Restructured Beef Steaks Manufactured Using Carbon Dioxide, Oxygen and Carbon Monoxide Gas

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(Received for publication April 9, 1984)

ABSTRACT

Restructured beef steaks were manufactured from boneless, tenderized USDA Utility inside cow rounds (semimembranosus) and USDA Choice beef plates which were treated with oxygen, carbon dioxide or a combination of carbon monoxide and nitrogen gas during the mixing stage of the manufacturing process. Treatments were preformulated to 15% fat and mixed for 15 min during which time the various gas atmospheres were incorporated into the mixer. All treatments received 2% water and 0.75% sodium chloride during the mixing cycle. Proximate analysis, objective and subjective color, mechanical shear and binding strength were examined. Gaseous treatments had no effect (P>0.05) on moisture, fat or protein percentages. Carbon monoxide (10.01% carbon monoxide mixed with nitrogen) treatment increased Hunter “a” and “b” and reflectance (685 nm) values. Oxygen treatment had no effect (P>0.05) on Hunter “L”, “a” or “b” values or reflectance (685 nm) values. Carbon dioxide decreased (P<0.05) both Hunter “b” and reflectance (685 nm) values. Subjective scores indicated more discoloration (P<0.05) for the carbon dioxide treatment than the carbon monoxide or oxygen treatments, but none of the treatment groups was different from the control. Shear (Kramer) and binding (Instron) values were unaffected (P>0.05) by the treatments.

Restructured meat systems present an opportunity to change the physical state of meat to a uniform appearance. In most processes this is accomplished through agitation of the meat block to extract salt soluble proteins. During this agitation, chemical as well as physical changes may occur. It is important that color not be adversely affected during processing of restructured products because meat color is one of the most important criteria consumers use for selection of meat. Color depends on a large degree on the state and amount of pigment oxidation. Various packaging materials have been used to protect pigments from oxidation; however, oxygen is needed for meat to retain its bright red color. Since aerobic microorganisms use oxygen for respiration, oxygen in the package is converted to carbon dioxide (5). An atmosphere of 100% oxygen allows meat to be fully oxygenated so that meat retains its bright color (7), but extended storage of meat in oxygen-rich atmospheres may cause oxidation and discoloration (10). The prevention of oxidation of pigments during the manufacturing process of meat products before packaging is extremely important. The most widely used atmospheres to protect pigments have been carbon dioxide, oxygen, nitrogen and mixtures of these gases.

Carbon dioxide atmospheres lower the pH (7,8), which may inhibit spoilage or organisms (7,11). Carbon dioxide, however, if used as 100% of the atmosphere, increases browning (2,5,11). Carbon monoxide gas storage atmospheres have shown positive results in improvement of color stability in meat (3), but its use in meat products has not been approved by the USDA because of carboxyhemoglobin formation. Even though carbon monoxide has been banned, it still has potential as an important ingredient to use for research purposes when evaluating atmospheres that affect color.

The objective of this study was to determine if oxygen, carbon dioxide and a mixture of carbon monoxide and nitrogen had an effect on color characteristics of restructured beef when added during the mixing step in the manufacturing process.

MATERIALS AND METHODS

Meat raw materials

A restructured beef product was manufactured using USDA Utility inside cow rounds (semimembranosus) and USDA Choice plates. Fresh rounds were chilled to 2°C, and tenderized by passing them twice through a reciprocating blade tenderizer (Bettcher model TR-2). Approximately one-half of the chilled (2°C) rounds were ground through a kidney-shaped plate attached to a grinder (Toledo model 552). The remainder of the chilled (2°C) rounds were flaked using a 2-K-060510 head attached to a model 3600 Urshel Comitrol. Choice plates were chilled to 0°C and passed through the same Comitrol head as was used for the rounds. The product was preformulated to contain 50% cow rounds that had been previously ground through the kidney-shaped
plate. A fat percentage of 15% was then formulated using the flaked plates and rounds.

Meat ingredients (11.4 kg) along with 0.75% NaCl and 2% water were added to a paddle mixer (Butcher Boy model 150, capacity 34 kg) which had been modified with a plexiglass cover so the desired atmospheres could be incorporated into the meat during a 15-min mixing period. The temperature of the meat at the beginning of the mixing cycle was ca. 2°C and increased to ca. 5°C during mixing.

Gases

Gases (USP oxygen, 99.5% pure carbon dioxide or 10.01% carbon monoxide mixed with nitrogen) were added during the mixing cycle at a rate of 1 m³/h. Atmospheric “air” was used as the control.

Steak manufacture

Restructured steaks were manufactured by the techniques outlined by Huffman (6). Steaks were initially placed in polyethylene freezer bags, then placed in waxed-lined cardboard cartons and stored at -18°C for subsequent physical, sensory and chemical analyses.

Color evaluation

Color of nine raw steaks per treatment was evaluated subjectively for discoloration. A panel of six judges were trained to specify percent brown or green discoloration on a 1 to 8 scale where 1 = 100% discoloration and 8 = 0% discoloration. Judges observed steak color under uniform soft white incandescent lighting.

Color of nine raw steaks per treatment was analyzed by the Hunter Color difference meter (Hunterlab model D25D2M) and by reflectance spectrophotometry as outlined by Ockerman and Cahill (9). Readings were taken on frozen steaks at six locations on each steak and averaged to give a value for the steak.

Method of cookery

Steaks were thawed for 24 h at 2°C, weighed, tagged and thermocouples inserted in the geometric center of each steak. Each steak was oven broiled at 165°C to an internal temperature of 70°C in a Blodgett convection oven (model GCL10).

Physical evaluations

Tenderness of six steaks per treatment was determined by evaluating 3.5×3.5-cm sections obtained from the center of each steak with the Allo-Kramer shear press (model SP12). Six steaks per treatment were analyzed for binding ability by use of an Instron Universal testing machine (model 1122). Six 1×5-cm strips were obtained from each steak and placed in the pneumatic jaws of the Instron and pulled apart using a crosshead speed of 100 mm/min.

Proximate analysis

Moisture, fat and protein analyses were performed according to AOAC procedures (1).

Statistical analysis

Data from all determinations were analyzed according to appropriate analysis of variance procedures and Duncan’s multiple range test (12). The experiment was replicated three times.

RESULTS AND DISCUSSION

Proximate analysis results (Table 1) indicated that there were no differences (P>0.05) for moisture, fat or protein percentages among treatments.

Hunter color values of “L”, “a” and “b” were used to determine if lightness, redness and yellowness of uncooked steaks were altered due to treatment effects. Gaseous atmospheres during mixing had no effect (P>0.05) on Hunter “L” (lightness) values when compared to control. However, steaks from the carbon monoxide (10.01% carbon monoxide mixed with nitrogen) treatment had higher Hunter “a” (redness) values. Holland (5) and Gee and Brown (4) reported that carbon monoxide gas inhibits pigment browning by combining with the reduced myoglobin to form a red pigment, carboxymyoglobin. The carboxymyoglobin pigment is more stable than oxymyoglobin and, therefore, may inhibit development of metmyoglobin or other oxidized forms of myoglobin. Hunter “b” (yellowness) values showed that carbon monoxide increased yellowness, carbon dioxide decreased yellowness and oxygen had no effect on yellowness in raw steaks (Table 2).

Ockerman and Cahill (9) proposed equations which indicated that reflectance values at 685 nm could be used to evaluate overall color of the product. Oxygen had no effect (P>0.05) on reflectance readings at 685 nm, whereas carbon dioxide had lower (P<0.05) readings and carbon monoxide higher (P<0.05) readings than the control. A possible explanation for the higher readings for steaks treated with carbon monoxide is that there were less oxidized pigments present in this group and therefore more light scattering would be evident at 685 nm, hence a higher reflectance reading. Steaks from the carbon dioxide treatment were judged to have more (P<0.05) discoloration than carbon monoxide- or oxygen-treated steaks, but none of the treatment groups was different.

<table>
<thead>
<tr>
<th>TABLE 1. Proximate analysis of restructured steaks.</th>
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<td>Factor</td>
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<td>Moisture (%)</td>
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<td>Fat (%)</td>
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<tr>
<td>Protein (%)</td>
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*No differences between means (P>0.05).

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<th>TABLE 2. Evaluation of sensory and physical properties of restructured steaks.</th>
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<td>Treatment</td>
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<td>Control</td>
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<tr>
<td>Carbon dioxide</td>
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<tr>
<td>Carbon monoxide</td>
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<td>Oxygen</td>
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*Means in the same column with the same superscript letter are not different (P>0.05).

b1 = 100% discoloration, 8 = 0% discoloration.
(P>0.05) from the control (Table 2). Use of oxygen did not improve color, and furthermore, carbon dioxide may have detrimental effects on color when used during the processing of restructured beef.

Gaseous treatments during manufacturing had no effect (P>0.05) on tenderness, when measured by the Allo Kramer shear test or for binding ability by the Instron (Table 2).

ACKNOWLEDGMENT

Alabama Agricultural Experiment Station Publication No. 4-84603.

REFERENCES