Stability of Beef Packaged in Air, Partial Vacuum, and in Oxygen-Carbon Dioxide Mixtures

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Introduction

Among several factors that determine the buyer's selection of prepackaged meat is the color of the meat (Rhodes, et. al., 1955). The consumer favors meat with a fresh appearance, i.e., meat with a reduced, oxygenated myoglobin surface. Therefore it is paramount to provide conditions that will assure the presence of adequate oxygen with a minimum opportunity for oxidation. Traditionally, oxygen is made available by using semi-permeable packaging films. Since oxidation results from the presence of microorganisms, it is customary to process meat in a sanitary manner that will result in minimal microbial contamination and store or display the meat in a temperature environment that will inhibit growth of the contaminating microorganisms that might be present. A practical temperature for this purpose is -2 to 0°C for unfrozen meat (Naumann, et. al., 1965).

Current industrial practice in the United States is to prepare and prepackage meat in the retail stores -- over six and one-half billion packages yearly. A severe labor shortage, the high overhead of this method, and a shelf life of only two to three days, among other factors, have caused many firms to explore the potentialities of centralized meat processing (Sacharow, 1970).

The functional realities of central meat processing systems dictate that a warehouse inventory of prepackaged product must be maintained and that the packages must be transported from the place of preparation to the retail outlet. Both of these functions take time and, ultimately, require a longer package life than the two to three day shelf-life encountered in retail store's prepackaged meat.

The overall objective of this study was to evaluate the effects of gaseous atmospheres upon the appearance, microbial development and eating characteristics of prepackaged beef steaks after various periods of refrigerated storage and illuminated display at -1.1°C.

Materials and Methods

Meat. Twelve pairs of U.S.D.A. Choice beef short loins (lumbar area) were used in this study. Each short loin was chilled to an internal temperature of -1.1°C before cutting into seventeen steaks, 19 mm thick. Cutting was performed on a band-saw in a -1.1°C room. The room and all equipment had previously been cleaned with 60°C water, detergent, a quaternary ammonium sanitizer and rinsed with 60°C water.

All steaks were placed in individual, serially numbered meat trays, wrapped in poly vinyl chloride shrink film and heat sealed. A random order of sampling was used to assign the steaks to experimental treatments.

Gaseous Atmospheres. Three experimental and one control atmosphere were used. The experimental atmospheres were: 1) partial vacuum, 2) a mixture of 15 percent carbon dioxide and 85 percent oxygen and 3) a mixture of 10 percent carbon dioxide and 90 percent oxygen. The partial vacuum atmosphere was designed to simulate the holding of prepackaged beef in a partially evacuated bulk container during storage and distribution. The treatment was accomplished by placing the prepackaged steak in a small, sturdy metal container of appropriate size to prevent the mashing of the steak when at reduced

pressure (18 inches of Hg) within a polyethylene-mylar pouch. Prepackaged steaks in the gas mixture treatments were in similar metal containers and placed in polyethylene-mylar pouches. The pouches were evacuated (18 inches Hg) and, subsequently, inflated with the gas mixture and sealed. Steaks on the control treatment had no additional packaging other than the original poly vinyl chloride film.

Storage and Display. All steaks were stored in a -1.1°C chamber. Storage periods were 3, 5, 7 and 10 days. A control steak from each short loin was designated as 0 day storage. Adjacent steaks were used in pairs. At the end of the storage period one of the steaks was evaluated and the other prepackaged steak of the treatment pairs was removed from the polyethylene-mylar pouch and the metal container. These steaks and the control steak were then displayed in a self service display case for three days. The display case was illuminated for 12 hours each day with fluorscent lighting adjusted to emit 120 foot candles of light at the surface of the steaks. The temperature was adjusted to -1.1°C at surface of the steak except during the twice daily defrost cycle which resulted in a maximum steak surface temperature of 2°C.

Visual Appraisal. One hour prior to visual appraisal the prepackaged steaks were removed from all packaging other than the original cardboard tray and poly vinyl chloride film and allowed to adjust to a normal air environment in a -1.1°C display case. The samples were scored for color desirability, color description and degree of discoloration by a five-member panel at the end of each storage and display period. The samples were illuminated with 200 foot candles of incandescent light during visual appraisal.

Microbiological Evaluation. Immediately after visual appraisal a 25.5 mm core was aseptically removed from the center, upper surface of the L. dorsi for a standard plate count determination. The samples were serially diluted, plated and incubated 72 hours at 21°C. The remaining portion of the steak was vacuum packaged, frozen and stored for taste evaluation.

Taste Panel Evaluation. Steaks were cooked in a 185°C convection oven to an internal temperature of 65.7°C. Samples of each steak were evaluated for flavor desirability and type of off flavor by a four-member trained taste panel.

Statistical Analysis. Statistical analysis of the data was by analysis of variance (Snedecor, 1956). Significance of differance between means was determined by a multiple range test (Duncan, 1955).

Results and Discussion

The growth of the initial mean inoculation of 774 microorganisms per square inch of steak surface was more effectively controlled by the carbon dioxide-oxygen mixture than the other atmosphere treatments (Table I). There was no signficant increase in microbial count on the steaks in the 15 percent carbon dioxide-oxygen treatment for the entire thirteen day storage and display period. The other gas mixture treatment exhibited a significant increase from the initial microbial count only after ten day storage and display. The growth of microorganisms in the partial vacuum treatment is probably due to the presence of residual air in the voids between the rigid, rectangular metal container and the irregular, thinner steak package contained

within the metal container. The rather depleted oxygen supply under these conditions was associated with a slower increase in microbial count than in the control treatment.

Color data in Tables II and III are similar and are compatible with the microbiological data. The gas mixture treatments were significantly more effective in maintaining the initial color desirability than the other treatments. The 15 percent carbon dioxide and 85 percent oxygen mixture was slightly more effective than the 10 percent carbon dioxide and 90 percent oxygen mixture. The appearance of the partial vacuum treatment steaks, however, was inferior to the appearance of the control steaks even though the control steaks had lower microbial counts. This result is probably due to increased oxidation of the pigment at the reduced partial pressure of oxygen caused by the voids in the vacuum package.

The presentation of Tables I, II, and III as two-way tables was dictated by the significant interaction of gaseous atmosphere treatments and time treatments. The longer the steaks were in storage, the greater the microbial numbers and the greater the deterioration in appearance. Three days of display accelerated the rate of microbial growth and color deterioration. These data do not reveal whether the acceleration was a direct result of the presence of light or of the somewhat greater variance of temperature in the display case with a programmed defrosting cycle, or a combination of these.

Flavor desirability data, Tables IV and V, were not significantly interacting. However, the trent of the results are the same. Gaseous packaging was superior to the other treatments. Flavor desirability declined with increased storage and display.

Carbon dioxide combine with oxygen measurable enhanced the package life of steaks in the study.

Literature Cited

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TABLE I

EFFECTS OF ATMOSPHERE AND TIME ON MICROBIAL COUNT
PREPACKAGED BEEF STEAKS

Gaseous Atmosphere	Mean microbial count (Log number per in^2)									
	Storage Time Plus Display Time (Days)									
	0 + 0	3 + 0	5 + 0	3 + 3	7 + 0	5 + 3	10 + 0	7 + 3	10 + 3	Mean
Partial Vacuum	2.89^{abc}	2.76^{abc}	3.13^{abcde}	3.29^{bcdef}	3.19^{abcde}	3.04^{abcd}	3.65^{efg}	4.10^{gh}	4.91^{i}	3.44
10 percent carbon dioxide and 90 percent oxygen mixture	2.89^{abc}	2.68^{abc}	2.79^{abc}	2.81^{abc}	2.78^{abc}	3.06^{abcde}	3.18^{abcde}	3.25^{bcdef}	3.54^{def}	2.99
15 percent carbon dioxide and 85 percent oxygen mixture	2.89^{abc}	2.80^{abc}	2.79^{abc}	2.62^{a}	2.60^{a}	2.95^{abcd}	3.08^{abcde}	2.99^{abcd}	3.14^{abcde}	2.87
Control	2.89^{abc}	3.03^{abcd}	3.31^{cdef}	3.26^{bcdef}	3.78^{g}	4.54^{hi}	5.04^{i}	5.93^{j}	6.54^{k}	4.26
Mean	2.89^{b}	2.81^{a}	3.00^{ab}	3.00^{ab}	3.09^{b}	3.40^{c}	3.74^{d}	4.07^{e}	4.53^{f}	

$^{a-k}$Any two means that do not have a common superscript letter are significant at $P<.05$.

TABLE II

EFFECTS OF ATMOSPHERE AND TIME ON DESIRABILITY SCORES OF PREPACKAGED BEEF STEAKS

Gaseous Atmosphere	Mean desirability score[1]									
	Storage Time Plus Display Time (Days)									
	0 + 0	3 + 0	5 + 0	3 + 3	7 + 0	5 + 3	10 + 0	7 + 3	10 + 3	Mean
Partial Vacuum	8.14^{ab}	6.15^{def}	5.85^{ef}	6.27^{def}	4.55^{gh}	5.75^{f}	4.68^{g}	4.39^{gh}	3.77^{h}	5.50
10 percent carbon dioxide and 90 percent oxygen mixture	8.14^{ab}	8.47^{a}	8.24^{ab}	7.94^{ab}	8.25^{a}	8.02^{ab}	8.10^{ab}	7.49^{abc}	7.24^{bc}	7.98
15 percent carbon dioxide and 85 percent oxygen mixture	8.14^{ab}	8.42^{a}	8.22^{ab}	7.97^{ab}	8.41^{a}	8.34^{a}	8.41^{a}	8.15^{ab}	7.72^{ab}	8.19
Control	8.14^{ab}	7.96^{ab}	7.56^{abc}	6.99^{cd}	7.24^{bc}	6.97^{cd}	6.65^{cde}	5.70^{f}	4.38^{gh}	6.84
Mean Score	8.14^{a}	7.75^{ab}	7.46^{bc}	7.29^{cd}	7.11^{cd}	7.27^{cd}	6.96^{d}	6.43^{e}	5.77^{f}	

[1]Hedonic Scale: 9 = Extremely Desirable .... 1 = Extremely Undesirable.

[a-h]Any two means that do not have a common superscript letter are significant at $P<.05$.

TABLE III

EFFECTS OF ATMOSPHERE AND TIME ON DISCOLORATION SCORE OF PREPACKAGED BEEF STEAKS

Gaseous Atmosphere	Mean discoloration score[1]									
	Storage Time Plus Display Time (Days)									
	0 + 0	3 + 0	5 + 0	3 + 3	7 + 0	5 + 3	10 + 0	7 + 3	10 + 3	Mean
Partial Vacuum	8.82^{a}	6.77^{ef}	6.25^{efg}	6.75^{ef}	4.90^{hi}	6.32^{fg}	5.05^{hi}	4.67^{hi}	4.48^{i}	6.00
10 percent carbon dioxide and 90 percent oxygen mixture	8.82^{a}	8.82^{a}	8.77^{a}	8.67^{ab}	8.75^{a}	8.40^{ab}	8.65^{ab}	8.10^{abc}	8.19^{abc}	8.57
15 percent carbon dioxide and 85 percent oxygen mixture	8.82^{a}	8.87^{a}	8.79^{a}	8.77^{a}	8.90^{a}	8.85^{a}	8.90^{a}	8.69^{ab}	8.44^{ab}	8.77
Control	8.82^{a}	8.59^{ab}	8.35^{abc}	7.90^{bcd}	8.22^{abc}	7.54^{bcde}	7.05^{def}	6.95^{ef}	5.52^{gh}	7.66
Mean Score	8.82^{a}	8.26^{b}	8.04^{bc}	8.02^{bc}	7.69^{cd}	7.77^{cd}	7.41^{de}	7.10^{e}	6.65^{f}	

[1]Hedonic Scale: 9 = No Discoloration .... 5 = 50% Discolored .... 1 = Completely Discolored.

$^{a-i}$Any two means that do not have a common superscript letter are significant at $P<.05$.

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TABLE IV

EFFECT OF ATMOSPHERE ON PALATABILITY
OF PREPACKAGED BEEF STEAKS[1]

Gaseous Atmosphere	Flavor Desirability[2] (Adjusted Mean)	Off-Flavor[3] (Adjusted Mean)
Partial Vacuum	4.78^{b}	2.48^{b}
10 percent carbon dioxide and 90 percent oxygen mixture	5.94^{a}	3.16^{a}
15 percent carbon dioxide and 85 percent oxygen mixture	6.06^{a}	3.31^{a}
Control	5.08^{b}	2.69^{b}

[1]Any two means in a column that do not have a common superscript letter are significant at $P<.05$.

[2]Hedonic Scale: 8 = Very Desirable .... 1 = Very Undesibable.

[3]4 = No off-flavor, 3 = Slight off-flavor, 2 = Moderate off-flavor, 1 = Very off-flavor.

TABLE V

EFFECT OF STORAGE AND DISPLAY TIME ON PALATIBILITY
OF PREPACKAGED BEEF STEAKS[1]

Storage and Display Time			Flavor Desirability[2] (Adjusted Mean)	Off-Flavor[3] (Adjusted Mean)
Storage (Days)	Display (Days)	Total (Days)		
0	0	0	7.50^{a}	3.90^{a}
3	0	3	6.56^{b}	3.51^{b}
5	0	5	6.33^{b}	3.39^{b}
3	3	6	6.25^{b}	3.36^{b}
7	0	7	5.26^{cd}	2.80^{c}
5	3	8	4.94^{cd}	2.63^{cd}
10	0	10	5.30^{c}	2.84^{c}
7	3	10	4.55^{de}	2.39^{de}
10	3	13	4.04^{e}	2.12^{e}

[1]Any two means in a column that do not have a common superscript are significant at $P<.05$.

[2]Hedonic Scale: 8 = Very Desirable .... 1 = Very Undesirable.

[3]4 = No off-flavor, 3 = Slight off-flavor, 2 = Moderate off-flavor, 1 = Very off-flavor.