Effect of Pre-Cure Freezing and Thawing on the Microflora, Fat Characteristics and Palatability of Dry-Cured Ham

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ABSTRACT

Hams were placed in cure after thawing by 3 methods: at 2°C, at 16°C, and in water at 37°C. A fourth group was placed in cure while still frozen. Microbiological populations and fat rancidity tests were determined at various intervals during processing. Sensory scores and tenderness values were determined after 3 months of aging. Cl. perfringens, Bacillus cereus, Escherichia coli, coliforms and enterococci were not detected after salt equalization. Hams cured without thawing had lower initial bacterial, yeast and mold counts but no differences among thaw groups were observed in counts during aging. Hams thawed in water had lower flavor and overall satisfaction scores than the other groups. Fat breakdown as noted by FFA, TBA and peroxide values increased with aging but were erratic among thaw groups were observed in counts during aging. Hams thawed in water had lower flavor and overall satisfaction scores than the other groups. Fat breakdown as noted by FFA, TBA and peroxide values increased with aging but were erratic

Fresh hams which are abundant at peak slaughter times may be placed in frozen storage and removed when fresh supplies decrease. Processors may thus avoid extremes in surpluses, shortages and prices. Producers of dry-cured hams have traditionally preferred fresh hams. Only a few researchers (4,9,12) have demonstrated that previously frozen hams can be used successfully to produce country hams. Several methods of thawing may be used including different thawing temperatures and thawing in water.

This project was designed to study the effects of four methods of thawing on the microbiology, fat characteristics and palatability of aged dry-cured hams.

MATERIALS AND METHODS

Experimental design

Forty hams were selected one day postmortem from a federally inspected packing house and transported to the University's Meat Laboratory and held at 2°C for 1 day. Surface swab samples were obtained from 8 randomly selected hams and used to determine the microbial quality of the hams before freezing and frozen storage. After fat and muscle samples were obtained for chemical analysis, the 8 hams were discarded. The remaining 32 hams were numbered, placed on wire trays and held at -30°C for 48 h. The hams were then held unwrapped in covered fiberglass vats at -20°C for 2 months. Eight hams were randomly allotted to each of the following groups: cooler thawed (CT), hams thawed at cooler temperature (2°C) for approximately 72 h; room thawed (RT), hams thawed at room temperature (16°C) for approximately 24 h; water thawed (WT), hams thawed by running water (37°C) through the storage vat for approximately 12 h; and not thawed (NT), hams not thawed prior to curing. Hams were considered thawed when the internal temperature was 0 to 2°C. Hams were cured upon thawing, except for the not thawed group which was cured while still frozen. The hams were individually weighed before freezing, after 2 months frozen storage, after thawing for groups CT, RT and WT, and after 3 months aging.

Curing procedure

The hams were processed using the procedure described by Langlois et al. (13), except that all hams were smoked.

Microbiological methods

The procedures described by Langlois et al. (13) were used for enumeration of microorganisms on the surface of the hams, except that KF Streptococcal agar was used for enterococci counts. Surface swab samples were obtained from 8 control hams before freezing and frozen storage and from all 32 hams before curing, after curing, after salt equalization and after 1, 2, and 3 months of aging. Microbial counts were determined by the same procedures as those described by Langlois et al. (13), except that salmonellae were not enumerated.

Subjective and organoleptic evaluations

The procedures used were the same described by Langlois et al. (13).

Chemical analysis

Subcutaneous fat and muscle samples were obtained from the 8 control hams before freezing and from each of the 32 hams before curing and after 3 months of aging. Muscle samples were taken from the center of the control hams before curing and from each of the 32 experimental hams after 3 months of aging. Fat was analyzed for free fatty acids content and peroxide numbers by procedures described by A.O.A.C. (1). The method of Tarladgis et al. (15) was used to determine TBA values.

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RESULTS AND DISCUSSION

The fresh hams were sampled before freezing and frozen storage to determine if the pre-treatment microbial load was normal and to establish a microbial base for future comparisons. Counts were 1- to 1.5-logs lower than counts reported in a previous study (11) but comparable to values obtained for hams stored 3 days at 2°C (7). The microbial load of the hams used in this study was considered to be normal.

Clostridium perfringens was not detected in fresh hams nor in dry-cured hams after 3 months of aging. These results were not unexpected, since a loss in viability of C. perfringens occurs when foods are frozen or held under prolonged refrigeration (5). Freezing of a food may result in a 99% reduction of vegetative cells of C. perfringens, while refrigeration may result in a 90% reduction (2). Kemp et al. (9) did not detect C. perfringens in any hams after storage at -18°C for 3 months or in aged dry-cured hams produced from these hams. In other studies, low numbers of this organism were detected on fresh hams but not on aged, dry-cured hams (10,11). Results of this and other studies in our laboratory (9-11,13) indicate that low numbers of C. perfringens may be present on fresh hams, but not on hams stored frozen before curing or on dry-cured hams after aging. C. perfringens should not present a health hazard on properly aged, dry-cured hams.

Fresh hams had a mean log count of Bacillus cereus of 2.84/12 cm². Pre-cure mean log counts were 5.48, 2.12, 1.81 and 1.01/12 cm² for WT, CT, RT and NT hams, respectively. The mean count for the WT group was significantly higher (P<0.05) than the mean counts of the other three groups. None of the other differences was significant. B. cereus was not detected in any ham after salt equalization. Kemp et al. (10) did not detect this organism before curing in hams stored for 3 months at -18°C, whereas Langlois et al. (13) found this organism in fresh hams, but not in aged, dry-cured hams.

Before freezing, the hams had a mean log enterococci count of 3.33/12 cm². Pre-cure mean log counts were highest (P<0.05) for the WT group (4.78/12 cm²) and lowest (P<0.05) for the NT group (1.98/12 cm²). The difference between the CT group (2.66/12 cm²) and RT group (2.48/12 cm²) was not significant. Enterococci were not detected in any hams after salt equalization which is in agreement with results of other studies (7,9-13).

Fresh hams had mean log coliforms and Escherichia coli counts of 1.98 and 0.72/12 cm², respectively. Before curing, coliforms were detected on thawed hams but not on unthawed hams. Pre-cure mean log coliform counts were higher (P<0.05) for the WT group (4.34/12 cm²) than for the CT (0.39/12 cm²) or RT (0.20/12 cm²) groups. Coliforms were not detected after curing or after salt equalization. Low numbers were detected in the WT (0.92/12 cm²) and NT (0.26/12 cm²) groups after 1 month of aging; however, no coliforms were detected after 2 and 3 months of aging. Based on gas production in EC broth at 44.5°C, the majority of coliforms were considered to be E. coli. In general, these results are similar to others reported by our laboratory where coliforms and E. coli were not detected in aged, dry-cured hams following salt equalization.

Fluorescent pseudomonads were detected in fresh hams before freezing (log₁₀ 1.94/12 cm²). After freezing and frozen storage fluorescent pseudomonads were found only sporadically, and in no case was the same ham found to yield these organisms in more than one sampling period. Fluorescent pseudomonads were detected in cooler thawed hams before curing and after 3 months of aging and in the non-thawed hams after 1 and 3 months of aging. At any one sample period no more than two hams contained fluorescent pseudomonads.

Except for the results discussed above, mean logarithms obtained for counts made on surface swab-samples are shown in Table 1.

Similar trends were observed for aerobic counts at 25 and 37°C. Pre-cure aerobic counts of the WT group were higher (P<0.05) than those of the other three groups, while the NT group had the lowest (P<0.05) aerobic counts. None of the differences between the pre-cure aerobic counts of the CT and RT groups was significant. Aerobic counts of the WT group were up to 4 logs higher than the aerobic counts of the NT group, and 1 to 3 logs higher than aerobic counts of the other two thaw groups.

The post-cure aerobic counts of the WT group were less than the corresponding pre-cure aerobic counts, while the aerobic counts of the other three groups were higher than the pre-cure aerobic counts. Aerobic counts of all four groups tended to increase through 2 months of aging and then decreased after 3 months of aging. None of the differences in aerobic counts among thaw groups was significant during the aging period. Unlike the results obtained in a previous study (9), hams cured frozen did not have the highest aerobic counts after aging. The RT group had the highest aerobic counts after aging, with the second highest aerobic counts being obtained for the WT and NT groups.

Based on testing of two colonies of each colony type from Baird-Parker agar, approximately 1.5% of the staphylococci from the fresh hams were considered to be coagulase-positive. Pre-cure staphylococci counts were highest (P<0.05) for the WT group. None of the differences between the other three groups was significant. Unlike the aerobic counts, the "after cure" staphylococci counts were all higher than corresponding pre-cure counts. Staphylococci counts of all groups, except NT, decreased after salt equalization. Staphylococci counts after salt equalization were higher (P<0.05) for the WT group than for the other three
groups. No significant differences were noted among staphylococci counts of the NT group and the CT and RT groups. Staphylococci counts tended to remain the same during the aging period with none of the differences among groups being significant. Less than 0.5% of the isolates obtained during the manufacture and aging of the dry-cured hams were coagulase-positive. Coagulase-positive staphylococci were detected in the CT group before and after cure and after 2 months of aging and in the WT group through salt equalization and after 2 months of aging. These organisms were not detected in the NT group after 2 months of aging. Coagulase-positive staphylococci were not detected in the RT group. These results were similar to those obtained in other studies (3,9,12,13).

Pre-cure yeast and mold counts were highest (P<0.05) for the WT group and lowest (P<0.05) for the NT group. Differences between the CT and RT groups were not significant. Counts decreased after cure and then tended to increase through 2 months of aging and decrease after 3 months of aging. None of the differences among groups was significant.

The results of this study are in agreement with other studies (3,9,12). Dry-cured hams may be produced from previously frozen hams with no problems developing from excessive microbial growth and with no danger from the development of pathogens during thawing before curing.

**Sensory evaluation, shear values and weight loss**

Freezing and method of thawing had no effect on the visual appearance of the cut surface of the hams. All were rated red with moderately aged aroma and excellent for general appearance. Some small but significant (P<0.05) differences were noted for flavor, tenderness and overall satisfaction scores (Table 2). The WT hams

**TABLE 1. Microbiological results of surface swab samples obtained during the manufacture of dry-cured aged hams from previously frozen hams.**

<table>
<thead>
<tr>
<th>Microbial counts</th>
<th>Sample time b</th>
<th>Treatment c</th>
<th>CT</th>
<th>RT</th>
<th>WT</th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic - 37 C</td>
<td></td>
<td></td>
<td>3.54 Y</td>
<td>3.45 Y</td>
<td>6.76 Z</td>
<td>2.89 X</td>
</tr>
<tr>
<td>PC</td>
<td></td>
<td></td>
<td>3.46</td>
<td>3.63</td>
<td>3.87</td>
<td>3.36</td>
</tr>
<tr>
<td>AC</td>
<td></td>
<td></td>
<td>4.97 Y</td>
<td>2.94 X</td>
<td>5.53 Y</td>
<td>4.60 Y</td>
</tr>
<tr>
<td>ASE</td>
<td></td>
<td></td>
<td>5.09</td>
<td>4.08</td>
<td>4.18</td>
<td>4.14</td>
</tr>
<tr>
<td>1 mo</td>
<td></td>
<td></td>
<td>6.88</td>
<td>4.91</td>
<td>3.85</td>
<td>3.91</td>
</tr>
<tr>
<td>2 mo</td>
<td></td>
<td></td>
<td>2.53</td>
<td>3.15</td>
<td>2.91</td>
<td>2.91</td>
</tr>
<tr>
<td>3 mo</td>
<td></td>
<td></td>
<td>4.14</td>
<td>5.12</td>
<td>5.12</td>
<td>5.12</td>
</tr>
<tr>
<td>Aerobic - 25 C</td>
<td></td>
<td></td>
<td>4.00 X</td>
<td>3.61 Y</td>
<td>6.74 Z</td>
<td>3.06 X</td>
</tr>
<tr>
<td>PC</td>
<td></td>
<td></td>
<td>4.05 Y</td>
<td>4.27 X</td>
<td>5.91 Y</td>
<td>4.84 X Y</td>
</tr>
<tr>
<td>AC</td>
<td></td>
<td></td>
<td>4.55 Y</td>
<td>4.72 X</td>
<td>5.12</td>
<td>5.12</td>
</tr>
<tr>
<td>ASE</td>
<td></td>
<td></td>
<td>5.02</td>
<td>5.10</td>
<td>4.19</td>
<td>4.69</td>
</tr>
<tr>
<td>1 mo</td>
<td></td>
<td></td>
<td>5.50</td>
<td>5.28</td>
<td>5.21</td>
<td>5.66</td>
</tr>
<tr>
<td>2 mo</td>
<td></td>
<td></td>
<td>4.54</td>
<td>5.18</td>
<td>4.49</td>
<td>5.12</td>
</tr>
<tr>
<td>3 mo</td>
<td></td>
<td></td>
<td>3.09</td>
<td>3.34</td>
<td>3.34</td>
<td>3.34</td>
</tr>
<tr>
<td>Staphylococci</td>
<td></td>
<td></td>
<td>2.69 Y</td>
<td>2.56 Y</td>
<td>4.38 Z</td>
<td>2.19 X</td>
</tr>
<tr>
<td>PC</td>
<td></td>
<td></td>
<td>5.25 X Y</td>
<td>4.17 X Y</td>
<td>6.04 Z</td>
<td>2.88 X</td>
</tr>
<tr>
<td>AC</td>
<td></td>
<td></td>
<td>2.88 X</td>
<td>3.11 X</td>
<td>4.02 Y</td>
<td>3.25 X</td>
</tr>
<tr>
<td>ASE</td>
<td></td>
<td></td>
<td>3.12</td>
<td>2.85</td>
<td>2.93</td>
<td>3.32</td>
</tr>
<tr>
<td>1 mo</td>
<td></td>
<td></td>
<td>3.27</td>
<td>2.81</td>
<td>3.25</td>
<td>3.34</td>
</tr>
<tr>
<td>2 mo</td>
<td></td>
<td></td>
<td>3.17</td>
<td>3.34</td>
<td>3.38</td>
<td>3.58</td>
</tr>
<tr>
<td>3 mo</td>
<td></td>
<td></td>
<td>2.49</td>
<td>3.09</td>
<td>3.09</td>
<td>3.09</td>
</tr>
<tr>
<td>Yeasts and molds</td>
<td></td>
<td></td>
<td>2.47 Y</td>
<td>2.40 Y</td>
<td>3.67 Z</td>
<td>1.77 X</td>
</tr>
<tr>
<td>PC</td>
<td></td>
<td></td>
<td>1.81</td>
<td>1.35</td>
<td>1.47</td>
<td>1.38</td>
</tr>
<tr>
<td>AC</td>
<td></td>
<td></td>
<td>3.43</td>
<td>3.27</td>
<td>4.11</td>
<td>3.68</td>
</tr>
<tr>
<td>ASE</td>
<td></td>
<td></td>
<td>4.82</td>
<td>5.04</td>
<td>4.30</td>
<td>5.06</td>
</tr>
<tr>
<td>1 mo</td>
<td></td>
<td></td>
<td>5.24</td>
<td>4.94</td>
<td>5.37</td>
<td>4.78</td>
</tr>
<tr>
<td>2 mo</td>
<td></td>
<td></td>
<td>3.23</td>
<td>3.11</td>
<td>2.97</td>
<td>3.18</td>
</tr>
<tr>
<td>3 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

aHams were stored at -20 C for 2 months before curing.
bF = Fresh, before freezing; PC = Pre-cure, after frozen storage; AC = After cure; ASE = After salt equalization; 1 mo = 1 month of aging; 2 mo = 2 months of aging; 3 mo = 3 months of aging.
cCT = Cooler thawed (2 C); RT = Room thawed (16 C); WT = Water thawed (37 C); NT = Not thawed.
dMeans of 8 samples.
x,y,zMeans within rows with different superscripts differ (P<0.05).
had lower flavor and overall satisfaction scores while the RT and WT hams had similar tenderness scores which were lower (P<0.05) than scores for the CT and NT hams. The same trends were noted for W.B. shear values although the differences were not significant. Shear values were approximately 1 kg higher for the RT and WT groups than for the CT and NT groups. The differences probably were related to weight loss as the RT and WT groups had mean weight loss percentages (based on pre-cure weights) of 24.0 and 24.2%, respectively, while the CT and NT groups had weight losses of 23.0 and 22.7%, respectively. Thus, it seems that slower thawing is advantageous both from yield and tenderness standpoints.

Fat characteristics

Mean free fatty acid (FFA) values, thiobarbituric acid (TBA) values, and peroxide numbers are shown in Table 3. FFA values before freezing were low and increased somewhat before curing. FFA values were lowest before curing for the NT hams followed by the RT hams, with the differences being significant (P<0.05) between the NT group and the CT group or the WT group. FFA values increased during processing and aging. A significant difference (P<0.05) occurred between the minimum mean of 14.66 for the WT group and the maximum mean of 18.22 for the RT group. Since FFA values generally are a measure of hydrolytic rancidity, the lower values for the WT group probably were the result of the presence of extra surface moisture which might have retarded FFA development.

TBA values of fresh uncured hams were low but values for all groups increased during freezer storage and thawing, with no differences among groups (Table 3). After aging the WT hams tended to have higher TBA values. The TBA values of the fat extracted from lean after aging, except for the NT group, followed the same pattern as values for the subcutaneous fat. The lean from the NT group would have been at a temperature suitable for rapid salt absorption for a shorter time than the other groups and should have a lower salt content. Thus, the fat extracted from that lean should have a lower TBA value since less salt was available to enhance oxidation.

Peroxide values also were low (Table 3) in fresh hams and were approximately equal to values reported by Kemp et al. (8). Values increased during freezing and thawing with no difference due to the method of thawing. There was a trend, however, for fat from hams subjected to high thawing temperatures to have higher peroxide values before curing showing that temperature is a pro-oxidant. This temperature effect continued through aging only for the CT group. As with TBA values, the lower values for the NT group may have been related to salt content as well as thawing temperature. No significant differences were noted among the other groups even though the means varied. All peroxide values were higher than previously reported for aged hams produced from hams that had not been frozen (8,14).

Satisfactory dry-cured, aged hams were produced regardless of method of thawing. However, hams thawed

### TABLE 2. Mean values of palatability panel results and shear values.

<table>
<thead>
<tr>
<th>Thaw method</th>
<th>Flavor</th>
<th>Salt</th>
<th>Tenderness</th>
<th>Overall Satisfaction</th>
<th>Warner-Bratzler Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooler (2 C) (CT)</td>
<td>7.41</td>
<td>6.39</td>
<td>6.64</td>
<td>7.22</td>
<td>7.58</td>
</tr>
<tr>
<td>Room (16 C) (RT)</td>
<td>7.32</td>
<td>6.54</td>
<td>5.82</td>
<td>7.01</td>
<td>8.60</td>
</tr>
<tr>
<td>Water (37 C) (WT)</td>
<td>6.79</td>
<td>6.57</td>
<td>5.71</td>
<td>6.44</td>
<td>8.55</td>
</tr>
<tr>
<td>Not thawed (NT)</td>
<td>7.28</td>
<td>6.43</td>
<td>6.54</td>
<td>7.12</td>
<td>7.69</td>
</tr>
</tbody>
</table>

aBased on a nine-point hedonic scale where 1 = least desirable and 9 = most desirable.
bBased on a nine-point rating scale where 1 = devoid of saltiness and 9 = extreme saltiness.
cKilograms force required to shear a 2.54-cm core.

### TABLE 3. Free fatty acid valuesa, TBA valuesb and peroxide numbersc.

<table>
<thead>
<tr>
<th>Thaw method</th>
<th>Before freezing</th>
<th>After aging</th>
<th>Controls</th>
<th>FFA</th>
<th>TBA (fat)</th>
<th>Per. No.c</th>
<th>FFA</th>
<th>TBA (fat)</th>
<th>TBA (lean)</th>
<th>Per. No.c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooler (2 C) (CT)</td>
<td>0.84x</td>
<td>16.06xy</td>
<td>75.80x</td>
<td>0.21x</td>
<td>0.20x</td>
<td>0.23xy</td>
<td>72.90xy</td>
<td>0.29x</td>
<td>0.25xy</td>
<td>62.23xy</td>
</tr>
<tr>
<td>Room (16 C) (RT)</td>
<td>0.67xy</td>
<td>18.22x</td>
<td>72.90xy</td>
<td>0.20x</td>
<td>0.17y</td>
<td>d0.19xy</td>
<td>72.90xy</td>
<td>0.25xy</td>
<td>0.23xy</td>
<td>62.23xy</td>
</tr>
<tr>
<td>Water (37 C) (WT)</td>
<td>0.80x</td>
<td>14.66y</td>
<td>62.23xy</td>
<td>0.21x</td>
<td>0.18x</td>
<td>0.25x</td>
<td>62.23xy</td>
<td>0.25x</td>
<td>0.23xy</td>
<td>62.23xy</td>
</tr>
<tr>
<td>Not thawed (NT)</td>
<td>0.59y</td>
<td>17.65xy</td>
<td>50.85y</td>
<td>0.15x</td>
<td>0.26xz</td>
<td>0.18y</td>
<td>50.85y</td>
<td>0.26xz</td>
<td>0.18y</td>
<td>50.85y</td>
</tr>
</tbody>
</table>

aFree fatty acid (FFA) values are reported as mg KOH/g.
bTBA values are reported as optical density at 530 nm.
cPeroxide numbers are reported as mg peroxide/kg.
dn = 7, all others, n = 8.
x,y,zMeans in columns with different superscripts differ (P<0.05).
during the curing process had lower initial bacterial and yeast and mold counts, had similar sensory evaluation scores and shear values, and had lower peroxide values than hams from the other thaw groups. In addition, less handling was required. Thus, it appears that it is not necessary to thaw hams before the initial application of curing salts in order to produce dry-cured, aged hams.

REFERENCES

Kruk and Lee, con't. from p. 243

ACKNOWLEDGMENTS
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REFERENCES