., not done.
7Mean values within a temperature with a different superscript are significantly different (P<0.05).
the mixed salt batch. Numbers of gram-negative bacteria were generally similar for the two pork preparations at all three temperatures. Although the initial numbers were low (4 CFU/g), numbers increased with increasing storage temperatures. At 10°C, numbers reached by day 14 were greater than 10^6 CFU/g. No growth of yeasts was observed at 2°C; at 5 and 10°C, maximum numbers were 10^3 to 10^4 CFU/g. Numbers were not influenced by the type of salt. The pH in the sliced pork loin was stable at 2°C, with a range of pH 6.0 to 6.2. At 5°C, the pH decreased to 5.9 to 6.0 after 3 to 4 wk of storage and at 10°C, pH 5.9 and 5.8 to 5.9 was reached after 2 and 3 wk, respectively.

The mean organoleptic scores (Table 2) indicate that the partial replacement of sodium chloride with potassium chloride had no adverse effect on organoleptic properties. Also, during storage at all temperatures the decreasing scores were similar for both preparations of pork loin. The samples held at 10°C were rejected after 4 wk of storage; the samples held at 2°C, however, were still acceptable after 32 d. The development of microorganisms in the vacuum-packaged, sliced pasteurized pork loin in this study, similar to observations made in other studies (3,7), as was observed in this experiment in which relatively low maximum numbers were reached (Table 1).

Rogosa agar, used for enumerating lactic acid bacteria, did not recover the total lactic flora as measured on APT by flooding plates with H_2O_2 solution. However, similar problems are seen with other media (4,8). Counts on APT revealed that lactic acid bacteria were the dominating flora at all temperatures. The development of gram-negative bacteria has been observed in other studies (9,11), especially at 10°C where the high numbers may have influenced the rapid decrease in organoleptic scores.

This study revealed that potassium chloride at the concentration used had no substantial influence on the microbial spoilage pattern of vacuum-packaged, pasteurized pork loin, whether at ideal refrigeration temperature or at 10°C. The slight microbial inhibition of KCl, which was seen in some model systems (9,17) was not observed in this study. This study indicates using a moderate amount of potassium chloride to substitute for sodium chloride in processed pork has no effect on microbial spoilage of the product.

ACKNOWLEDGMENT

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REFERENCES


TABLE 2. Mean values of organoleptic scores during storage of sliced, vacuum-packed, cured and cooked pork loin produced with NaCl or mixed NaCl and KCl.

<table>
<thead>
<tr>
<th>Days</th>
<th>2°C</th>
<th>5°C</th>
<th>10°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.6</td>
<td>2.0</td>
<td>0.4</td>
</tr>
<tr>
<td>13</td>
<td>0.4</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>21</td>
<td>0.4</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>27</td>
<td>-0.9</td>
<td>0.0</td>
<td>-0.5</td>
</tr>
<tr>
<td>32</td>
<td>-0.4</td>
<td>-0.2</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

*Odor and overall acceptability.

b,c Mean values within a temperature with a different superscript are significantly different (P<0.05).

Donnelly and Briggs, con't. from p. 998