Aroma Profile of Subprimals From Beef Carcasses Decontaminated With Chlorine and Lactic Acid

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ABSTRACT

Aroma notes of chuck rolls from decontaminated beef carcasses were evaluated. Carcasses were spray-treated with either water, 200 ppm chlorine or 3% lactic acid immediately after inspection and again after spray chilling. Following fabrication, each chuck roll was divided into four pieces; vacuum-packaged; and stored for 10, 40, 80 or 120 days at 4°C. At different storage times, a six-member, professional, sensory panel evaluated beefy, bloody, sour, grassy, spoiled and metallic aromatic impressions on cooked patties made from ground chuck roll pieces using a 15-point attribute scale. Psychrotrophic bacterial counts were conducted on raw, ground samples. Principal component statistical analysis showed that the first principal component described 96% of the data and, therefore, it was used as an average acceptability score that explained all aroma descriptors. Chucks from chlorine-treated carcasses tended to have higher (P = 0.08) acceptability scores, followed by lactic acid – and water-treated counterparts. The rate of change in aroma occurred faster between 10 and 40 days for lactic acid – and water-treated samples and between 40 and 80 days for chlorine-treated samples. Bacterial counts increased during storage up to 80 days; however, treatments were not different (P >0.05).

Key Words: Beef, aroma-profile, carcass-decontamination, lactic acid, chlorine

Beef is one of the most important export commodities of the United States meat industry. About 340,000 metric tons of beef and veal, mainly carcasses and primal cuts, representing $1,580.3 million total export value, are shipped yearly to countries such as Japan, South Korea, Canada and Mexico. Maximum commercial storage life of U.S. vacuum-packaged primal cuts of beef ranges from 45 to 60 days at 0°C compared to 120 days of storage life for Australian export beef (18). This advantage is due to strict good manufacturing practices including initial low total bacterial counts, low gas-permeability of packaging films and good control of temperature. Therefore, to be more competitive, the U.S. meat industry needs to extend the shelf-life of export meat and minimize organisms associated with foodborne diseases (7,15,16,28).

Shelf-life of refrigerated, fresh, red meat can be maximized by controlling microbial contamination and growth on the carcasses and suppressing further contamination and growth during fabrication of carcasses into primal, subprimal and retail cuts (1). Most of the microflora are psychrotrophic bacteria capable of growing and causing spoilage at refrigerated temperatures, and some are potential pathogens that can cause foodborne illnesses. When the beef carcass is fabricated into retail cuts, contamination is spread to newly exposed surfaces. Shelf-life of these cuts and ground beef in retail meat display varies inversely with initial microbial load of the carcass (14). The current trend toward the establishment of microbiological standards and/or guidelines for meat products has resulted in increased interest in ways to minimize bacterial contamination on beef carcasses and subprimals before they are fabricated and packaged (14).

Surface decontamination practices of either spraying freshly slaughtered beef carcasses (10,12,25) or dipping (4) subprimals (major subcomponents of beef primal cuts), using organic acids such as acetic, lactic and propionic (4,6,9,17) or chlorine (3,21) at different concentrations have been investigated. Subprimal decontamination studies include work by Smulders (27), and Smulders and Woolthuis (29), who reported that vacuum-packaged beef steaks prepared under strict sanitary fabrication procedures had lower aerobic plate counts and often less off-odor than conventionally fabricated steaks. No microbiological differences were found by Dixon et al. (13) between acid-treated beef strip loin steaks and control steaks. Even though extensive research has been performed in these areas, few investigations have addressed the use of chlorine and organic acid decontamination after carcass washing and after spray chilling. Furthermore, even less information is available on the...
effect of such treatments and vacuum storage on the flavor and aroma characteristics of the meat. Therefore, the objective of this project was to characterize and compare aroma of inside chuck subprimals (vacuum-stored for 10, 40, 80 or 120 days) from untreated, lactic acid- (3.0%) or chlorine-treated (200 ppm) carcasses just after washing and again after spray chilling.

**MATERIALS AND METHODS**

Chuck rolls (n = 9), cut as specified by the National Association of Meat Purveyors Guide (23), were removed at 96 h postmortem from U.S. Department of Agriculture (USDA) Choice, yield grade I-4, beef carcasses that were manually spray-treated with either water, 200 ppm chlorine or 3% lactic acid using a 7.5 L, hand-held sprayer immediately after washing and rail inspection and again after spray chilling at the Kansas State University abattoir. Each side was sprayed for 2 min with the appropriate 20°C sanitizing solution at a distance of 50 cm from the carcass. Based on preliminary tests with these sprayers, this time would allow 1.34 L of solution to be dispensed per side. Sides were intermittently spray chilled with cold water (2°C) for 30 s, every 15 min for a total of 8 h, after which water, chlorine or lactic acid spray-treated carcasses were similarly treated again. These carcasses were held at 3°C until fabrication at 72 h postmortem. One chuck was taken from each of three different carcass sides and experimentally replicated three times. Each chuck roll was divided into four pieces; vacuum-stored for 10, 40, 80 or 120 days at 4°C. Oxygen and water vapor transmission rates of vacuum bags used in this study were 4 cc/100 sq in./24 hr at 22°C and 45% relative humidity (RH) and 0.6 g/100 sq in./24 hr at 37.7°C and 90% RH, respectively. Chuck rolls were then blast frozen and stored at -40°C for 14 days until subsequent evaluations.

**Sample preparation**

Chuck roll samples were removed from the freezer and thawed at 4°C for 18 h. Samples were cut and ground twice through a 0.32 cm plate Oster meat grinder. The ground meat was made into 113 g patties. Patties were cooked according to American Meat Science Association (AMSA) Cookery Guidelines (2) on a preheated electric Farberware grill (No. 450, “Open Hearth” broiler) to 70°C internal temperature. To obtain uniform heat distribution, patties were turned every 30 s. Patties were removed from the grill when they reached 1 to 1.5°C below the desired endpoint temperature, so that internal patty temperature did not exceed the desired temperature because of postcooking temperature rise. The starting and endpoint temperatures were monitored by a hypodermic probe-type thermocouple connected to a Doric temperature recorder (Emerson Electric S.A., Doric Division, Brussels, Belgium). This technique allowed for a more accurate determination of the endpoint temperature than by cooking patties for a set amount of time.

**Cooked sample sensory evaluation**

A six-member, professional, sensory panel from the Kansas State University Sensory Analysis Center evaluated aroma profile of the patties. Professional panelists had completed 120 h of training in flavor and texture analysis; had completed a minimum of 1,000 h of general sensory testing, and had experience on flavor and aroma profile analysis in meat and meat products. All panelists received 2 h of orientation appropriate to this study. Panel training consisted of panel members individually examining a product representative of that under consideration and discussing their opinions in open sessions to establish unanimity of flavor descriptors. After training, the panel leader combined panel input as to potential descriptors of the product. Sample evaluations were made on pie-shaped pieces of cooked patties kept warm in double boilers. Panelists evaluated on a 15-point attribute scale (0 = none to 15 = very intense, no other anchors) the following descriptors: beefy (the aromatic impression of beefiness ranging from mild as in veal to strong as in round steak of mature beef); bloody/serumy (the aromatic associated with redness of rare meat); metallic (the aromatic associated with an oxidized silver or other metal utensil when rubbed inside the mouth); grassy/barnyard (the aromatic impression of earthy, moldy animal feedstuff); sour (the aromatic associated with acidic taste); and spoiled (the aromatic associated with meat in a state of putrefaction). Panelists were also asked to state if they would have served the sample. Sensory sessions were held in individual booths under red lights once a day for three days, until all treatments were evaluated. Twelve samples were presented at each session.

**Microbiological analysis**

Total psychrotrophic counts were determined on ground chuck samples at 10, 40, 80 and 120 days. Duplicate 11 g samples were placed in a filter stomacher bag (Spiral Systems Inc. Bethesda, MD) and mixed with 99 ml of sterile phosphate buffer solution for 1 min using a Stomacher Lab-blender 400 (Model STO-400; Tekmar Co., Cincinnati, OH). Samples were withdrawn from the stomacher bag for viable cell count determination using Plate Count Agar and standard methods (24). The Spiral Plater (Model DU-2; Spiral) was used to dispense the liquid sample on the surface of a rotating agar plate. Samples were incubated aerobically for 10 days at 7°C. A Laser Spiral System Bacterial Colony Counter (Spiral, Model 500A) set at 2.5 spot size, 10 cm plate size and 999 area limit, and three degrees of sensitivity were used to automatically scan the petri dishes and count the number of colonies growing on or in the culture medium. The counts were reported as Colony Forming Units per gram (CFU/g) of sample.

**Statistical analysis**

Aroma was analyzed by principal component analysis in which the first principal component was used to describe acceptability (19). This analysis technique reduces the set of variables to a smaller set of indices (called the principal components) which are linear combinations of the original variables. This reflects another ‘dimension’ of the data so that variation in the data can be accounted for as concisely as possible (25). Analysis of variance (5) was performed to obtain least significant means differences (6) by treatment and day for microbial and sensory data. Least square procedures of Statistical Analysis System (SAS) (30) were used to separate means. In addition, nonlinear fitted decay curves were obtained for each treatment to describe the aroma response over time for chuck subprimals. Treatment comparisons were made in terms of rate of decline. Three replications were run for the experiment.

**RESULTS**

**Sensory attributes**

Shown in Fig. 1 are the mean values of aroma attributes scores for chuck subprimals as affected by length of vacuum-storage and chlorine, lactic acid and water treatments, respectively. At day 10, as expected, the beefy note was most predominant, followed by bloody and metallic notes across treatments. Grassy, sour and spoiled aromatic impressions were present in small amounts for all treatments. As storage time increased to 40 days, a slight reduction of beefy and bloody aroma notes and a substantial increase of sour notes were observed for the lactic acid and water treatments compared to the chlorine treatment.
At day 80, a further reduction of beefy and bloody impressions and a substantial increase of metallic, grassy, sour and spoiled notes was observed across treatments, with sour and spoiled being highest for the water treatment. At day 120, metallic, grassy, sour and spoiled notes were highest across treatments compared to beefy and bloody aromatic impressions. In addition, sour and spoiled notes were lowest for the chlorine treatment.

Principal component analysis showed that the first principal aroma component described 96% of the data and, therefore, it was used as an average acceptability score that explained all aroma descriptors. This finding made significant differences of mean values among aroma attributes of minor importance and was the reason for not showing P-values or superscript letters in Fig. 1.

Correlation coefficients of aroma descriptors as given by the principal component analysis showed that all aroma impressions correlated highly to each other. Beefy ($R^2 = -0.99$) and bloody ($R^2 = -0.97$) notes had negative correlations to other aroma descriptors. Metallic ($R^2 = 0.95$), grassy ($R^2 = 0.99$), sour ($R^2 = 0.99$) and spoiled ($R^2 = 0.99$) notes correlated positively with each other.

**Curve fitting**

The nonlinear equation that best fitted the data was:

$$Y = (a-b) \times [1 - \exp (-c \times day)^d]$$

where "Y" is the measured acceptability response variable, "a", "b", "c" and "d" the parameters of the equation. Table 1 shows the parameter estimates of the fitted nonlinear equation found for each treatment. Parameters "a", "b" and "d" remained constant across treatments, whereas the c parameter, which described the rate of change and shape of the curve, changed for each treatment. Plots of nonlinear models of acceptability mean response (Fig. 2) showed that chuck subprimals from chlorine-treated carcasses tended to have higher (P < 0.08) aroma acceptability scores, followed by lactic acid-treated and untreated counterparts. The acceptability composite score scale is a standardized weighted average of the attributes.

**TABLE 1. Parameter estimates of fitted nonlinear equations.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Parameter estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>C + C</td>
<td>-2.93026, -5.69048, 0.0000006701, 2.706817</td>
</tr>
<tr>
<td>L + L</td>
<td>-2.93026, -5.69048, 0.000012, 2.706817</td>
</tr>
<tr>
<td>W + W</td>
<td>-2.93026, -5.69048, 0.000019, 2.706817</td>
</tr>
</tbody>
</table>

W + W = water  
C + C = chlorine  
L + L = lactic acid  

Based on the panelists’ response of yes to the question, “Would you serve the sample?”, statistical analysis showed that the rate of change in aroma occurred faster between 10 and 40 days for lactic acid- and water-treated samples and between 40 and 80 days for the chlorine-treated samples. Lactic acid and water treatments were less effective in controlling off-flavor notes of chuck subprimals than the chlorine treatment.

**Figure 1. Aroma attribute scores of chuck subprimals as affected by length of vacuum-storage for the chlorine (C + C), lactic acid (L + L) and water treatments (W + W). Lmean SE for day 10 and 80 of vacuum-storage = 1.30 for all treatments. Lmean SE for day 40 and 120 of vacuum-storage = 1.05 for all treatments.**
Psychrotrophic counts

Bacterial counts increased with storage time up to 80 days (Fig. 3). After that, a decline phase in the typical bacterial growth curve was clearly observed for each treatment. Lactic acid tended to be more efficient in controlling bacterial growth; however, no treatment differences occurred (P > 0.05) among bacterial populations.

DISCUSSION

Even though the effects of organic acids and chlorine as bacteriostatics are well documented in recent literature (11), little research has addressed their effects on the aroma or flavor profile of meat. Our findings showed that, although chlorine did not consistently produce significant reduction in the bacterial population of subprimal cuts, it was the most effective in reducing off-flavor aromatic notes of chuck subprimals. Three factors may have influenced these results. First, chlorine dissipates faster from the carcass application sites, leaving no residual aroma to subprimals (20). Second, lactic acid as a carcass-sanitizing agent could have promoted protein or lipid breakdown and subsequent formation of non-desirable endproducts through acid hydrolysis of myofibrillar or sarcoplasmic proteins or ester bonds in fats. The latter is less likely to occur, because in fats containing long-chain fatty acids, such as those in meat, hydrolysis has little effect on flavor even when fatty acids are present at relatively high levels (22). In addition, lactic acid would reduce meat pH, thus minimizing lipid hydrolysis. Third, since the predominant aroma noted at 80 and 120 days of sample storage was the sour aromatic impression, it is possible that the chlorine and lactic acid treatments may have altered the composition of the microflora, and that this shift in microflora may account for some of the observed differences. More research is needed for a better understanding of the basic principles causing flavor or aroma changes when beef carcasses and/or subprimals are subjected to sanitizing agents. Colder storage temperatures than those used in this study, and the use of DeMan, Rogosa and Sharpe Agar (MRS), which better meets the nutritional needs of lactic acid bacteria, also should be investigated.

REFERENCES

temperature improves beef shelf-life. J. Food Prot. 44:297-299.