The Spoilage Characteristics of Ground Beef Packaged in High-Oxygen and Low-Oxygen Modified Atmosphere Packages

J. Chance Brooks, Mindy M. Brashears, Mark F. Miller, Amy R. Hoyle, John D. Kellermeier, and John M. Mehaffey

Introduction

Spoilage is a subjective measurement and includes changes in color, texture, odor, taste, and microbial counts. Gill (1986) defined meat spoilage as any single symptom or group of symptoms of overt microbial activity, manifested by changes in meat odor, flavor or appearance . However, many factors including storage temperature, atmospheric oxygen, light, meat constituents, microorganisms, and indigenous enzymes can affect meat quality over an extended period of time (Lambert *et al.*, 1991). Several scientists have concluded that microbial growth is the most important factor in controlling the spoilage of meat (Lambert *et al.*, 1991; Nassos *et al.*, 1983; Jay 1996). Bacterial numbers of 10^7 and 10^8 per cm^2 have been shown to cause noticeable changes in off-odor and slime, respectively (Ayers, 1960). Jay (1964) concluded that microbial populations must reach approximately 10^8/g for raw beef to have a tackiness when touched while others claim that proteolytic changes in raw beef do not occur until bacterial populations greater than $3.2 \times 10^9/cm^2$ (Dainty *et al.*, 1975) are reached indicating there are discrepancies in the amount of bacteria that must be present before meat is considered spoiled. In addition, the length of time it takes to get an accurate number of bacteria present in the meat as well as disagreements about the correlation between bacteria counts and organoleptic properties of meat make it difficult to assess future shelf life of the meat (Nassos *et al.*, 1983).

Lipid oxidation is known to produce off-odors and off-colors typically associated with spoiled meat products, as well. Lipid oxidation is responsible for the conversion of oxymyglobin to metmyoglobin; resulting in a brown meat color. Thiobarbituric acid (TBA) analysis can measure the amount of oxidation that has occurred and can serve as an indicator of oxidized odor or color in meat when those sensory attributes are correlated to a trained sensory panel (Greene and Cumuze, 1981; Turner *et al.*, 1954; Younathan and Watts, 1959). Green and Cumuze (1981) noted panelists first detected a difference in intensity of oxidized flavor when TBA scores of 0.6 to 2.0 were present. This range was similar to the 0.5 to 1.0 TBA scores that were correlated to rancid odor detection by a trained panel in another study (Tarladgis *et al.*, 1960). However, variability in laboratories and procedures often causes variability in TBA scores, making it difficult to establish industry thresholds without supporting sensory panel data.

Among the factors that have the greatest impact on the microbial and oxidation potential of a meat product, meat packaging and the package environment clearly has the greatest effect. Modified atmosphere packaging (MAP) is defined as packaging that encloses a food in an atmosphere with a different composition than that of air. MAP can include packaging methods such as vacuum packaging, gas-flush MAP, and MAP by active packaging. In the past few decades, MAP has become more widely used in the storage and distribution of foods. There are several advantages to using MAP. It can increase shelf life by 50 to 400%, reducing distribution costs due to centralized packaging, fewer deliveries, and longer shipping distances (O Connor-Shaw and Reyes, 2000; Farber, 1991; Sivertsvik *et al.*, 2002). Other advantages include the ability to market a higher quality product because of an extended shelf life without the addition of preservatives for a natural product, improved presentation, and odorless and convenient packages.

It becomes evident after a search of the literature that definitive measures of spoilage have not been identified. To address some of these issues, research was conducted to determine the spoilage characteristics of low-oxygen carbon

J. Chance Brooks
Texas Tech University
Animal and Food Sciences Building
Box 42141
Lubbock, Texas 79409-2141

Email: chance.brooks@ttu.edu

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monoxide gas flush, high-oxygen gas flush, and rosemary extract in modified atmosphere packaging of ground beef patties through affective and analytical sensory analysis, psychotropic Aerobic Plate Counts (APC), lactobacillus, total APC and total coliforms.

Materials and Methods

Ground beef patties were evaluated because of the ability to obtain spoilage characteristics in an accelerated time frame. Five treatments were evaluated:

1. control (foam tray with film over-wrap)
2. high-oxygen (80% O2 / 20% CO2) modified atmosphere package (MAP)
3. high-oxygen MAP with added rosemary extract (Kalsec, Inc.)
4. low-oxygen carbon monoxide (0.4% CO, 30% CO2, 69.6% N2) MAP
5. low-oxygen carbon monoxide MAP with added rosemary extract.

Beef patties were evaluated for changes in color and odor (trained and consumer panelists) over time (0,1, 3, 5, 7, 14 and 21 d) under simulated retail display conditions using coffin-style and multi-deck cases under continuous fluorescent lighting (approximately 1900 lux using high-output bulbs with a color temperature rating of 3500°K).

Both trained and consumer panelists were used to detect differences in color and odor. Panelists were trained by meat science faculty in multiple sessions using representative samples prior to the start of the project. Trained panelists evaluated the color of ground beef patties using a five-point, verbally anchored scale (1 = very bright red; 5 = very dark red or brown) and surface discoloration (1 = no discoloration; 5 = severe discoloration, 61-100%) according to AMSA color guidelines. Consumer panelists were recruited from the surrounding area and asked to determine if the ground beef patties had good color (1 = very strongly agree; 7 = very strongly disagree) and how likely they would be to purchase (1 = definitely would purchase; 5 = definitely would not purchase) the package based on the color (AMSA, 1991).

Odor panels were conducted on packages removed from the cases at each sampling interval. Odor samples were presented to trained and consumer panelists under red lighting. Trained panelists were asked to determine if an off-odor is present (1 = no off-odor; 5 = extreme off-odor) and to characterize the off-odor if present (1 = rancid; 2 = arid; 3 = sweet; 4 = sour; 5 = acid; and 6 = putrid). Consumer panelists were asked if the meat in the package smelled fresh (1 = very strongly agree, 7 = very strongly disagree) and how likely they would be to consume the meat (1 = definitely would consume; 5 = definitely would not consume) based upon the odor.

Microbial loads were determined using standardized methods. Total Aerobic Plate Counts (APC) were determined by plating on total plate count agar, Lactobacilli were determined by plating on LBS agar and total coliforms were determined by plating on VRBA agar. The plates were incubated at 37 °C for 48 h. Total psychrophilic aerobic bacteria were determined by plating onto APC agar and incubating at 7 °C for 7 d.

The project was a split-plot design with meat block serving as the main plot, and blocked by retail display case. Data was analyzed using the GLM procedures of SAS (Cary, NC). Least-square means were computed for each dependent variable, and statistically separated by pair-wise t-test (PDIFF option of SAS) with predetermined $\alpha = 0.05$. MAP samples could not be unpackaged and used for repeated measures, so samples were replicated over time.

Results

Trained panelists scores for lean color and percentage of surface discoloration are presented in Figures 1 and 2, respectively. There was a treatment by day of retail display interaction for trained panel color scores and percent surface discoloration scores. Results indicate the low oxygen carbon monoxide gas flush had a stabilizing effect on meat color after the formation of carboxymyoglobin. The carbon monoxide gas mixture was also effective at preventing the development of surface discoloration during retail display.

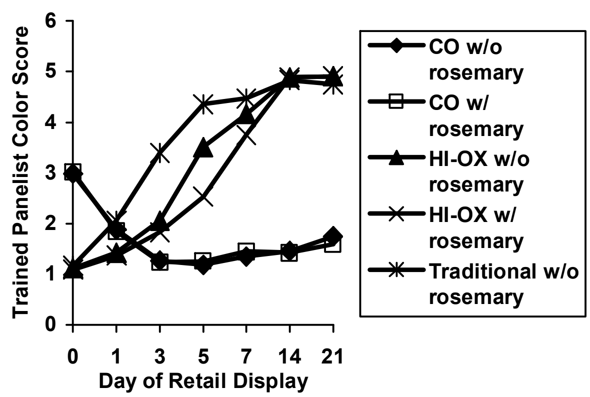

Figure 1 – Trained Panelists Color Scores for Each Packaging Treatment Over Retail Display Time. Color Scores: 1 = very bright red; 5 = very dark red or brown (AMSA color guidelines).

Consumer responses to the statement The meat in this package has good color and purchase intent scores based on the color of the meat in the package are shown in Figures 3 and 4, respectively. There was a significant treatment by day of retail display interaction for both consumer responses to color. Consumer panel scores followed the same pattern as trained panel scores for meat color. Consumers in this study also ranked high-oxygen packages containing meat with rosemary extract to be more desirable at days 5 and 7 of display than high oxygen packages containing meat without rosemary extract. After the development of carboxymyoglobin in packages containing carbon monoxide, consumers indicated they would purchase meat in these packages that had been displayed 21 days at 0-2 °C.

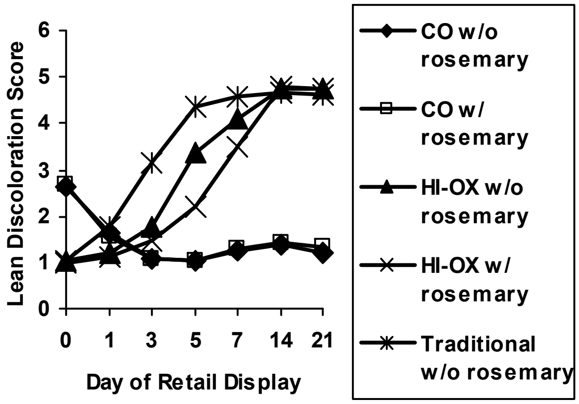

Figure 2 – Trained Panelists Percent Surface Discoloration Scores for Each Packaging Treatment over Retail Display Time. Surface discoloration 1 = no discoloration; 5 = severe discoloration, 61-100% (AMSA color guidelines).

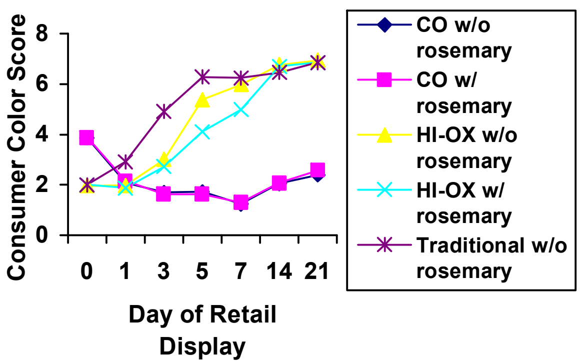

Figure 3 – Consumer Responses to the Statement "The meat in this package has good color". Color Scores: 1 = very strongly agree; 7 = very strongly disagree.

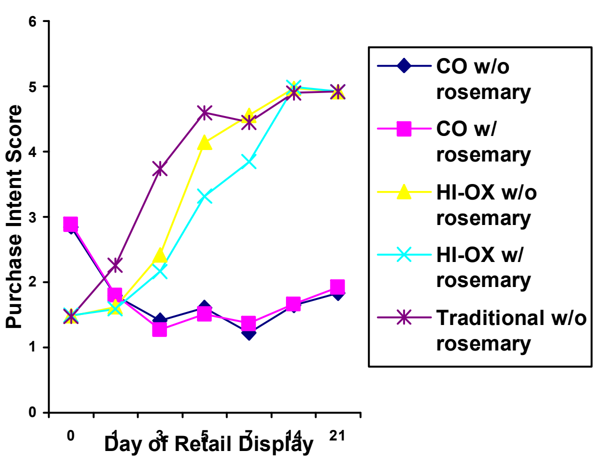

Figure 4 - Consumer Scores for Likeliness to Purchase Based on the Color of the Meat in the Package. Intent scores: 1 = definitely would purchase; 5 = definitely would not purchase the package based on the color of the meat.

Figure 5 depicts the percentage of trained panelists detecting no off-odors among treatments during retail display. These results indicate that off-odors will develop in traditional and modified atmosphere packages over time. Traditional and high-oxygen packages develop off-odors earlier in the display period than packages containing carbon monoxide gas.

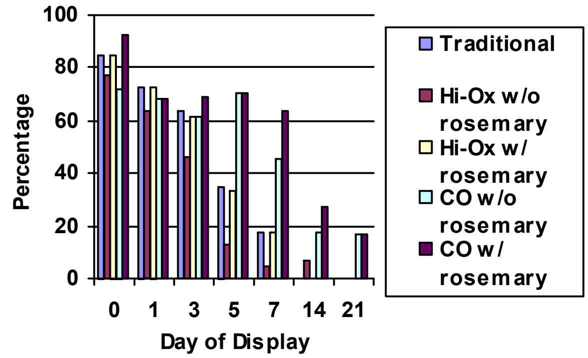

Figure 5 – Percentage of Trained Panelists Detecting No Off-Odor in Packages Over Retail Display.

Consumer responses to the statement The meat is this package smells fresh and their likeliness to consume the product based upon its odor are presented in Figures 6 and 7, respectively. Consumer indicated that beef patties packaged in an atmosphere containing carbon monoxide were more likely to smell fresh at 7, 14, and 21 days of display, but they would probably not consume these product after 14 days of display based upon the odor.

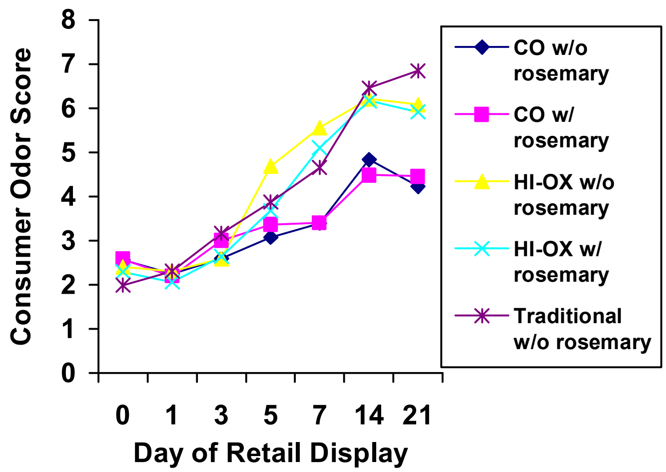

Figure 6 – Consumer Responses to the Statement "The meat is this package smells fresh". Consumer Odor Scores: 1 = very strongly agree, 7 = very strongly disagree.

There was a significant packaging treatment by day of retail display interaction for psychrophilic aerobic bacteria counts (Table 1) and total coliforms (Table 2). These results indicate that modified atmosphere packaging suppresses the growth of psychrophilic aerobic bacteria when compare to traditional packages exposed to air. Packaging treatment main effects for total aerobic plate counts and lactobacillus are present in Table 3. Generally, traditional packages had significantly higher total plate counts and lactobacillus bacteria counts than modified atmosphere packages. Changes in total aerobic plate counts and lactobacillus during retail display are shown in Table 4. These results indicate that total plate counts and lactobacillus bacteria increased as day of retail display increased for all packaging treatments.

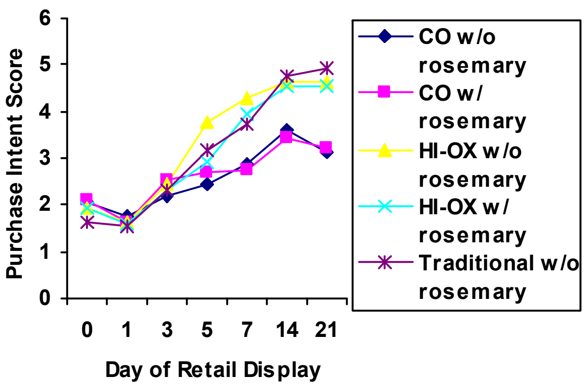

Figure 7 - Consumer Scores for Likeliness to Consume Meat Based On the Odor of the Meat in the Package. Intent scores: 1 = definitely would consume; 5 = definitely would not consume based

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Table 1. Least squares means for psychrophilic aerobic bacteria counts (log cfu/g) for the treatment by day of display interaction (P = 0.0507) means.

Treatment	Retail Display, d						
	0	1	3	5	7	14	21
Traditional over-wrap package	$2.33^{a,x}$	$2.09^{a,x}$	$4.08^{b,y}$	$5.89^{c,y}$	$5.91^{c,y}$	$8.21^{d,z}$	$8.49^{d,y}$
High-oxygen without rosemary	$2.16^{a,x}$	$2.14^{a,x}$	$2.87^{ab,x}$	$3.34^{ab,x}$	$3.88^{b,x}$	$6.31^{c,xy}$	$6.72^{c,x}$
High-oxygen with rosemary	$2.69^{a,x}$	$2.69^{a,x}$	$3.07^{a,x}$	$3.59^{ab,x}$	$4.55^{b,x}$	$6.57^{c,y}$	$6.41^{c,x}$
Low oxygen CO without rosemary	$2.33^{a,x}$	$1.98^{a,x}$	$2.61^{ab,x}$	$2.98^{ab,x}$	$3.70^{b,x}$	$5.25^{c,x}$	$5.92^{c,x}$
Low oxygen CO with rosemary	$2.80^{a,x}$	$2.65^{a,x}$	$3.16^{a,x}$	$3.68^{a,x}$	$3.82^{a,x}$	$5.38^{b,xy}$	$6.13^{b,x}$

[a,b,c]Least squares means within a row lacking a common superscript letter differ ($P < 0.05$).
[x,y,z]Least squares means within a column lacking a common superscript letter differ ($P < 0.05$).

Table 2. Least squares means for total coliform counts (log cfu/g) for the treatment by day of retail display interaction (P = 0.0013) means.

Treatment	Retail Display, d						
	0	1	3	5	7	14	21
Traditional over-wrap package	$1.22^{a,x}$	$1.80^{ab,x}$	$2.65^{b,x}$	$5.60^{c,y}$	$4.83^{c,z}$	$7.35^{d,z}$	$7.62^{d,z}$
High-oxygen without rosemary	$1.18^{a,x}$	$1.83^{a,x}$	$2.81^{ab,x}$	$1.95^{a,x}$	$1.99^{a,xy}$	$5.62^{c,y}$	$3.65^{b,xy}$
High-oxygen with rosemary	$1.59^{a,x}$	$1.91^{ab,x}$	$2.82^{ab,x}$	$2.18^{ab,x}$	$3.28^{b,y}$	$5.79^{c,y}$	$4.51^{c,y}$
Low oxygen CO without rosemary	$1.08^{a,x}$	$1.72^{ab,x}$	$2.98^{bc,x}$	$1.30^{a,x}$	$1.44^{ab,x}$	$3.61^{c,x}$	$2.67^{abc,x}$
Low oxygen CO with rosemary	$2.00^{ab,x}$	$2.17^{ab,x}$	$3.31^{bc,x}$	$1.98^{ab,x}$	$1.86^{a,x}$	$3.66^{c,x}$	$3.83^{c,xy}$

[a,b,c,d]Least squares means within a row lacking a common superscript letter differ ($P < 0.05$).
[x,y,z]Least squares means within a column lacking a common superscript letter differ ($P < 0.05$).

Table 3. Least squares means for treatment effect on Total Aerobic Plate Counts (APC) and Lactobacillus counts (log cfu/g).

	Traditional	High oxygen without rosemary	High oxygen with rosemary	Low oxygen CO without rosemary	Low oxygen CO with rosemary
APC	5.60^{c}	4.72^{ab}	4.97^{b}	4.15^{a}	4.52^{ab}
Lactobacillus	4.14^{b}	3.68^{a}	3.51^{a}	3.33^{a}	3.61^{a}

[a,b]Least squares means within a row lacking a common superscript letter differ ($P < 0.05$).

Table 4. Least squares means for Total Aerobic Plate Counts (APC) and Lactobacillus counts (log cfu/g) over display time (days).

	Retail Display, day						
	0	1	3	5	7	14	21
APC	2.97^{a}	2.92^{a}	4.09^{b}	4.53^{b}	4.69^{b}	6.79^{c}	7.59^{d}
Lactobacillus	1.97^{a}	2.41^{ab}	2.57^{b}	3.34^{c}	4.25^{d}	5.78^{e}	5.30^{e}

[a,b,c,d,e]Least squares means within a row lacking a common superscript letter differ ($P < 0.05$).