Cured Pigment and Color Development in Fermented Sausage Containing Glucono-Delta-Lactone

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ABSTRACT

Addition of 0.41% glucono-delta-lactone (GDL) to meat mixtures for fermented sausages produced an immediate acidulation response, lowering the initial pH from 6.0 to 5.4. After fermentation, control sausages had a pH of 5.1 which decreased to 5.0 at 16 days of drying. Sausages containing GDL had a pH of 4.8 at the end of the fermentation phase and the pH remained constant through heat processing and drying. Additional acidity from GDL usage promoted greater color development when lactic acid was produced from added carbohydrate. The pH generally found in initial sausage fermentation development increases (7). The primary conditions in meat mixtures favorable to development of a cured color are high hydrogen ion concentration (6, 7) and input of heat during the last stage of processing (7, 13). Favorable acidic conditions for the reaction of nitric oxide with myoglobin are developed during the fermentation phase of dry sausage preparation when lactic acid is produced from added carbohydrate. The pH generally found in initial sausage preparations is near 6.0 and decreases to 5.4 to 4.8 during fermentation (3, 10). In fermentation, usually conducted at 30 to 37 C, there is a slow but substantial heat input. With heat processing, as temperature increases in the range from 49 to 60 C, rate of color development increases (7).

Glucono-delta-lactone (GDL) was introduced during the 1960s to give a more rapid and improved color development to cooked comminuted products such as frankfurters, bologna, and luncheon meats (6). Although introduced for production involving rapid processing operations of several hours, GDL has been successfully used in the manufacture of dry sausages (9, 16) where final products are not obtained for 10 to 120 days. On hydrolysis and with the application of heat, GDL yields gluconic acid, effectively reducing the pH of the sausage to "accelerate" color development (10). Fox et al. (7) and Monagle et al. (13) found that maximum color development occurred faster when GDL was included in frankfurter preparations. However, both research groups (7, 13) reported no color differences between final product samples with or without GDL when these were processed to the same final internal temperature (68 to 70 C).

In fresh (uncured) meats, Landrock and Wallace (11) stated that dehydration increases the concentration of meat pigments at the meat surface. Dehydration of fermented, dry sausages results in a loss of the nitric oxide heme pigment (7). Townsend (19) reported significantly less conversion of the total heme pigments to the nitric oxide heme pigment form in sausages containing 25 to 30% moisture when compared to those containing 45 to 60% moisture.

This study was conducted to determine the effect of GDL on development of fermented sausage color and to examine color stability on dehydration. Sausage preparations were analyzed at several processing phases for percent of total pigments converted to the cured pigment form. Color was determined by color difference measurements.

MATERIALS AND METHODS

Sausage preparation and processing

Two sausage mixes were prepared using a blend of fresh boneless beef and beef fat adjusted to approximately 24% fat. Additional ingredients and their quantities per kg of meat were as follows: 0.078 g of NaNO3, 0.156 g of NaNO2, 0.47 g of sodium erythorbate, 30.0 g of NaCl, 10.61 g of seasoning mix, 5.05 ml of Lactic acid in water (LACTACE), 7.51 g of dextrose, and 25.0 ml of water. The starter culture yielded an approximate initial level of 1.7 x 10^7 cells/g mix. The effect of GDL was determined with batches containing 4.45 g of GDL per kg of meat.

The curing agents, seasonings, and dextrose were mixed into the meat for 3 min in a Hobart H-600 mixer. The water and starter culture were then added and the mixture blended for an additional 4.45 g of GDL per kg of meat.

The curing agents, seasonings, and dextrose were mixed into the meat for 3 min in a Hobart H-600 mixer. The water and starter culture were then added and the mixture blended for an additional 2 min. When used, GDL was added after the water but before adding the starter culture. The initial mix temperature was approximately 2 C and increased to 8 C during the 5 min of blending.

Sausages were stuffed into 52-mm diameter dry sausage fibrous casings (Union Carbide) to approximately 460 g. The chubs were

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fermented at 38 C and 95% relative humidity for 21 h. After fermentation, all sausages were initially heated at 71 C for 45 min, increased to 77 C for 45 min, and finally heated at 82 C until an internal temperature of 60 C was attained (0.0 to 2.5 h total). The sausage chubs were cooled to 24 C by a cold water spray and placed in a 7.5 x 2 C drying room having temperature of 60 C. Drying room humidity ranged from 80 to 85%. Sausages were removed for color analyses at 8 and 16 days of drying.

Sampling and compositional analyses
Two sausage chubs of the control and GDL groups were collected for compositional and color analyses at each of the following process phases: (a) on completion of mixing and stuffing, (b) after fermentation for 21 h (c) after heat processing to 60 C internal, (d) after 8 days of drying, and (e) after 16 days of drying.

All samples were analyzed in duplicate or triplicate for moisture, fat, ash, and protein (Kjeldahl N x 6.25) following AOAC (4) procedures. The sausage pH and percent weight loss on drying were determined as described by Acton and Keller (3). Two sausage chubs were composited for duplicate heme pigment analyses and color measurements.

Data were analyzed by analysis of variance and the differences between means tested by the least significant difference method (14).

Heme pigment analyses
The methods for nitric oxide heme pigments and total pigment were those described by Hornsey (8) with the extraction procedure modifications outlined by Acton and Dick (4). The results, reported as percent conversion, are the percent of total heme pigment converted to the nitric oxide heme pigment (wet sample basis).

Color determinations
Color measurements were conducted with a Gardner Color Difference Meter, Model C4 (Gardner Laboratory, Bethesda, Maryland). The instrument was standardized with a pink standard plate (No. CG-6632; L = 52.9, aL = 31.9, bL = 11.4). Results were obtained in terms of L*, a*, and b* values.

RESULTS AND DISCUSSION
The pH differences attained during the course of sausage processing are shown in Fig. 1. Within 15 min of GDL addition, the initial mix pH had decreased (P < 0.05) from pH 6.0 to pH 5.4. The initial drop in pH was maintained through the drying phase and was not affected by the starter culture. This is in agreement with the findings of Skjelkvale et al. (17). The control sausages had an ultimate pH of 5.0 in the drying phase as compared to a pH of 4.8 for the sausages containing GDL. Fermented sausages range in pH from 5.4 to 4.4, with most sausage types having a pH near 5.0 (2).

The composition (Table 1) and weight losses (Table 2) of both sausage groups at each stage of processing were similar. In curing hams, Pate et al. (15) reported

<table>
<thead>
<tr>
<th>Process stage</th>
<th>Sample</th>
<th>Moisture (%)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial mix</td>
<td>control with GDL</td>
<td>55.8ab</td>
<td>23.5b</td>
<td>14.8b</td>
<td>3.7cde</td>
</tr>
<tr>
<td>Fermented mix</td>
<td>control with GDL</td>
<td>56.9a</td>
<td>22.0a</td>
<td>15.8bc</td>
<td>3.2bc</td>
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<tr>
<td>Heat processed</td>
<td>control with GDL</td>
<td>56.3a</td>
<td>22.3ab</td>
<td>16.7d</td>
<td>3.1a</td>
</tr>
<tr>
<td>Dried, 8 days with GDL</td>
<td>45.7c</td>
<td>28.3c</td>
<td>19.4e</td>
<td>3.9f</td>
<td></td>
</tr>
<tr>
<td>Dried, 16 days with GDL</td>
<td>34.6d</td>
<td>35.1d</td>
<td>23.4e</td>
<td>5.0f</td>
<td></td>
</tr>
</tbody>
</table>

*Means in columns having the same superscript letter are not different (P < 0.05).

TABLE 1. Compositiona of sausage at various phases of processing

<table>
<thead>
<tr>
<th>Sausage sample</th>
<th>Days of drying</th>
<th>2</th>
<th>6</th>
<th>8</th>
<th>12</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.50</td>
<td>14.95</td>
<td>19.30</td>
<td>26.67</td>
<td>32.24</td>
<td></td>
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<tr>
<td>With GDL</td>
<td>5.84</td>
<td>14.61</td>
<td>19.35</td>
<td>27.25</td>
<td>33.09</td>
<td></td>
</tr>
</tbody>
</table>

*Column means are not different (P < 0.05). Each horizontal mean is different (P < 0.05).

Table 2. Percent weight loss of sausage during drying

that moisture content significantly decreases as levels of GDL in the pumping medium increased. A similar decrease in moisture content of dry sausage containing 0.6% GDL was reported by Kotter et al. (9). In our study, GDL at a level of 0.41% did not affect the moisture content or weight loss of the sausages. Based on compositional data and percent weight losses, both sausage groups would be classified as “semidry” at 8 days and “fully dry” at 16 days of drying (2).

The percent of the total heme pigment converted to the nitric oxide heme pigment form is shown in Fig. 2. The control sausage showed a substantial increase (P < 0.05) from an initial 13.5% conversion to 60.1% conversion at the end of fermentation. A further increase (P < 0.05) to 81.5% was found after heat processing. Cured pigment production was favored by two occurrences: (a) the decrease in pH during fermentation, and (b) the heat input during fermentation at 38 C and heat processing to 60 C internal. Fox and Thompson (6) reported that the overall reaction rate in the production of the nitric oxide pigment increases sharply with decreasing pH, particularly in the pH range of 5.5 to 4.5. The percent conversion during heat processing of frankfurters progressively increased as product temperature increased from 49 to 60 C (7). Thus temperature and hydrogen ion concentration appear interrelated under the experimental conditions used in this study.

At each phase of processing, increased (P < 0.05)
cured pigment production occurred in sausages containing GDL compared to control sausages (Figure 2). Higher levels of nitric oxide pigment were maintained after heat processing. The additional acidity contributed by GDL addition in early preparation (initial mixing) may have caused a more rapid formation of the nitric oxide heme pigment, which is in agreement with the report of Sair and Henry (16).

A loss of cured pigment on sausage dehydration was reported by Acton and Dick (1). The loss may involve dissociation of nitric oxide from the nitric oxide heme pigment (5,18). Townsend (19) found that lower conversion percentages occur in sausage products containing 25 to 30% moisture than in those containing 45 to 60% moisture. While GDL contributed to pigment formation, it did not (Fig. 2) contribute to “stability” of the cured pigment (once formed) as suggested by Sair and Henry (16). The loss of converted pigment in the sausages containing GDL occurred at approximately the same rate as for the control sausages.

Gardner color values, Saturation Index, and hue angles of the sausages are given in Table 3. In the processing sequence, the sample 'L' values decreased slightly, showing a darkening of the sausages. The ‘aL’ values increased, denoting positive movement toward redness while the ‘bL’ values decreased, indicating a decrease in yellowness. Through heat processing the ‘aL’ and Saturation Index values for sausages containing GDL increased more rapidly as compared to the respective values of the control sausages. Hue angles also indicated a more rapid “redness” development in GDL sausages than in the control sausages. These results are in agreement with the increased levels of nitric oxide heme pigment production, due to GDL use, as previously discussed.

At 16 days of drying, the Saturation Index for both sausage groups indicate approximately equivalent color intensity. However, the lower hue angles for the GDL sausages showed a greater redness development which may be related to the pH difference between the sausage groups. As a result of moisture loss on dehydration, there is a concentrating of the remaining undissociated cured pigment (5) and a visual “browning” of the sausage color. The development of a brownish-red color on sausage dehydration has also been described by Lu and Townsend (12) which may be due to oxidation of the remaining free pigment (20).

**ACKNOWLEDGMENT**

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Reference to a firm or trade name does not imply endorsement over firms or products not mentioned.

**REFERENCES**


**TABLE 3.** Gardner color values, Saturation Index and hue angles for sausage at various phases of processing.

<table>
<thead>
<tr>
<th>Process stage</th>
<th>Gardner L value</th>
<th>Gardner a&lt;sub&gt;L&lt;/sub&gt; value</th>
<th>Gardner b&lt;sub&gt;L&lt;/sub&gt; value</th>
<th>Saturation Index</th>
<th>Hue angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control With GDL</td>
<td>Control With GDL</td>
<td>Control With GDL</td>
<td>Control With GDL</td>
<td>Control With GDL</td>
</tr>
<tr>
<td>Initial mix</td>
<td>45.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fermented mix</td>
<td>42.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Heat processed</td>
<td>44.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.6&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dried</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8 days</td>
<td>42.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.1&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>16 days</td>
<td>40.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>40.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.7&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Means in columns having the same superscript letter are not different (P < 0.05).
<sup>b</sup>Using mean Gardner a<sub>L</sub> and b<sub>L</sub> values, Saturation Index = (a<sup>2</sup> + b<sup>2</sup>)<sup>1/2</sup>.
<sup>c</sup>Using mean Gardner a<sub>L</sub> and b<sub>L</sub> values, hue angle is the angle whose tan<sup>-1</sup> = b/a.