

ATTACHMENT 4

Final Report

**EVALUATION OF BEEF STEAKS AND GROUND BEEF IN THE PACTIV
ACTIVE TECH PACKAGING SYSTEM:
EFFECTS OF CARBON MONOXIDE IN THE PACKAGE ATMOSPHERE**

for

Pactiv Corporation
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PROJECT SUMMARY

The effects of carbon monoxide (CO) in Active Tech modified atmosphere packages (MAP) were determined for:

- A. Initial product color,
- B. Stability of color during display, and
- C. Relationships of color deterioration and microbial populations.

Steaks from three beef cuts (strip loin, tenderloin, and inside round steaks) and ground beef were packaged in a MAP certified gas blend (0.4% CO, 30% carbon dioxide and 69.6% nitrogen) and stored at 35° or 43°F for up to 35 days. Cuts then were removed from MAP and displayed at 34°F until their color was approaching consumer unacceptability. Color and microbial parameters were measured and compared to baseline data of comparable product exposed to oxygen but not CO.

A fundamental goal of this research was to determine if CO extended the color life of beef cuts and ground beef beyond their microbial soundness, i.e., did color mask spoilage.

CONCLUSIONS

- The Active Tech MAP system containing CO in the gas blend produced products that were equally as red as products packaged with traditional oxygen permeable overwrap.
- Improvement in visual appearance especially in the tenderloin and inner portion of the inside round steaks were observed on day zero of display and throughout display.
- Color of products exposed to CO was a typical, bright red when the outer MAP bag was removed and products were allowed to bloom for 60 to 90 minutes.
- Color declines for products stored in MAP with CO compared well to baseline products exposed to oxygen. Hence, a typical discoloration pattern was seen in both baseline and MAP studies.
- Color life for tenderloin and inside round steaks (and to a lesser extent ground beef) was slightly longer than their baseline counter parts, especially when stored 35°F vs. 43°F.
- Although microbial growth curves changed in slope and exponential growth based on the environment in the packages, bacterial growth was neither encouraged nor suppressed by the addition of CO to the MAP gas blend.
- Aerobic bacteria and facultative anaerobes followed typical patterns of growth contingent upon the environmental conditions.
- Effects of storage temperature (35° vs. 43°F) and increased storage time (21 or 35 days) resulted in typical redness decline, increase in off-odors and microbiological changes.
- CO neither masked spoilage nor resulted in color life extension beyond the point of microbial soundness.

INTRODUCTION

Marketing of case-ready meats has moved beyond the concept stage to reality. This method of delivering meat to retailers is expected to be the predominate system within five years. Some of the largest retailers are already paving the way for this makes-sense marketing system.

Modified atmosphere packaging (MAP) systems are a necessity for case-ready meats because current retail meat over wrapping does not fulfill requirements for shelf life and other needs. Processors can choose either high-oxygen or low-oxygen MAP for retail-ready meats.

Both systems rely upon the meat having certain functional properties needed to optimize delivery of cuts with excellent display color life and sound microbial quality.

In low-oxygen MAP, such as the Active Tech System of Pactiv Corporation, it is essential that the meat achieve a stable red color that extends throughout storage and display. This usually is accomplished by modifying the package atmosphere so that the meat pigment returns to its purple-red state (deoxymyoglobin). Then, at display, packaged cuts are re-exposed to oxygen (air) to re-form a bright-red color (oxymyoglobin). Some muscles can easily accomplish this function whereas other muscles have a difficult time – due principally to short comings of their inherent muscle chemistry. Thus, novel ways to aid in obtaining desirable color during storage and display would be beneficial.

Gas atmosphere composition plays a critical role in the functionality and efficacy of MAP systems for meat. The atmosphere affects one or more of the following: product appearance, shelf life, microbial and palatability issues, gas dynamics, purge, and myoglobin functionality.

Typical atmospheres for low-oxygen MAP utilize carbon dioxide (CO₂) and/or nitrogen (N₂) prior to the meat being re-exposed to oxygen. Addition of small amounts of carbon monoxide (CO) to a CO₂ and/or N₂ atmosphere could aid in producing a more functional pigment color in MAP, especially in meat cuts known to have lower color stability. CO is well known for its ability to bind to myoglobin and form a bright, crimson-red colored pigment known as carboxymyoglobin. However, carboxymyoglobin is believed to stabilize meat color beyond its microbial shelf life. Consequently, consumers may not be able to rely on color as an indicator of quality at time of purchase. Research is needed to address the use of low levels of CO in a MAP system.

HYPOTHESIS AND OBJECTIVES

This research was based on the hypothesis that a small quantity (<0.5%) of CO combined with the typical gases of MAP (CO₂ and N₂) would produce meat color complimentary to the quality needs of a case-ready meat delivery system without compromising consumer quality issues. More specific objectives evaluated the effects of CO in the Active Tech System for:

- **The initial color of intact muscles and ground beef** – this objective addressed color differences between meat in MAP containing CO vs. packaging in O₂.
- **The color deterioration of these products during display** -- these data defined the color display stability of meat in MAP containing CO vs. packaging in O₂.
- **The microbial profile of the meat stored with or without mild temperature abuse** – this portion provided information about microbial growth with CO in MAP relative to the time-honored relationship between color deterioration and spoilage.

EXPERIMENTAL PROCEDURES

This project involved two phases. The **Baseline Display Study** characterized the color and microbial traits of selected cuts and ground beef using typical oxygen-permeable packaging under typical retail display conditions. The **MAP Display Study** utilized the Pactiv Active Tech Packaging System in combination with a unique, certified gas blend (0.4% CO, 30% CO₂ and 69.6% N₂) in the package atmosphere during storage conditions (pre-display).

The outer MAP bag was removed and the products were displayed in the same manner as the baseline samples. All data from the MAP Portion were compared to the Baseline product.

RAW MATERIALS:

Twelve beef strip loins (NAMP #180 containing the *Longissimus* muscle), 18 tenderloins (NAMP #189A containing the *Psoas major* muscle), 12 inside rounds (NAMP #169A containing the *Semimembranosus* muscle), and 6 batches of ground chuck (80% lean) were obtained from a commercial source (PrairieLand Processors, Inc., Kansas City, KS) at four to six days postmortem. Vacuum packaged subprimals and trim that were received at the KSU Meats Laboratory had an internal temperature of 34°F and had never been frozen. Prior to product preparation, subprimals were stored at 34°F. This product was allocated to 6 replications (2 each of the strip loins and inside rounds and 3 tenderloins constituted a replication).

PRODUCT PREPARATION AND PACKAGING:

One inch thick steaks cut from each subprimal and ground beef formed into about one-pound blocks (Beef Steaker, Model 600, Hobart Corp., Troy, OH) were placed on Styrofoam trays (17S for strip loins, 4P for inside rounds, 1 for tenderloins, and 2P for ground beef) containing an absorbent pad (Ultra Zap Soakers, Paper Pak Products, La Verne, CA). Product was overwrapped with polyvinyl chloride (PVC) film (23,000ccO₂/m²/24hrs; Filmco MW4, LinPac, UK or Omnifilm 4P, Huntsman, Salt Lake City, UT) using a mechanical wrapper (Filmizer Model CSW-3, Hobart Corporation, Troy OH) and was assigned randomly to either a **Baseline Display Study** using only PVC-wrapped packages or a **MAP Display Study** using the Active Tech System of Pactiv Corporation. Trays for MAP were placed individually in barrier bags (4.5ccO₂/m²/24hrs: NXE 1-300, Alec Enterprises, Burnsville, MN) along with an oxygen absorber (MRM-200, Multisorb Technologies, Buffalo, NY) activated using Pactiv Active Tech Activator No.1. Barrier bags were evacuated, flushed with a certified gas blend containing 0.4% CO, 30% CO₂, and 69.6% N₂, and sealed (Freshvac Model A300, CVP Systems, Inc., Downers Grove, IL).

TREATMENTS:

Baseline Display Study: Twelve packages of ground beef and one steak ($\leq 1/8$ " fat trim) from each subprimal (12 strip loins, 12 inside rounds, 18 tenderloins, and the 6 batches of ground beef), were evaluated in a baseline study to establish the color and microbial parameters for meat never in MAP and exposed only to atmospheric oxygen. These packages were placed in display about 4 hours post-packaging (see display and measurement details below).

MAP Display Study: To test the effects of CO in MAP, one package of each product from each of 6 replications was selected at random for assignment to all possible combinations of two storage temperatures (35 and 43°F) and three storage times (7, 14, and 21 days for ground beef and 7, 21, and 35 days for steaks). The lower temperature represented reasonably good industry practice, and the higher temperature represented a mildly abusive storage conditions. The storage times represented current industry practice.

Prior to display (post-MAP), the O₂ and CO₂ levels in the outer barrier bags were measured using a MOCON head space analyzer (Pac Check™ Model 650, MOCON/Modern Controls, Inc., Minneapolis, MN).

DISPLAY CONDITIONS:

Meat samples were placed in simulated retail display at 34 ± 3°F under 1614 lux (150 ± 5 foot candles; Model 201, General Electric, Cleveland, OH) light intensity (Philips, 34 Watt, Ultralume 30) in open-top display cases (Unit Model DMF8, Tyler Refrigeration Corporation, Niles, MI). Cases were programed to defrost two-times per day at 12 hour intervals. Display case temperatures were monitored during display using temperature loggers (Omega Engineering, Inc., Stamford, CT). Display times varied based on product type, initial microbial loads, and storage conditions. Product was removed from display when the color score was deemed unacceptable by a visual panel (a color score of 3.5). Baseline products were displayed 7, 5, 4, and 3 days for strip steaks, inside rounds, ground beef, and tenderloins, respectively.

VISUAL COLOR EVALUATION:

Ten trained visual panelists evaluated color using a five-point scale where 1 = very bright red, 2 = Bright red, 3 = Slightly dark red or tan, 4 = Moderately dark red or tan, and 5 = Extremely dark red or brown. The cut-off score for consumer acceptable color was ≥3.5.

Two portions of the inside round muscle were scored separately. The outer 1/3 portion (OSM) and the deep, inner 1/3 portion (ISM). The middle 1/3 area was not scored. The 10 panel scores were averaged for statistical analysis.

INSTRUMENTAL COLOR AND SPECTRAL DATA:

Samples were instrumentally analyzed for lightness (L*), redness (a*), and yellowness (b*) for Illuminant D-65 (daylight) using a HunterLab MiniScan Spectrophotometer (1.25 inch diameter aperture, Hunter Associates Laboratory, inc., Reston, VA). Multiple readings (2 to 4 depending on cut size) were taken and averaged for statistical analysis on each cut at each testing period.

ODORS:

At the end of display, each package from the MAP Display Study was evaluated for off odors by two experienced panelists using a 5-point scale were 1 = no, 2 = slight, 3 = small, 4 = moderate, and 5 = extreme off odor. A score of 3.5 was assumed to be unacceptable to consumers.

MICROBIOLOGICAL PROCEDURES:

Microbial populations were estimated at the end of MAP storage (day 0 of display) and at the end of display (day of unacceptable color). For each post-display sample, a portion of the surface area (top surface) that had been exposed to light was excised. After each package was opened aseptically, two cores (ca 2 in²) were removed (approximately 1/8 inch depth), placed in a sterile stomacher bag, and blended two minutes with 0.1% peptone diluent. Serial dilutions of the homogenate were prepared in 0.1% peptone and appropriate dilutions were plated in duplicate on Aerobic Plate Count Petrifilm™ to determine total aerobic bacterial populations and on E. coli Count Petrifilm™ to estimate generic *E. coli* and total coliform bacterial counts. In addition, appropriate dilutions also were plated in duplicate on MRS agar to determine lactic acid bacterial populations. Aerobic Plate Count Petrifilm™ and E. coli Count Petrifilm™ (3M Microbiology Products, St. Paul, MN) were incubated at 90°F for 48 hours prior to enumeration. LAB populations were counted after 48 hours of 92°F incubation in a CO₂ chamber. Microbial detection limits for intact muscle and ground beef were 1.76 count/cm² and 5.0 count/gram, respectively.

pH:

pH was determined on intact muscle and ground beef samples collected on the day of production. Ten grams of sample were added to 100 mL of distilled water and blended for two minutes. A standardized pH meter with an electrode was used to measure pH according to the procedure outlined in the Handbook for Meat Chemists.

FAT AND MOISTURE:

Ground beef samples collected on the day of production were analyzed in duplicate for moisture and fat using AOAC procedures 985.14 and 985.15, respectively.

EXPERIMENTAL DESIGN AND STATISTICS:

The design was a randomized complete block with six replications. A replication consisted of 1 to 3 subprimals (number depended on the size of each cut). Steaks cut from the subprimals and separate batches of ground beef trim were randomly assigned to replication and the treatment combinations. Data were analyzed using analysis of variance and significant differences determined using least significant difference tests at P<0.05.

SAMPLING TIMES/PARAMETERS MEASURED:

1. MAP Gas Composition for oxygen and carbon dioxide levels

- Subsample of several ActiveTech packages on production day (2-3 hours post-packaging) to verify gas composition being obtained
- End of MAP storage at two temperatures

2. Microbiology:

- Initial counts for subprimals and ground beef on the day of production
- End of MAP storage at two temperatures
- End of display

3. Visual Color:

- Initial color prior to display lighting
- End of MAP storage at each of two temperatures and after 60 to 90 min bloom at 34°F (equal to 0 time of display)
- Daily during display

4. Instrumental Color:

- Initial color = After packaging in PVC on production day for baseline data, minimal exposure to light
- End of MAP storage at each of two temperatures and after 60 to 90 min bloom at 34°F (equal to 0 time of display)
- Daily during display

5. Odor:

- At end of display (prior to microbial testing)

RESULTS AND DISCUSSION

The Baseline Study: A random selection of all steaks and ground beef packaged in PVC film were placed in display to serve as a baseline for color and microbiological comparisons. Products were expected to have the lowest microbiological load and ideal color stability using traditional packaging and display conditions for products exposed only to atmospheric oxygen. The inherent muscle chemistry responsible for good color life also was optimal. If the product exposed to CO were to have extended meat color life, then it will be compared to the baseline "control" with the "best" possible color.

Color Reference Points: The discussion below involves both visual and instrumental measures of color. Visual scores were considered the "standard" with instrumental color being discussed relative to its agreement or disagreement with the visual panel, ie, did the objective measurements confirm what the color panel saw. Visual scores of ≥ 3.5 were considered borderline acceptable. When samples reached this discoloration, they were removed from display. Normally, a^* values (higher values indicate more redness) are highly correlated to visual appraisal.

Inside round steaks typically are two-toned in color. The inner portion (ISM) is much less color stable compared to the outer portion (OSM). These portions were scored separately since one portion may have acceptable color while the other has unacceptable color that would be discriminated against by consumers resulting in the whole cut being judged

unacceptable in color. The effects of CO on this bi-colored muscle were needed to confirm that color was not excessively extended in either portion.

FAT AND MOISTURE, pH, AND INITIAL MICROBIAL LOAD:

Average fat and moisture contents of the ground beef were 19.5 and 61.6%, respectively. pH of both intact muscles and the ground beef ranged from 5.3 to 5.7. The initial aerobic plate counts and lactic bacteria counts for all products were relatively low and indicative of microbial quality of the raw materials and good sanitation. Furthermore, coliforms and *E. coli* were below the detection limit throughout the study.

GAS COMPOSITION AT END OF MAP:

At the end of MAP storage, each package atmosphere was analyzed for O₂ and CO₂ (Table 1). Only 6 (each from a different treatment combination) of 288 packages were removed from the experiment due to leakage.

INITIAL PRODUCT COLOR AND APPEARANCE:

The color of ground beef and steaks entering display (after MAP storage at 2 temperatures) was an attractive, typical red color. Although there were several significant differences in visual scores and a* values (Table 2 and Figures 1-10 at day 0) for product in CO vs. baseline cuts, the variation in color was usually within ± 0.5 of a color score. In general, the initial color of product exposed to CO was very similar to the color of steaks from the baseline display (never exposed to CO). When differences occurred, they were more related to either storage temperature or postmortem age of the product.

Panelists did not consider the color of product exposed to CO atypical. Cuts exposed to CO generally appeared more uniformly bright-red and would be expected to have high consumer appeal. These results were expected, as CO is known to preferentially form a ligand with the colored pigment (myoglobin) in meat resulting in an intensely red pigment known as carboxymyoglobin. At higher levels of CO (0.4% vs. 0.6 to 1%) than used in this experiment, meat color has been described as being an unusual crimson, bright-red color compared to the normal red of oxymyoglobin.

A critical next question was whether the carboxymyoglobin formed on the surface was more stable than the oxymyoglobin formed in baseline product. Further, did the carboxy

pigment deteriorate in a predictable way that consumers could continue to use visual color to judge freshness or potential spoilage.

COLOR DETERIORATION PROFILE:

Visual panel scores (Figures 1-5) and instrumental color (a^* values, Figures 6-10) clearly showed that product exposed to CO during MAP storage had color deterioration during display. As expected, visual scores increased (color deteriorated) and a^* values decreased (loss of redness) as days in display increased.

In several instances, color appeared to improve late in display – as indicated by a decrease in visual scores (see ground beef, strips loins and tenderloins at 43°F). These decreases were not a return of redness. Rather the apparent decrease resulted from removal of discolored packages the preceding period, leaving product with less overall discoloration remaining in the case.

In general, the color deterioration profiles followed an expected pattern. Namely, the freshest product (baseline packages) had the most stable, red color and the most days in display needed to reach borderline discoloration (Table 3 scores to 3.5) of all treatments. Exceptions occurred for the inside portion of the inside round and tenderloin products, where the product exposed to CO had slightly more stable color than the baseline product (Table 3). These two muscle areas are well known by retailers as having short color life. Thus, CO appeared to improve color life when the inherent muscle chemistry desired for color was limited.

For product from MAP, the longer the storage time, the faster the deterioration, especially at the higher storage temperature (Tables 2 and 3). For packages stored at 43°F, which was a mildly abusive temperature, color deterioration would be expected to accelerate. This phenomenon also is illustrated in Figures 1-10.

Changes in a^* values (and other instrumental measures of color not shown) followed the same pattern of color deterioration observed by the visual panelists. There was no evidence that color shelf life was unexpectedly lengthened by exposure of meat to CO in MAP. The question remaining is whether the color life of product in CO masked spoilage, ie, were microbial counts higher than expected based on the degree of discoloration?

COLOR DETERIORATION AND MICROBIAL GROWTH:

Baseline Display Study: Initial, pre-display microbiological data suggested that the raw materials were fresh and processed using good hygienic practices. For intact cuts, lactic acid bacteria, generic *E. coli*, and total coliform counts were below the detection limit of 1.76 CFU/in². Initial, pre-display APC for intact muscles ranged from 1 to 1.63 log₁₀ CFU/in². Post-display counts were higher (P<0.05) than pre-display APC which was an increase in bacterial proliferation and typical deterioration. However, all product had sufficient microbes to be susceptible to spoilage.

Baseline products were pulled from display when the visual panel scores reached ≥ 3.5 . However, the APC did not exceed 5 log₁₀ CFU/unit as shown in Figures 11-14 and lactic bacterial did not exceed 6 log₁₀ CFU/unit as shown in Figures 15-18. Furthermore, off-odor scores for product at end of display (Table 3) ranged from no to slight off odor. Thus, color life in this base population did not exceed microbial soundness.

MAP Display Study: Similar trends in microbial growth occurred in post-displayed samples stored in MAP compared to baseline products. Microbial patterns for product deterioration are shown in Table 4 and Figures 11-18. Products stored under MAP at a slightly abusive temperature showed, as expected, a more rapid increase (P<0.05) in microbial counts compared to samples stored at 35°F. For post-MAP (pre-display) and post-display samples, APC were higher at 43°F than 35°F (Table 4), and during the later days of storage at the higher temperature, differences were more obvious. Significant changes (P<0.05) occurred in all cuts and ground beef with the exception of SM. Counts for the SM muscle were lower than expected and no significant changes occurring until day 35 of MAP storage. This suggests that quality products that have been handled in a sanitary fashion can be stored in the MAP system up to 35 days without comprising microbial quality. The APCs for intact strip loin and tenderloin steaks stored at 35°F were lower (P<0.05) on all days of display on days 21 and 35 post-MAP than steaks stored at 43°F (Figures 12 and 14). Although products did not show a difference in APCs 7 days post-MAP, those products stored at the higher temperature (43°F) were more inferior 21 and 35 days post-MAP.

Did Color Mask Spoilage? Central to this research was to evaluate the idea that the color of CO treated meat might mask spoilage. Food scientists generally agree that meat

color is seriously discolored when microbial counts approach $\log 10^6$, and that off odors frequently appear at counts of 10^7 to 10^8 . Numerous studies of ground beef, frequently the product with the highest counts, show that consumer-purchased retail product often has counts of 10^5 to 10^8 .

Visual color scoring was considered as the "standard" for determining the time to remove products from display. Because the visual panel scores were the deciding factor for length of shelf life, the interdependence between visual color and APC, LAB, and odor were considered quite important.

Figures 19-21 show aerobic and lactic bacterial growth and odor scores at the end of display plotted against their corresponding visual color scores. All data observations were summed over storage temperature, storage time, and product type and plotted in one graph. If color masked spoilage, then there should be multiple points in the upper left quadrant of the plot, the area represented by unacceptable microbial counts and off odors but with acceptable color (i.e., scores <3.5). This did not occur with any frequency in any of the three plots. Thus, it does not appear that exposure of meat to CO during extended (up to 35 days at either 35° or 43°F) caused meat color to hide spoilage.

Table 1 - Carbon Dioxide (CO₂) and Oxygen (O₂) Levels in MAP Packages of ground beef (GB) and steaks from strip loins (LD), inside round (SM), and tenderloin (TL).

Meat Cut	Storage Temperature, °F	Storage Time, days	CO ₂ , %	O ₂ , %
GB	35	7	28.4	0
GB	43	7	28.7	0
GB	35	14	27.7	0
GB	43	14	28.3	0
GB	35	21	27.4	0
GB	43	21	28.0	0
LD	35	7	33.3	0
LD	43	7	34.2	0
LD	35	21	32.4	0
LD	43	21	31.8	0
LD	35	35	31.1	0
LD	43	35	28.5	0
SM	35	7	28.9	0
SM	43	7	29.7	0
SM	35	21	27.9	0
SM	43	21	27.3	0
SM	35	35	26.8	0
SM	43	35	24.6	0
TL	35	7	34.3	0
TL	43	7	34.8	0
TL	35	21	33.6	0
TL	43	21	32.3	0
TL	35	35	32.5	0
TL	43	35	29.2	0

Table 2 - Means for initial visual color and a* values for beef cuts exposed to carbon monoxide during storage at 35° and 43°F in Active Tech MAP vs. baseline cuts exposed only to oxygen.

Trait	Product	Baseline cuts	Time ^d in Active Tech MAP, days at 35° F		
			7	14 / 21	21 / 35
Initial Visual Color	GB	1.3a	1.6b	1.7b	1.8b
	LD	2.2b	2.5b	1.8a	2.2b
	ISM	1.8ab	2.0b	1.7a	2.0b
	OSM	2.6b	2.6b	1.9a	2.5b
	TL	1.9a	2.0a	1.9a	2.1a
Initial a* Values (redness)	GB	23.4a	25.6b	25.9b	25.6b
	LD	25.8a	25.7a	27.1ab	28.1b
	ISM	28.5a	26.9a	30.0a	29.4a
	OSM	27.4a	27.7a	29.8a	29.5a
	TL	23.6a	27.5b	30.0c	29.3c
			Time ^d in Active Tech MAP, days at 43° F		
Initial Visual Color	GB	1.3a	1.7b	1.8b	2.5c
	LD	2.2a	2.3a	2.1a	2.0a
	ISM	1.8a	1.8a	1.7a	2.4b
	OSM	2.6b	2.2a	2.2a	2.0a
	TL	1.9a	2.0ab	1.8a	2.2b
Initial a* Values (redness)	GB	23.4a	25.7b	25.1b	25.5b
	LD	25.8a	25.5a	28.7b	27.5b
	ISM	28.5a	28.7a	28.6a	27.5a
	OSM	27.4a	27.7a	30.2b	29.4ab
	TL	23.6a	27.8b	28.7b	26.4b

a-c Means in the same row with a different letter differ (P<0.05).

d Ground beef stored 7, 14, and 21 days, other muscles 7, 21, and 35 days.

Table 3 - Means for days to visual unacceptable visual color (score of 3.5) and odor at end of display for beef cuts exposed to carbon monoxide during storage at 35° and 43°F in Active Tech MAP vs. baseline cuts exposed only to oxygen.

Trait	Product	Baseline cuts	Time ^e in Active Tech MAP, days at 35° F		
			7	14 / 21	21 / 35
Days in display to unacceptable color	GB	3.6c	3.0b	3.0b	2.3a
	LD	6.2c	5.0b	5.2b	3.8a
	ISM	3.2a	4.8c	4.0bc	3.5ab
	OSM	4.8c	3.5b	3.4b	2.6a
	TL	2.6a	3.0b	3.2b	2.8ab
			Time ^e in Active Tech MAP, days at 43° F		
Days in display to unacceptable color	GB	3.6d	3.0cd	2.3b	1.5a
	LD	6.2d	5.0c	3.3b	2.3a
	ISM	3.2b	4.0bc	3.1b	2.0a
	OSM	4.5d	3.0c	2.4b	1.6a
	TL	2.6ab	3.0b	2.3ab	1.7a
			Time ^e in Active Tech MAP, days at 35° F		
Off-odor score ^f at end of display	GB	1.5a	1.9a	2.8b	2.4ab
	LD	1.3a	1.3a	2.3b	2.3b
	SM	1.5a	2.2a	3.0b	3.0b
	TL	1.6a	1.2a	3.1b	3.3b
			Time ^e in Active Tech MAP, days at 43° F		
Off-odor score ^f at end of display	GB	1.5a	3.3a	3.6a	3.9a
	LD	1.3a	2.9a	3.3ab	3.6b
	SM	1.5a	2.2a	3.4b	4.0b
	TL	1.6a	2.7a	3.3b	3.8c

a-d Means in the same row with a different letter differ (P<0.05).

^e Ground beef stored 7, 14, and 21 days, other muscles 7, 21, and 35 days.

^f Off-odor scale: 1 = none, 2 = slight, 3 = Small, 4 = Moderate, 5 = Extreme

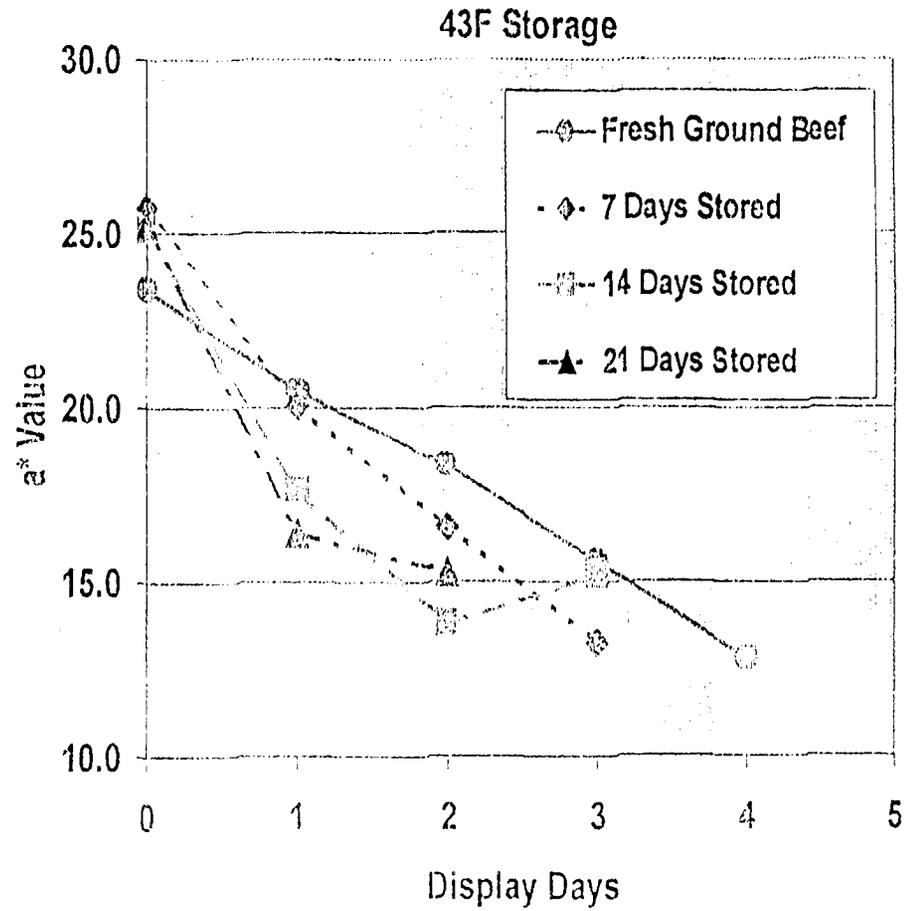
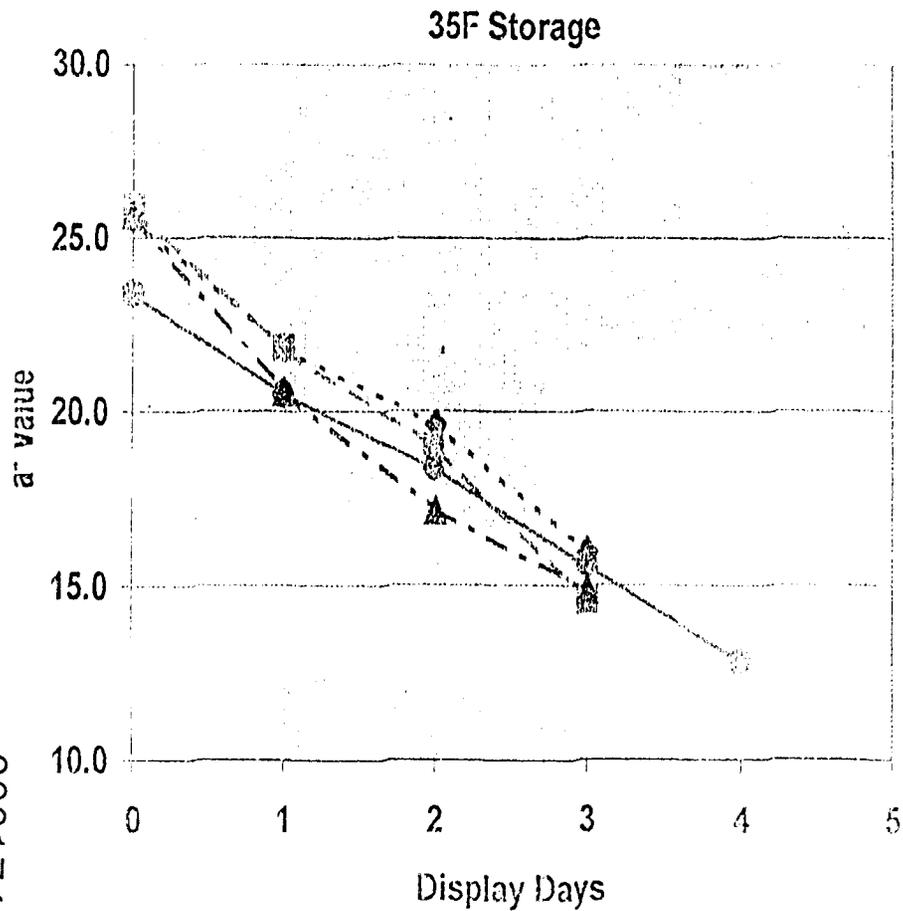
Table 4 - Means for aerobic plate counts (APC) on beef cuts exposed to carbon monoxide during storage at 35° and 43°F in Active Tech MAP vs. baseline cuts exposed only to oxygen.

Trait	Product	Baseline cuts	Time ^e in Active Tech MAP, days at 35° F		
			7	14 / 21	21 / 35
End of MAP storage APCs, log 10 cfu	GB	2.7a	2.6a	4.7b	5.5b
	LD	.7ab	0.2a	1.4bc	1.7c
	SM	1.0b	0.3a	0.3a	0.3a
	TL	1.3b	0.2a	2.6bc	3.1c
End of display APCs, log 10 cfu	GB	4.3a	4.4ab	5.6b	5.5b
	LD	1.4ab	0.4a	2.9bc	3.4c
	SM	0.6a	0.1a	0.6a	2.0b
	TL	0.3a	1.3b	3.5c	3.4c
			Time ^e in Active Tech MAP, days at 43° F		
End of MAP storage APCs, log 10 cfu	GB	2.7a	4.6b	5.8c	6.0c
	LD	0.7a	1.3ab	3.2c	5.1d
	SM	1.0b	0.1a	0.1a	2.8c
	TL	1.3a	1.6a	3.7b	4.0b
End of display APCs, log 10 cfu	GB	4.3a	5.8b	5.9b	6.1b
	LD	1.4a	1.3a	2.8b	5.3c
	SM	0.6a	0.3a	0.7a	2.5b
	TL	0.3a	3.3b	4.2b	4.6b

a-d Means in the same row with a different letter differ (P<0.05).

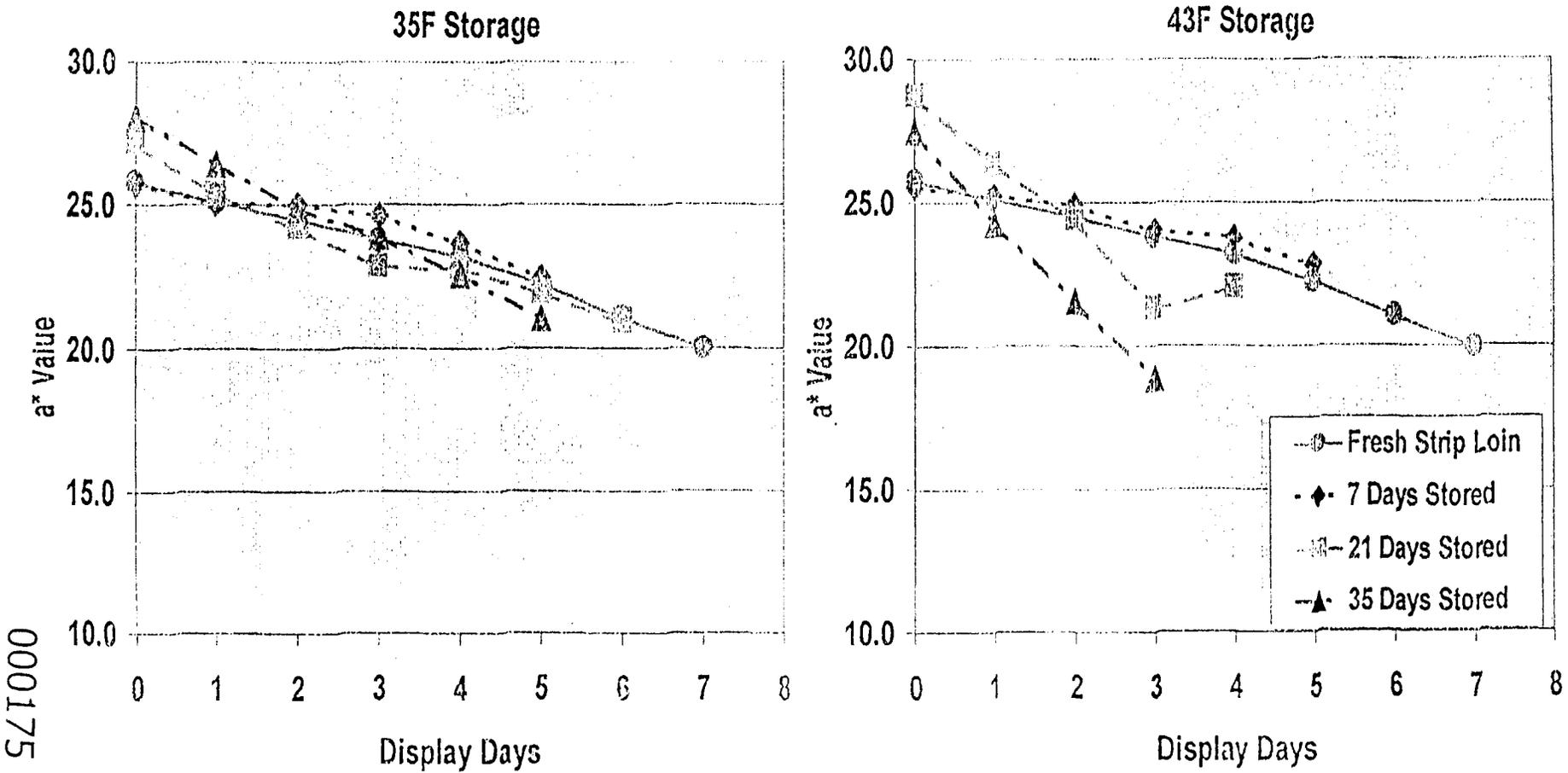
e Ground beef stored 7, 14, and 21 days, other muscles 7, 21, and 35 days.

Figure 6
Ground Beef a* Values (Redness) Deterioration
During Display Following Storage



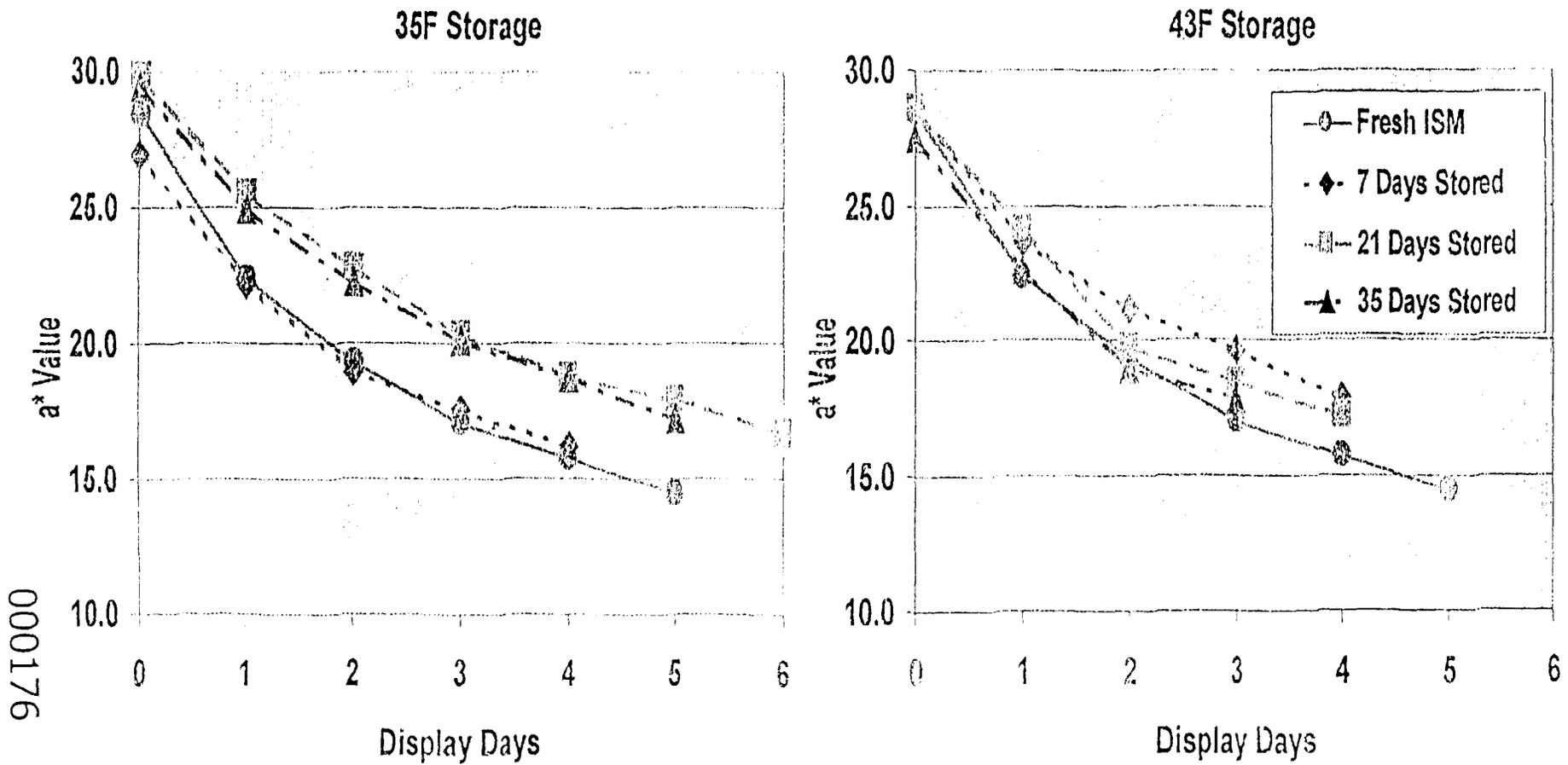
000174

Figure 7
Strip Loin a* Values (Redness) Deterioration
During Display Following Storage



000175

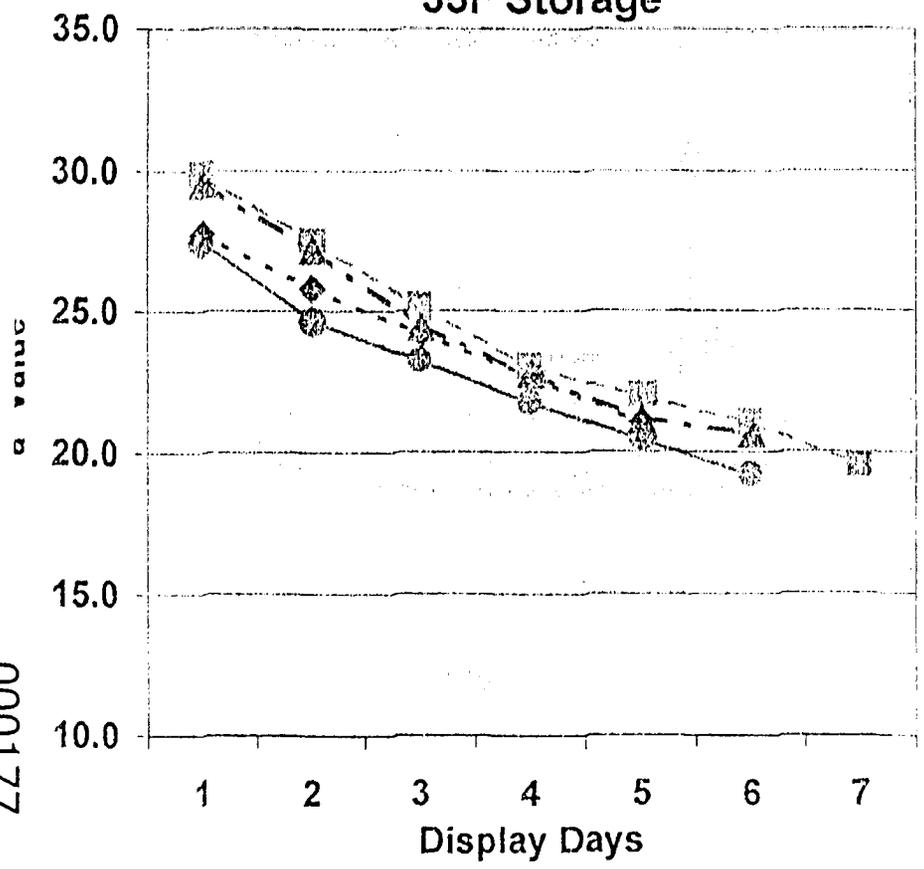
Figure 8
Inside Round (inside portion) a^* Values (Redness)
Deterioration During Display Following Storage



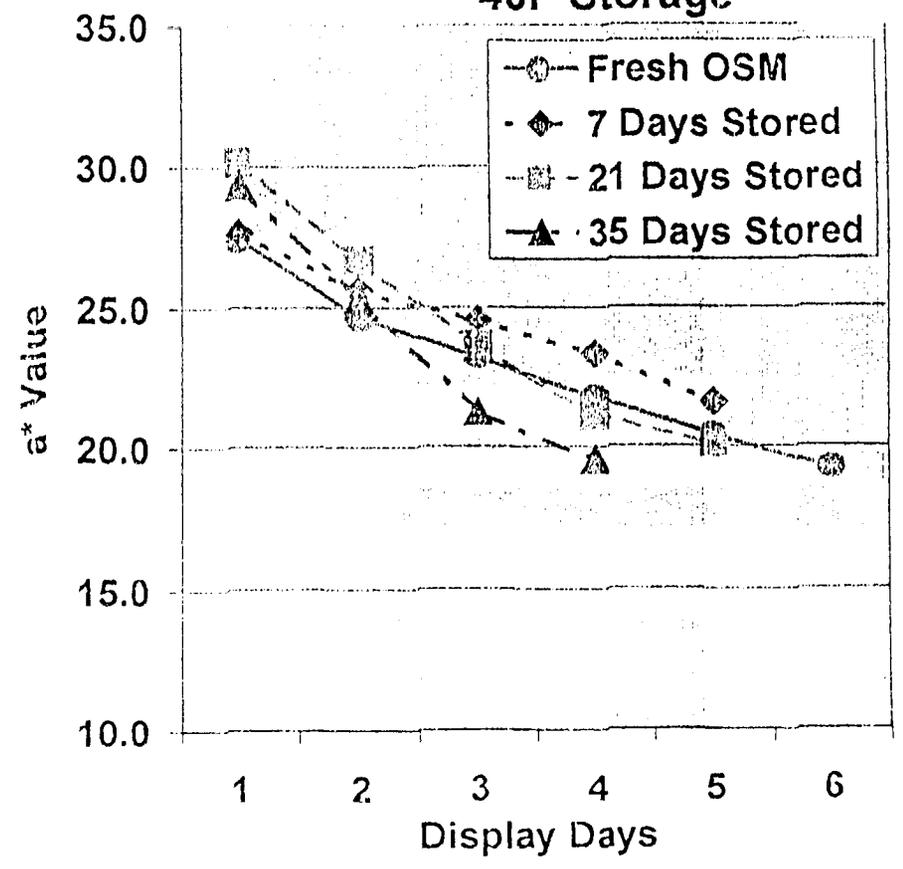
000176

Figure 9
Inside Round (outside portion) a* Values (Redness)
Deterioration During Display Following Storage

35F Storage

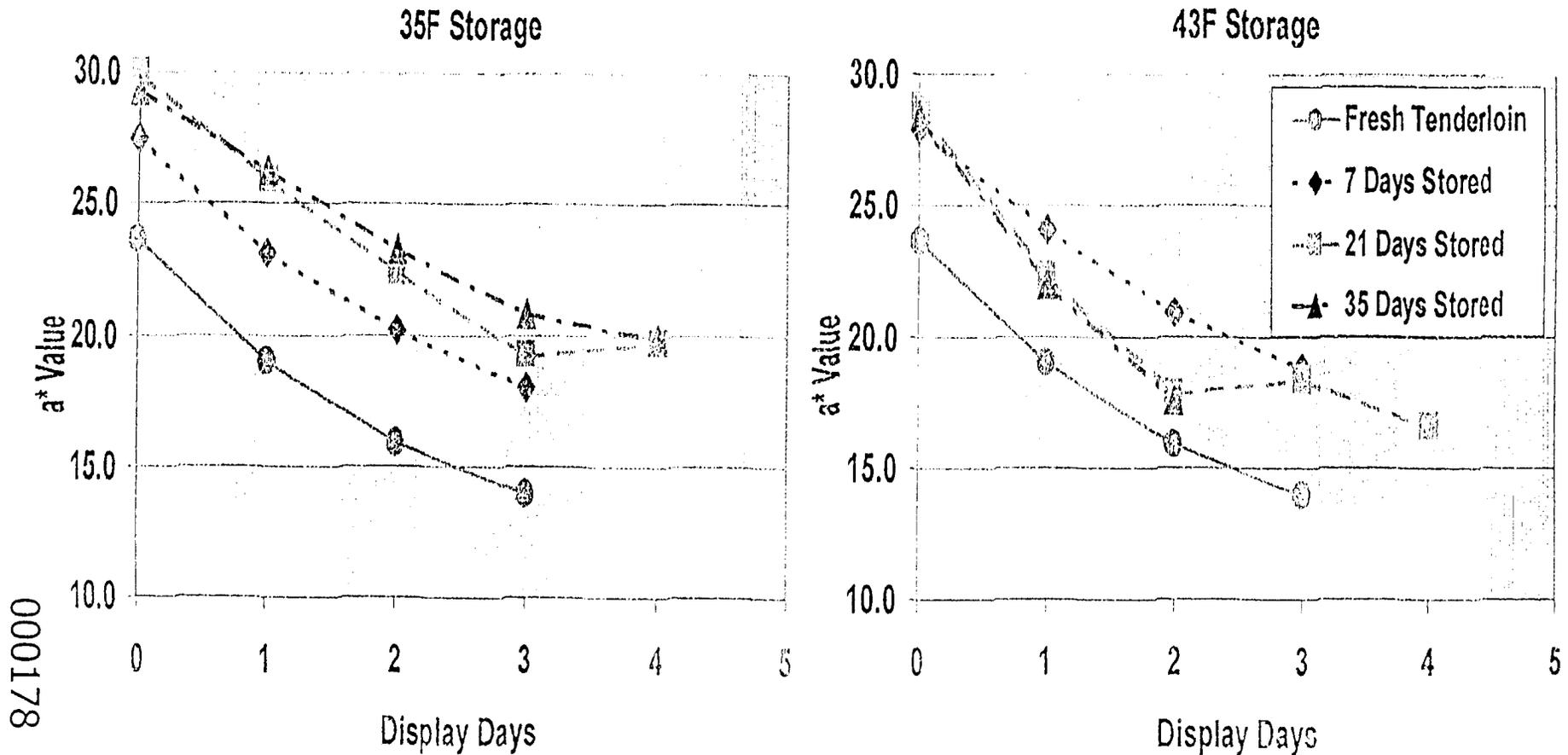


43F Storage



000177

Figure 10
Tenderloin a* Values (Redness) Deterioration
During Display Following Storage



87100

Figure 11
Ground Beef Total Aerobic Plate Counts
During Display Following Storage

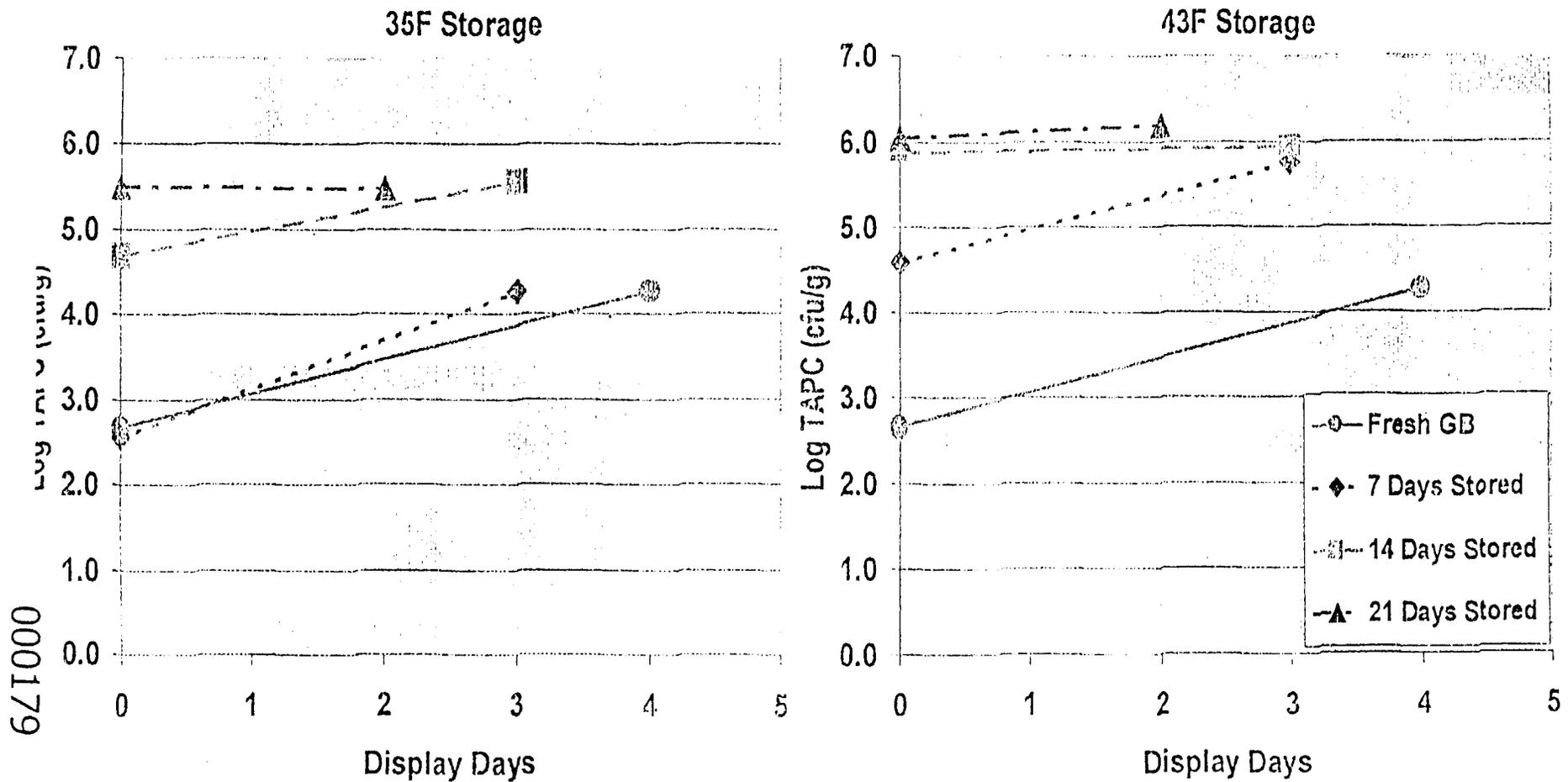


Figure 12
Strip Loin Total Aerobic Plate Counts
During Display Following Storage

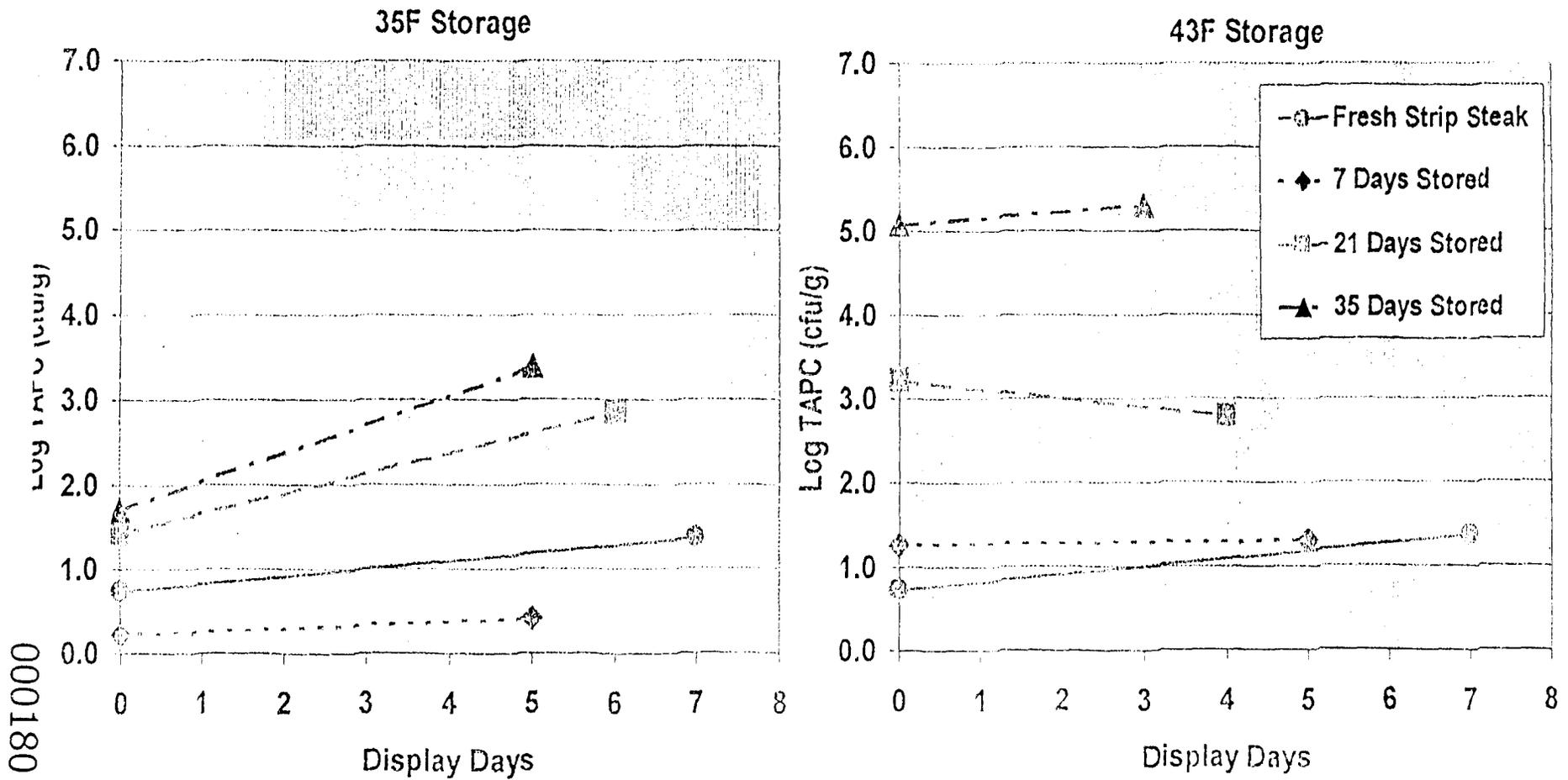


Figure 13
Inside Round Total Aerobic Plate Counts
During Display Following Storage

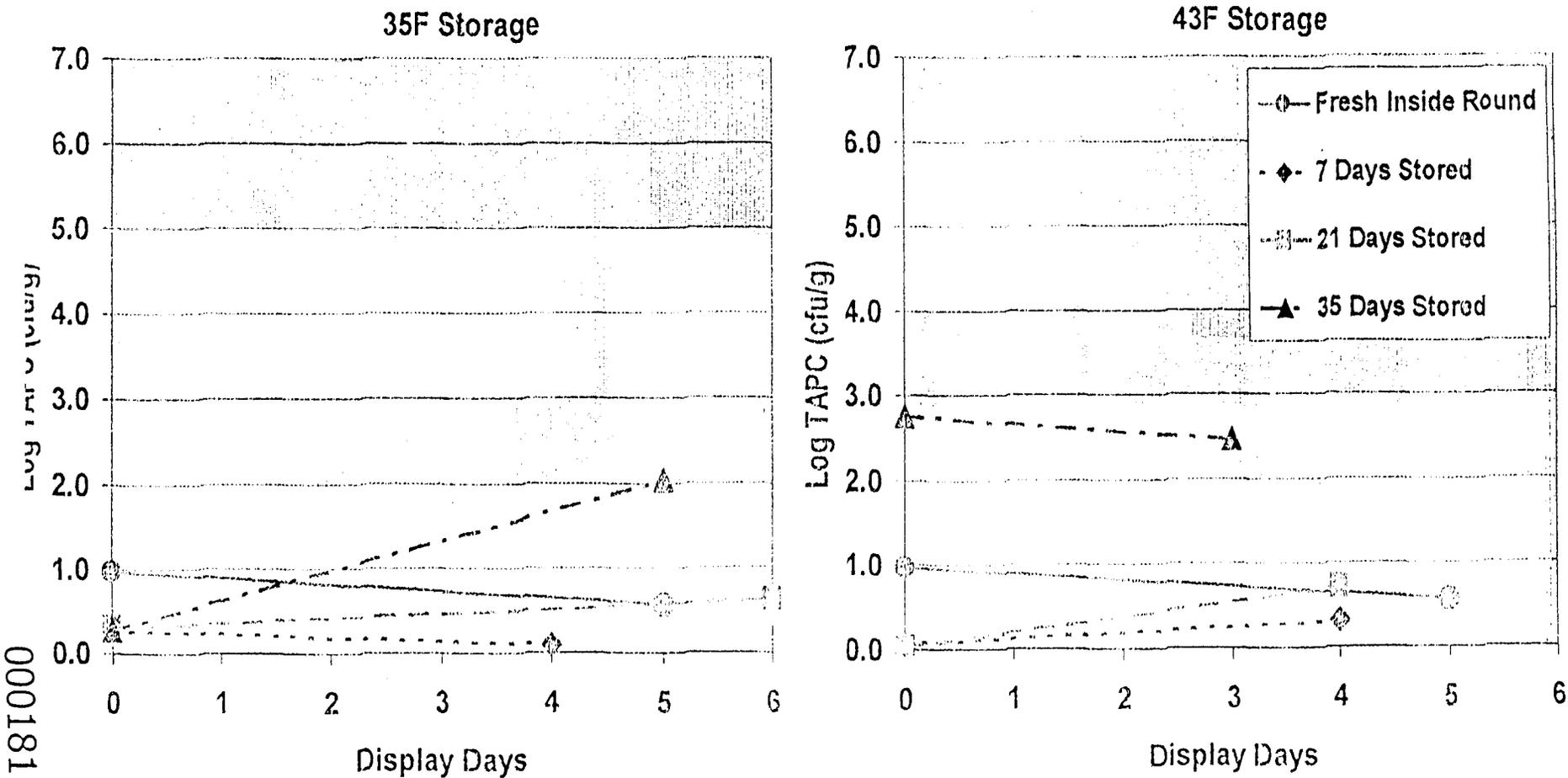
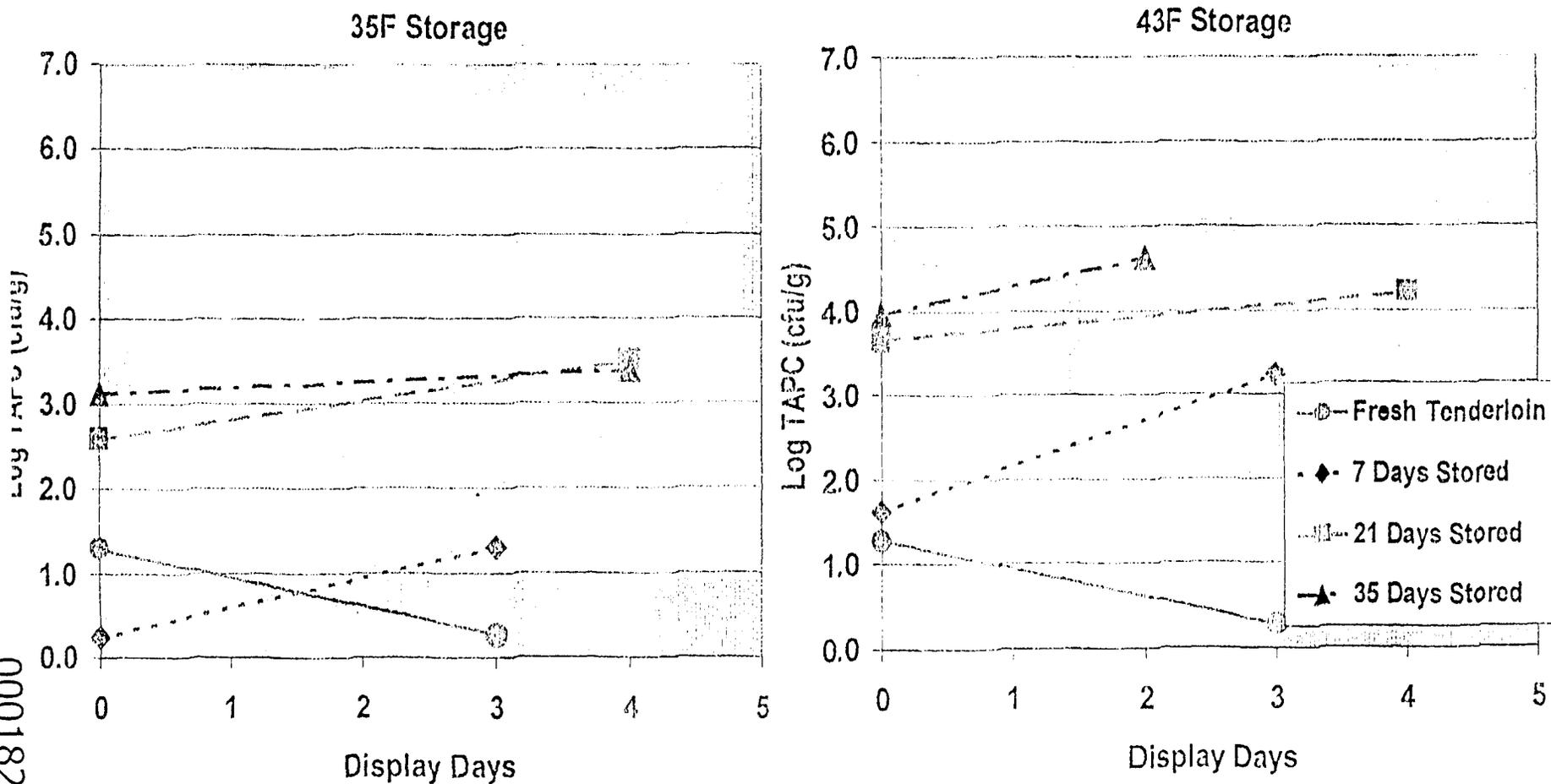


Figure 14

Tenderloin Total Aerobic Plate Counts During Display Following Storage

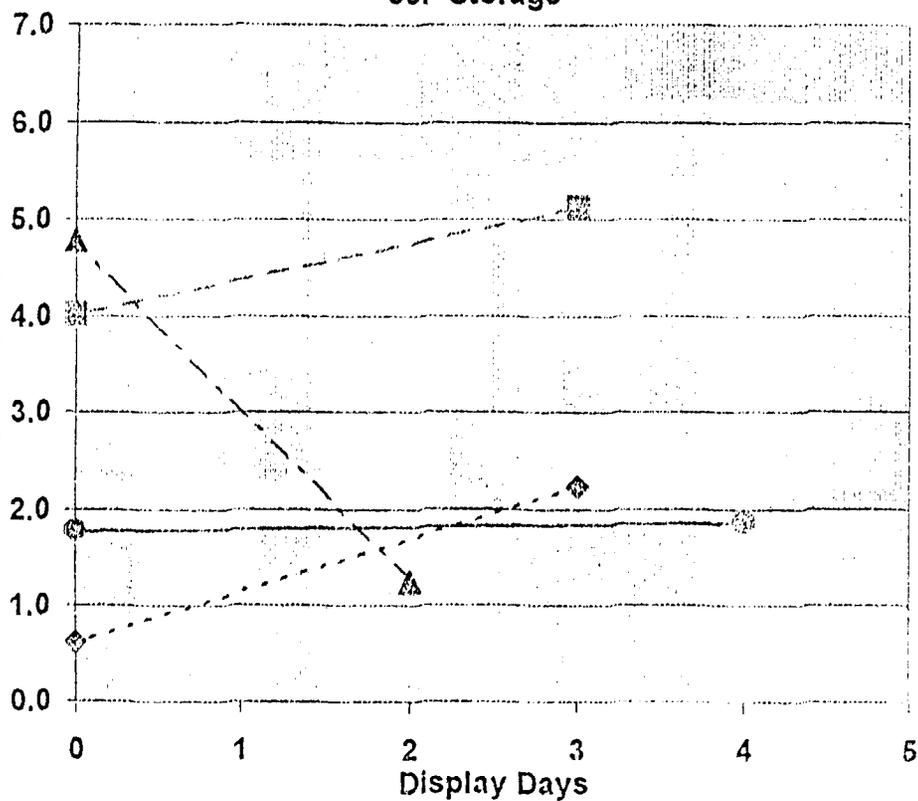


000182

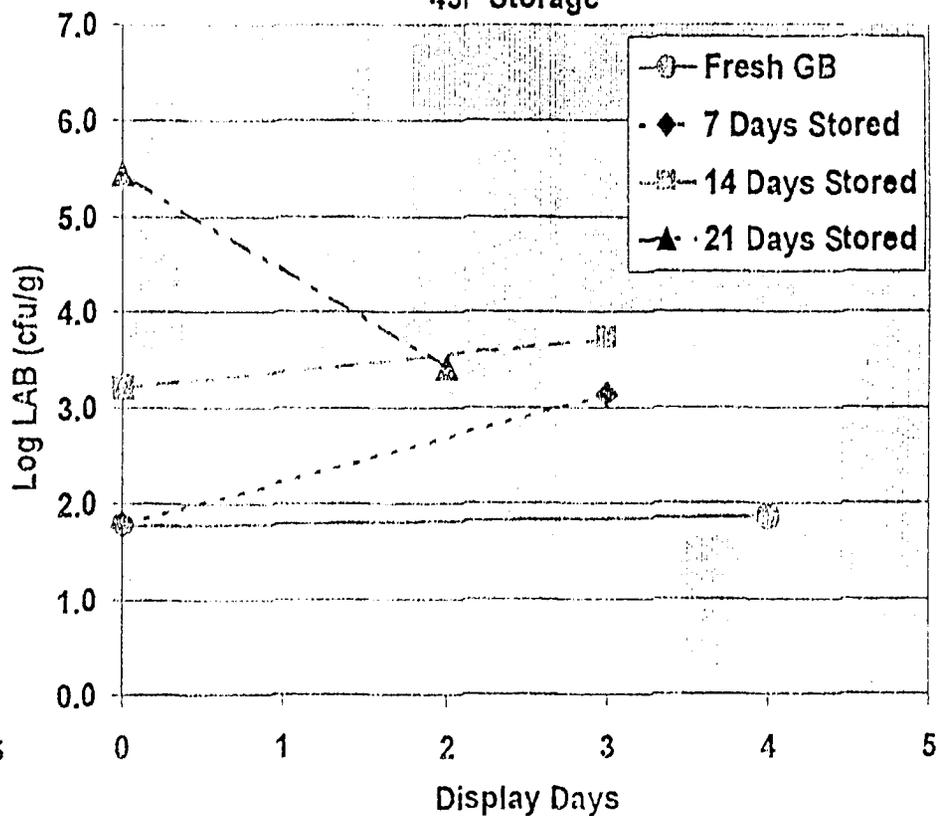
Figure 15

Ground Beef Lactic Acid Bacteria During Display Following Storage

36F Storage



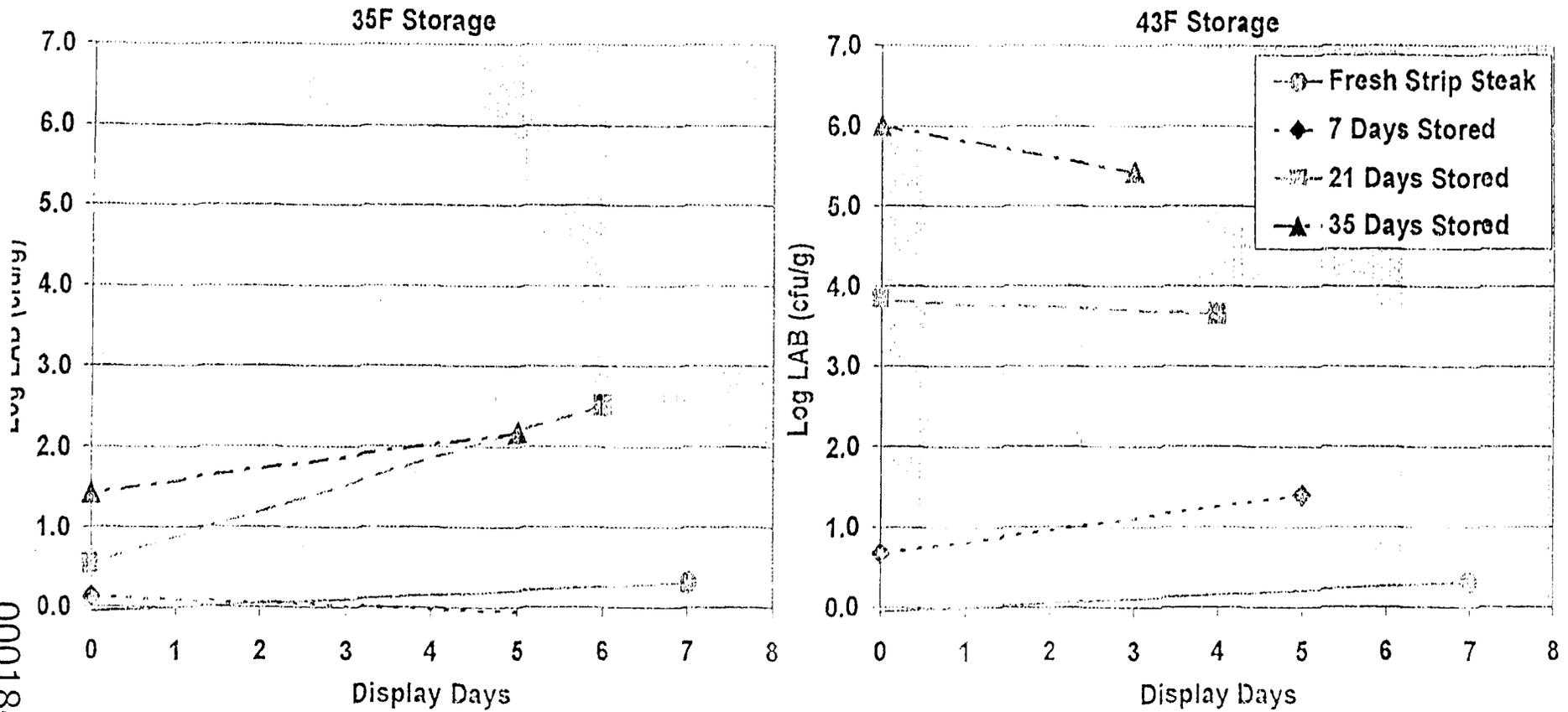
43F Storage



000183

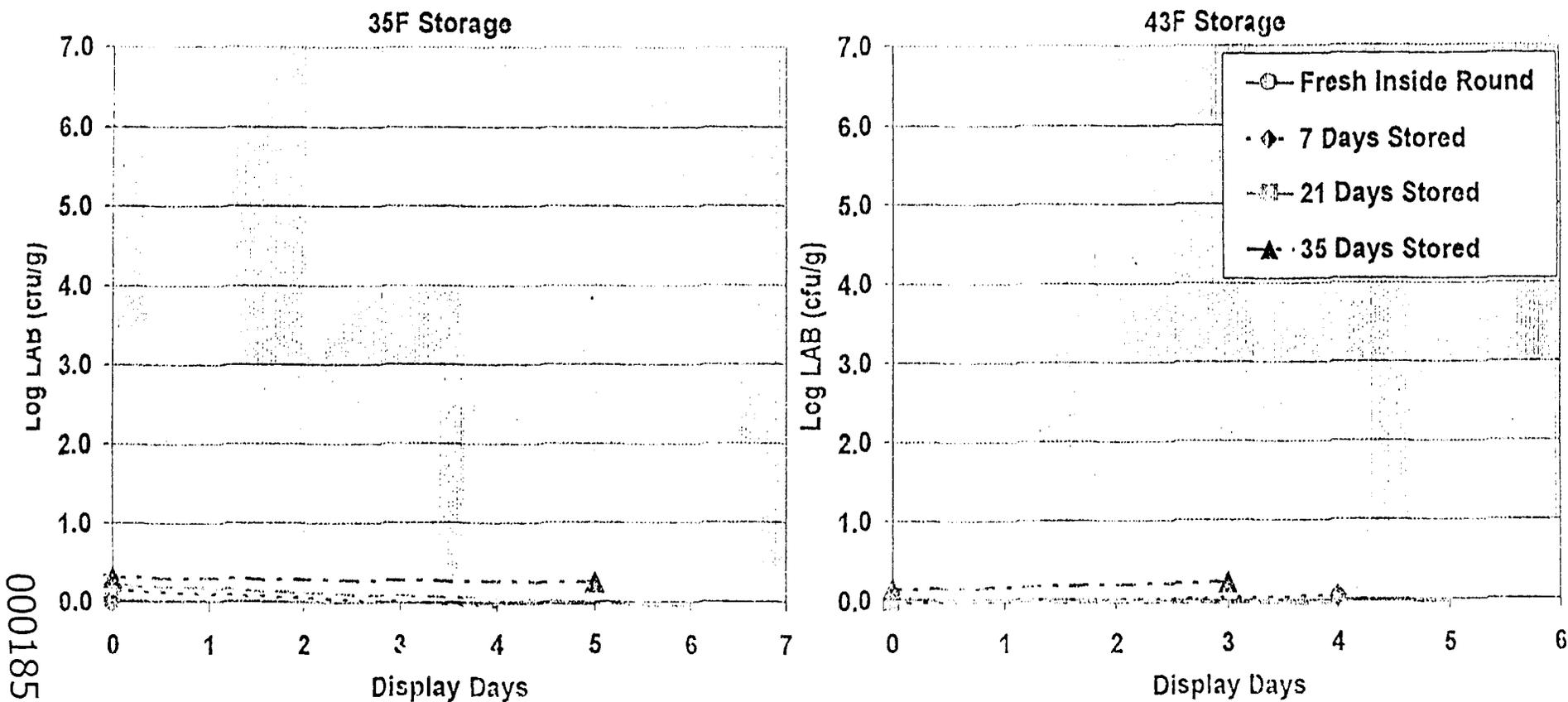
Figure 16

Strip Loin Lactic Acid Bacteria During Display Following Storage



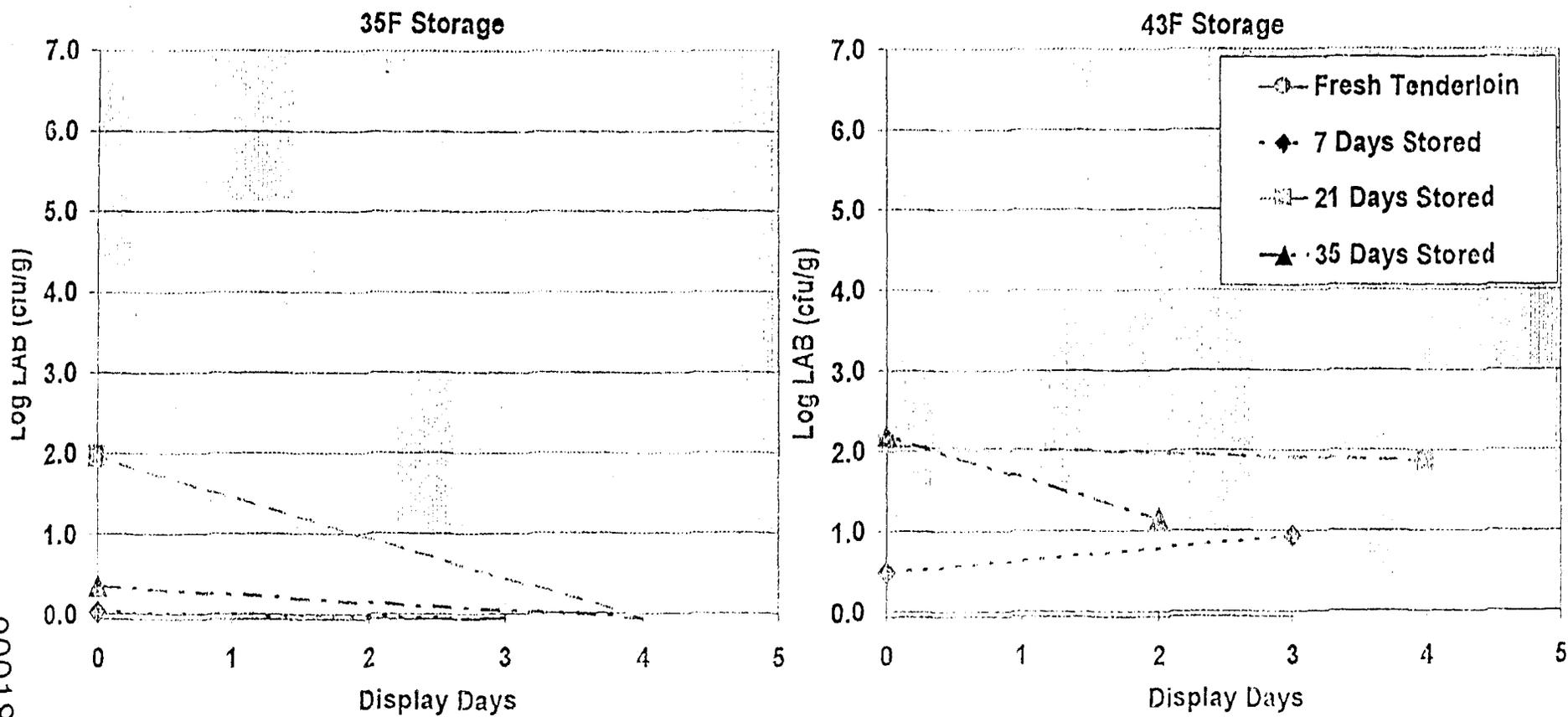
000184

Figure 17
Inside Round Lactic Acid Bacteria
During Display Following Storage



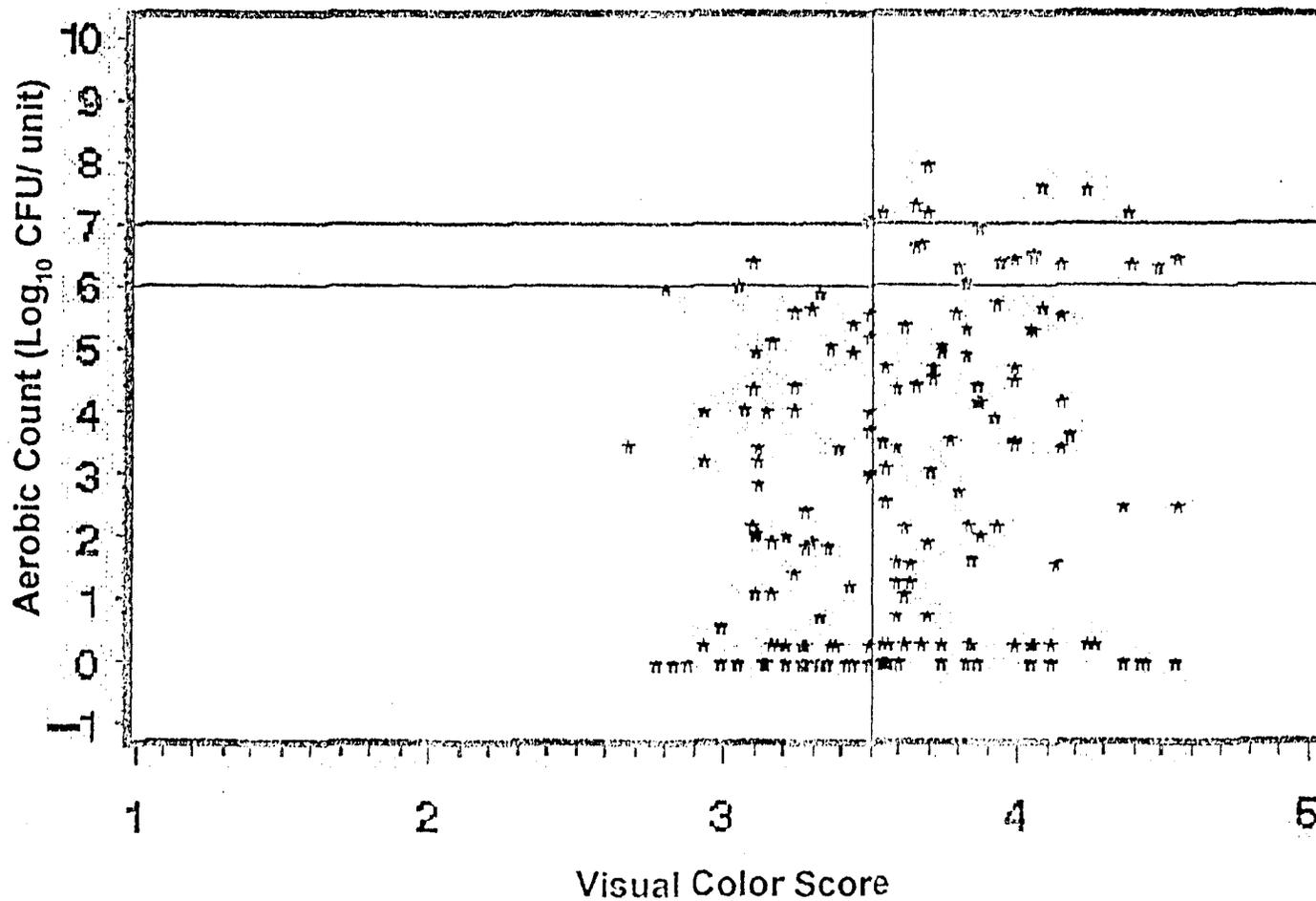
000185

Figure 18
Tenderloin Lactic Acid Bacteria
During Display Following Storage



000186

Figure 19
Aerobic Plate Count \log_{10} CFU vs Visual Color



000187

000188

Figure 20
Lactic Acid Bacteria Count \log_{10} CFU vs Visual Color

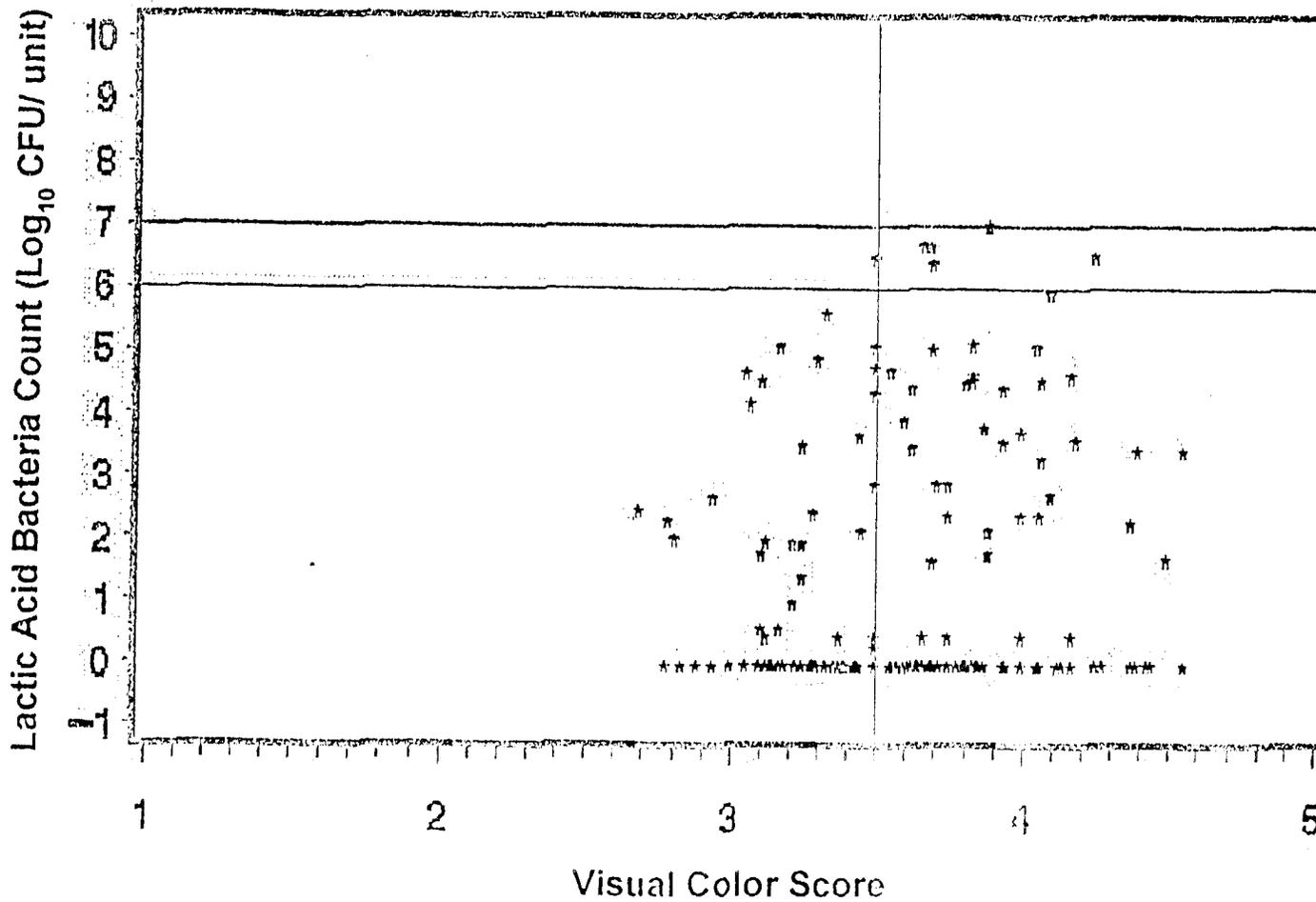
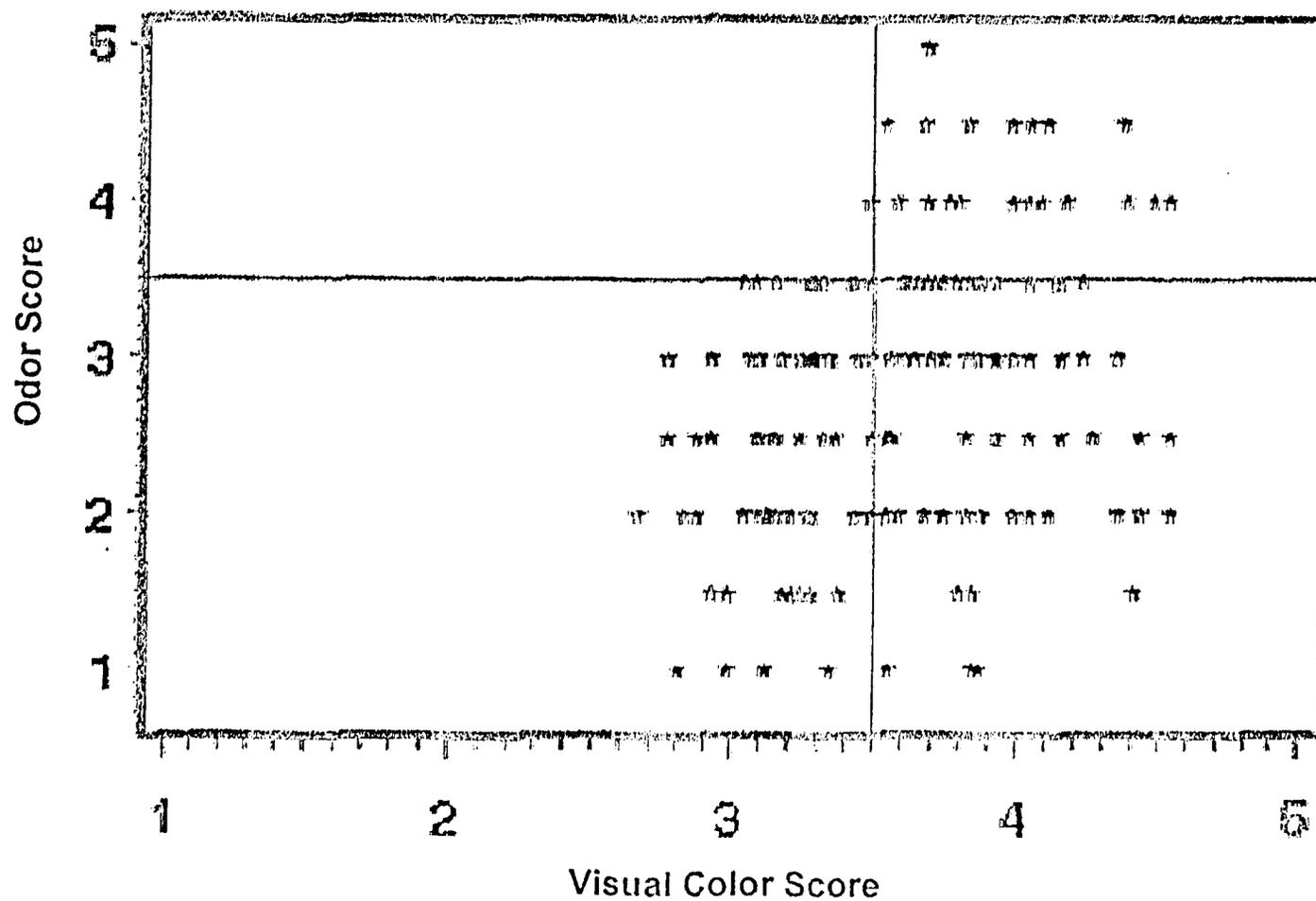


Figure 21
Odor vs. Visual Color



681000