Experiments in Food Science

Activity #6

Effect of Curing on Meat Color

A Science Unit for Secondary School Curriculum

Institute of Food Technologists
The Society for Food Science and Technology
TEACHER ACTIVITY GUIDE

Effect of Curing on Meat Color

Curing is a process in which the addition of a nitrite salt causes flavor and color changes in fresh meat. The nitrite also acts as a preservative and inhibits the growth of pathogenic microorganisms. The nitrite in this process is always used in conjunction with at least some other additive, such as salt, sugar, spices, or smoke.

While some questions remain concerning the exact nature of the flavor changes, the color development of meat during curing is well documented. The principal pigment in muscle is myoglobin. Its function is similar to the blood pigment hemoglobin in that both serve to form a complex with oxygen required for metabolic activity. Myoglobin consists of a single polypeptide chain of about 150 amino acid units (hemoglobin has four polypeptide chains) and a heme group. The heme group contains an iron atom, whose various oxidation states and ability to form a complex with other compounds results in different colors. Muscle color ranges from light to dark, depending on the concentration of myoglobin in the muscle. The meat colors of concern are all interrelated (see diagram on next page).

It is important to distinguish between oxidation-reduction reactions and oxygenation reactions. Oxidation reactions involve a transfer of electrons such as between nitrosomyoglobin and metmyoglobin. Oxygenation reactions involve the addition of molecular oxygen and no electron transfer, such as between myoglobin and oxymyoglobin.

In any cured meat product, there exists a potential for nitrosamine formation. Nitrosamines can form by the reaction between secondary or tertiary amines and certain oxides of nitrogen. Nitrosamines have been shown to be potent carcinogens in animals but have been detected in cured meats only sporadically and at extremely low concentrations. The nitrite in cured meats performs a very important function, preventing the growth of Clostridium botulinum, the organism which produces the deadly toxin associated with botulism.

PROCESSING CONSIDERATIONS

The commercial processing of cured meats has changed little over the years. Nonfermented meats are soaked in a brine containing the curing ingredients (salt, nitrite, sugar, and spices), or the dry ingredients are rubbed on the surface and the meat is held under refrigeration until the salt penetrates to the center. In more-modern processes, the brine is injected, using large needles, to facilitate uniform distribution of the curing agents.

The nitrite ion is the ultimate source of nitric oxide which combines with myoglobin to give the cured meat color. Nitrate ion used to be added as well but is no longer used. It has now become routine to add reducing agents such as ascorbates to speed the curing, inhibit formation of nitrosamines, and improve color stability.

In fermented meats, such as salami and pepperoni, microorganisms are added to the meat mixture. These "lactic starter cultures" produce acid to give sausage that familiar mild sour taste, as well as contribute to flavor.
MATERIALS REQUIRED

Raw hamburger
150-mL beakers
Sodium nitrite (NaNO₂)
Plastic bag
Hot-water or steam bath

TEACHING TIPS

1. Curing salts cause color and flavor changes. This experiment documents the color changes but not flavor changes because the sodium nitrite used may not be of food quality and the microbial quality of meat after being handled by the students is
suspect at best. It is important that this meat be disposed of properly and not consumed. One further word of caution: sodium nitrite is toxic in sufficiently high concentrations and is potentially dangerous.

2. The surface of the meat the students will be starting with should be in the bright oxymyoglobin form. The interior, where oxygen does not penetrate, will be the purple-red myoglobin color. The addition of nitrite to one batch will form the dark-red nitrosomyoglobin after 24 hours of refrigerated storage. Heating the nitrosomyoglobin will form the more-stable nitrosohemochrome (light pink). A gray-brown denatured myoglobin in the control sample will result from heating. This is the characteristic color of uncurled cooked meat.

5. Place the beakers in a refrigerator overnight.

6. The next day, remove the beakers from the refrigerator and again examine the surface and interior colors.

7. Cook the meat by heating the beakers over a steam bath or in a boiling water bath for 15–20 minutes, then again examine the surface and interior colors.

8. Record your observations in the table provided.

QUESTIONS & ANSWERS

1. What effect does the addition of sodium nitrite to fresh meat have on the color before and after cooking?
   Ans. It becomes a dark-red color before cooking and turns to a light-pink, cured-meat color after cooking.

2. The legal maximum level of nitrite (NO₂) in a finished product is 156 ppm. How much sodium nitrite can you legally add to 1 kg of meat? (This question may be too advanced for junior high students.)
   Ans. At the legal maximum of 156 ppm, the maximum permissible weight of nitrite in 1,000 g of meat is:

   \[
   NO₂ = \frac{156}{1,000,000} \times 1,000 \text{ g}
   \]

   \[
   = \frac{156}{1,000} \text{ g}
   \]

   \[
   = 156 \text{ mg}
   \]
And the amount of nitrite in sodium nitrite is found as a proportion of the molecular weights (Na = 23, N = 14, O = 16):

\[
\begin{align*}
NO_2 & \quad 14 + 32 \quad 46 \\
NaNO_2 & \quad 23 + 14 + 32 \quad 69
\end{align*}
\]

Thus, the maximum permissible amount of sodium nitrite is:

\[
\begin{align*}
156 \text{ mg} & \quad 46 \\
NaNO_2 & \quad 69
\end{align*}
\]

\[
NaNO_2 = 156 \text{ mg} \times \frac{69}{46} = 234 \text{ mg}
\]

In the experiment, 200 mg of sodium nitrite, or a little less than the legal maximum, was used.

3. Which of the samples after cooking most closely resembles ham or sausage?

Ans. Obviously, the sample with nitrite added most closely resembled ham because this is essentially the treatment ham gets.

4. Which of the cooked samples do you prefer as ham?

Ans. The student will undoubtedly choose the nitrite-containing sample. Having an attractive color, however, does not alone justify the use of nitrites in meat. Nitrites also alter flavor. Without them, a cured ham would be a salty pork roast. They also act as powerful antioxidants, effectively inhibiting growth of clostridia, the bacteria that cause botulism. The formation of nitrosamines remains a potential problem. This is an excellent opportunity to discuss the risk/benefit concept of food additives.

5. Would you purchase meats processed without nitrites? Why?

Ans. Yes, because they are not only attractive and tasty but also safe.

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DATA TABLE (Typical Results)

<table>
<thead>
<tr>
<th>Time</th>
<th>Control (no nitrite)</th>
<th>Experimental (with nitrite)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
<td>Interior</td>
</tr>
<tr>
<td>Before storage</td>
<td>Purple-red</td>
<td>Purple-red</td>
</tr>
<tr>
<td>After storage</td>
<td>Purple-red, perhaps brown</td>
<td>Purple-red</td>
</tr>
<tr>
<td>After cooking</td>
<td>Gray-brown</td>
<td>Gray-brown</td>
</tr>
</tbody>
</table>