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OLSSON, FRANK AND WEEDA, P.C.

ATTORNEYS AT LAW
SUITE 400
1400 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036-2220
(202) 789-1212
FACSIMILE (202) 234-3550

PHILIP C. OLSSON
RICHARD L. FRANK
DAVID F. WEEDA (1948-2001)
DENNIS R. JOHNSON
ARTHUR Y. TSIEN
JOHN W. BODE*
STEPHEN D. TERMAN
MARSHALL L. MATZ
MICHAEL J. O'FLAHERTY
DAVID L. DURKIN
NEIL F. O'FLAHERTY
PAMELA J. FURMAN
BRETT T. SCHWEMER
TISH E. PAHL
ROBERT A. HAHN

*PRACTICE WITHIN THE DISTRICT OF COLUMBIA IS LIMITED TO MATTERS AND PROCEEDINGS BEFORE FEDERAL COURTS AND AGENCIES

STEPHEN L. LACEY
EVAN P. PHELPS
VALERIE B. SOLOMON
JOLYDA O. SWAIM
KATHRYN E. BALMFORD

COUNSEL
NAOMI J. L. HALPERN

OF COUNSEL
JUR T. STROBOS
JACQUELINE H. EAGLE
KENNETH D. ACKERMAN
MARK L. ITZKOFF
DAVID A. BIEGING

SR. GOVERNMENT AFFAIRS ADVISOR
JOHN R. BLOCK
CHARLES W. STENHOLM
BRIAN E. JOHNSON
SALLY S. DONNER

Sender's Direct Phone (202) 518-6327
Sender's Direct Facsimile (202) 234-2686

March 7, 2005

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FOOD ADDITIVE SAFETY

BY FEDERAL EXPRESS

Office of Premarket Approval
(HFS-200)
Center for Food Safety and Applied Nutrition
Food and Drug Administration
5100 Paint Branch Parkway
College Park, MD 20740-3835

Re: GRAS Claim for the Use of Carbon Monoxide in Brine and Modified Atmosphere Packaging for Red Meat Products

Dear Sirs:

On behalf of our client, Freezing Machines, Inc., we are hereby submitting four (4) copies of a GRAS Notification for use of Carbon Monoxide in Brine and Modified Atmosphere Packaging for Red Meat Products.

Should you have any questions regarding this submission, please do not hesitate to contact me.

Sincerely yours,

Mark L. Itzkoff

MLI:jdm
Enclosures

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2005
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FOOD ADDITIVE SAFETY

GRAS Claim for the Use of Carbon Monoxide In Brine and Modified Atmosphere Packaging For Red Meat Products

Submitted by Freezing Machines, Inc.
March 7, 2005

Section I

GRAS Claim

Freezing Machines, Inc. hereby submits this GRAS claim for the use of carbon monoxide (CO) in brine and modified atmosphere packaging (MAP) for red meat products.

A. Name and Address of Notifier:

Freezing Machines, Inc.
891 Two Rivers Drive
Dakota Dunes, SD 57049

B. Common or Usual Name of Substance:

The common or usual name of the substance is carbon monoxide. The Chemical Abstract Services Registration Number (CASRN) for this substance is 630-08-0.

C. Conditions of Use:

In this Notification, CO will be used in water-based brine or marinade for MAP packaging for red meat products. This application is the same end use and technical purpose, MAP packaged red meat products, described in GRAS Notices GRASN 83 and 143. This Notice differs only in the method used to introduce CO to the food.

In the previous notices, CO was added to the gas mixture used to package the brined meat. In this application, CO will be introduced via the brine or marinade solution that is injected into the red meat products. The quantity of brine or marinade is limited to 27.8 percent by weight of the processed red meat ("28 percent pump"). At this level, the concentration of CO in the processed red meat will be equal to or less than the concentration that may be present from the applications described in GRASN's 83 and 143, *i.e.*, 1.88 mg/250 grams of red meat in the pre-cooked product.

D. Basis for GRAS Determination:

FDA has previously reviewed the safety of the use of CO in modified atmosphere packaging in two GRAS Notifications, GRASN 83 and 143. The data submitted to FDA in those Notices is hereby included by reference in this Notice.

The use of CO proposed herein will not result in any increased dietary exposure to CO. The dietary exposure will not increase because the potential concentration of CO in red meat processed using the method described in this Notice will be less than or equal to the levels that are expected to result from the applications detailed in the previous Notices. Since the final product of this instant application is the same product currently packaged using the process detailed in the previous Notices, the exposure to CO from this

proposed use is already included in the exposure estimates for the previous Notices, *i.e.*, there will be no increase in CO consumption. Since neither the concentration of CO in the processed food nor new applications for CO will result from the use described herein, there will be no increase in total dietary exposure. Therefore, the data used to support the two effective GRAS Notices also demonstrate the safety of CO in this application.

In addition to the question of CO consumption, a secondary safety question has been raised regarding the possibility that the use of CO in this application will "mask" normal spoilage of the processed red meat during storage prior to use by consumers. Freezing Machines, Inc has sponsored a study conducted by South Dakota State University, "Retail Display Life of Case-Ready Beef Steaks Enhanced by FMI Technology." This study demonstrates that the effect of the CO on retail cuts of red meat will dissipate before the end of the product's retail shelf life, and the retail cuts discolored to the point of rejection by a consumer panel before spoilage occurred.

E. **Data Availability Statement:**

The data and information that are the basis for the Notifier's GRAS determination will be sent to FDA upon request.

Respectfully Submitted,

Mark L. Itzkoff
Counsel for Freezing Machines, Inc.

Section II

Identity of the Notified Substance

The substance that is the subject of this Notice is Carbon Monoxide (CO), a colorless, odorless gas, with the CASRN 630-08-0. A Material Safety Data Sheet for this material is attached in Appendix I.

The specific CO used in this process will be commercial, "food grade" CO. The purity specifications will be the same as those set forth for CO in GRASN 143, *i.e.*, the minimum purity will be 98 percent carbon monoxide while the other 2 percent will be residual atmospheric gases (nitrogen, oxygen, carbon dioxide, argon, water, hydrogen and/or methane). Thus, the use of carbon monoxide set forth herein will not result in the introduction into processed red meat of any materials not previously considered under GRASN's 83and 143.

Section III

Information on Self-Limiting Levels of Use

As noted in Section I, this Notification is limited to the use of CO in brines and marinades that are injected into the red meat products. Notifier is proposing to limit the concentration of the brines and marinades to 27.8 percent by weight of red meat. As shown in the following calculation, even assuming that all of the CO in the brine is absorbed by the meat, the proposed limit on brine/marinade concentration will also limit the concentration of CO in the processed red meat to 0.136 mg per ounce of red meat, and will limit the concentration of CO to 1.3 mg per serving 250 g serving.

The solubility of carbon monoxide in water at room temperature is 21.4 ml/liter.

The density of CO at RT is 1.145 g/liter.

(21.4 ml)(1.145 g/1000 ml) = 24.5 mg

24.5 mg/liter = 2.45 mg/ 100 ml.

At the Notification limit for the pump (27.8% per 1 kg of red meat), 278 grams of brine/marinade will be added to each kilogram of red meat. Thus the total weight of one kilogram of injected red meat will be 1278 g.

Assuming that the density of the brine is 1.0 g/ml, 278 g of brine = 278 ml. The quantity of CO in the marinade used in 1 kg of red meat, assuming saturation of CO in the brine, will be:

(278 ml)(2.45 mg/100 ml) = 6.8 mg.

The concentration of CO in the red meat will be:

(6.8 mg)/[(1000 g red meat) + (278 g brine)] = 5.3×10^{-3} mg/g red meat.

For a 250 g portion of red meat, the quantity of CO that may be consumed would be:

(250 g)(5.3×10^{-3} mg/g) = 1.3 mg.

At 20 % pump, the maximum exposure will be 1.0 mg/250 g red meat.

This level is equivalent to the level estimated by Precept in GRASN 143 (1.2 mg CO/ 8.8 ounce serving) and is small when compared to the level of CO exposure deemed to be safe by the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA)[1]

In the previous GRASN's, both Precept Foods and Pactiv Corporation estimated that 85% of the CO present in the uncooked red meat would volatilize out of the meat during cooking. Using the same estimate, the quantity of CO present in 250 grams (8.8 ounces) of cooked red meat at the 27.8% pump level would be:

$$(1.3 \text{ mg})(0.15) = 0.195 \text{ mg}$$

At the 20% pump level, the quantity of CO would be 0.15 mg.

[1] "EPA's National Ambient Air Quality Standards is 9 ppm CO in air, resulting in the inhalation of 52 mg CO in 8 hours. The OSHA Permissible Exposure Limit is 50 ppm in air, resulting in the inhalation of 290 mg CO in 8 hours." FDA, Agency Response Letter GRAS Notice No. GRN 000143, July 29, 2004 (footnote 1).

Section IV

Basis for Notifier's Claim

The proposed use of carbon monoxide raises two safety issues: (1) an assessment of the safety of the consumption of CO from the application; and (2) whether the use of CO will "mask" the effect of spoilage organisms on the processed red meat.

The use of CO in the same food products (red meat) is the subject of GRAS Notification 143. The use of CO in this application for beef products was also the subject of GRASN 83. The information referenced in those Notices is hereby included in this Notice by reference. Further, as discussed in Section III, we have demonstrated that the method of application proposed by Freezing Machines, Inc will not result in any increase in the dietary consumption of carbon monoxide. Since neither the food products nor the potential concentration of CO in those food products will change, the data cited in support of the previous Notifications also demonstrates the safety of carbon monoxide when applied using the Freezing Machines process.

To answer the second issue, Freezing Machines has sponsored a study to review the impact of the new process on the appearance of the processed beef.[2] This study concluded that "the steaks in this study discolored to the point of unacceptability [to consumers] before the meat was spoiled by bacteria."[3] In other words, the use of CO did not mask the color changes associated by consumers with spoilage. Based on this study, Freezing Machines has determined that the proposed use of carbon monoxide will not affect the consumer's ability to discern the suitability of the processed beef.

Based on the information previously cited to FDA and the case-life study discussed above, Freezing Machines, Inc. has determined that carbon monoxide is generally recognized as safe when used in brine for pumping followed by modified atmosphere packaging. The CO saturated brine or solution is pumped into the red meat prior to MAP packaging, and will not exceed 27.8 percent by weight of the pre-brined meat.

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[2] Wulf et al, Retail Display Life of Case-Ready Beef Steaks Enhanced by FMI Technology, November 9, 2004. Attached as Appendix II.
[3] *Id.* At 3.

APPENDIX I

BOC GASES

MATERIAL SAFETY DATA SHEET

PRODUCT NAME: CARBON MONOXIDE

1. Chemical Product and Company Identification

BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974

TELEPHONE NUMBER: (908) 464-8100
24-HOUR EMERGENCY TELEPHONE NUMBER:
CHEMTREC (800) 424-9300

BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6

TELEPHONE NUMBER: (905) 501-1700
24-HOUR EMERGENCY TELEPHONE NUMBER:
(905) 501-0802
EMERGENCY RESPONSE PLAN NO: 20101

PRODUCT NAME: CARBON MONOXIDE
CHEMICAL NAME: Carbon Monoxide
COMMON NAMES/SYNONYMS: Carbonic Oxide, Exhaust Gas, Flue Gas
TDG (Canada) CLASSIFICATION: 2.3 (2.1)
WHMIS CLASSIFICATION: A, D1A, D2A, D2B, B1

PREPARED BY: Loss Control (908)464-8100/(905)501-1700
PREPARATION DATE: 6/1/95
REVIEW DATES: 6/7/96

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2. Composition, Information on Ingredients

INGREDIENT	% VOLUME	PEL-OSHA[1]	TLV-ACGIH[2]	LD_{50} or LC_{50} Route/Species
Carbon Monoxide FORMULA: CO CAS: 630-08-0 RTECS #: FG3500000	100.0	50 ppm TWA	25 ppm TWA	LC_{50} 1807 ppm/4H (rat)

[1] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)
[2] As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents

3. Hazards Identification

EMERGENCY OVERVIEW

Inhaled Carbon Monoxide binds to the blood hemoglobin, greatly reducing the red blood cell's ability to transport oxygen to body tissues. Effects may include headaches, dizziness, convulsions, loss of consciousness and death. Extremely flammable gas.

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ROUTE OF ENTRY:

Skin Contact	Skin Absorption	Eye Contact	Inhalation	Ingestion
No	No	No	Yes	No

HEALTH EFFECTS:

Exposure Limits	Irritant	Sensitization
Yes	No	No
Teratogen	Reproductive Hazard	Mutagen
Yes	Yes	Yes
Synergistic Effects None Reported		

Carcinogenicity: -- NTP: No IARC: No OSHA: No

EYE EFFECTS:
None reported.

SKIN EFFECTS:
None reported.

INGESTION EFFECTS:
None reported.

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INHALATION EFFECTS:
Inhaled carbon monoxide binds with blood hemoglobin to form carboxyhemoglobin. Carboxyhemoglobin can not take part in normal oxygen transport, greatly reducing the blood's ability to transport oxygen. Depending on levels and duration of exposure, symptoms may include headache, dizziness, heart palpitations, weakness, confusion, nausea, and even convulsions, eventual unconsciousness and death.

Some experimental evidence indicating teratogenic and reproductive effects.

NFPA HAZARD CODES		HMIS HAZARD CODES		RATINGS SYSTEM
Health:	2	Health:	2	0 = No Hazard
Flammability:	4	Flammability:	4	1 = Slight Hazard
Reactivity:	0	Reactivity:	0	2 = Moderate Hazard
				3 = Serious Hazard
				4 = Severe Hazard

4. First Aid Measures

EYES:
None required.

SKIN EFFECTS:
None required.

INGESTION:
None required.

INGESTION EFFECTS:
None required.

INHALATION:
Conscious persons should be assisted to an uncontaminated area and be treated with supplemental oxygen. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area and be given artificial respiration and oxygen at the same time. The administering of the oxygen at an elevated pressure (up to 2 to 2.5 atmospheres) has shown to be beneficial as has treatment in a hyperbaric chamber. The physician should be informed that the patient has inhaled toxic quantities of carbon monoxide. PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE TO CARBON MONOXIDE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND BE COGNIZANT OF EXTREME FIRE AND EXPLOSION HAZARD.

5. Fire Fighting Measures

Conditions of Flammability: Flammable gas		
Flash point: Not Available	Method: Not Applicable	Autoignition: Temperature: 116 °F (639 °C)
LEL(%): 12.5	UEL(%): 74.0	
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: Not Available		

FIRE AND EXPLOSION HAZARDS:
Having almost the same density as air, it will not diffuse by rising as with some lighter flammable gases such as hydrogen or natural gas (methane). Flammable in air over a very wide range. It reacts violently with oxygen difluoride and barium peroxide.

EXTINGUISHING MEDIA:
Water, dry chemical, carbon dioxide.

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FIRE FIGHTING INSTRUCTIONS:
If possible, stop flow of gas; use water spray to cool surrounding containers.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in user's equipment, be certain to purge piping with inert gas prior to attempting repairs. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage

Electrical Classification:
Class 1, Group C

Earth-ground and bond all lines and equipment associated with the carbon monoxide system. Electrical equipment should be non sparking or explosion proof.

Carbon Monoxide can be handled in all commonly used metals up to approximately 500 psig (3450 kPa). Above that pressure it forms toxic and corrosive carbonyl compounds with some metals. Carbon steels, aluminum alloys, copper and copper alloys, low carbon stainless steels and nickel-based alloys such as Hastelloy A, B & C are recommended for higher pressure applications.

Protect cylinders from physical damage. Store in cool, dry, well-ventilated areas away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 130°F (54°C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time. Post "NO SMOKING OR OPEN FLAMES" signs in the storage area or use area. There should be no sources of ignition in the storage area or use area.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the system.

ENGINEERING CONTROLS:
Hood with forced ventilation. Use local exhaust to prevent accumulation above the exposure limit. Use general mechanical ventilation in accordance with electrical codes.

8. Exposure Controls, Personal Protection

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EXPOSURE LIMITS[1]:

INGREDIENT	% VOLUME	PEL-OSHA[2]	TLV-ACGIH[3]	LD_{50} or LC_{50} Route/Species
Carbon Monoxide FORMULA: CO CAS: 630-08-0 RTECS #: FG3500000	100.0	50 ppm TWA	25 ppm TWA	LC_{50} 1807 ppm/4H (rat)

[1] Refer to individual state of provincial regulations, as applicable, for limits which may be more stringent than those listed here.
[2] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)
[3] As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

EYE/FACE PROTECTION:
Safety goggles or glasses.

SKIN PROTECTION:
Any material protective gloves.

RESPIRATORY PROTECTION:
Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:
Safety shoes.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure	: >220.4	psia
Vapor density (Air = 1)	: Not Available	
Evaporation point	: Not Available	
Boiling point	: -312.7	°F
	: -191.5	°C
Freezing point	: -337.1	°F
	: -205.1	°C
pH	: Not Available	
Specific gravity	: 0.96	
Oil/water partition coefficient	: Not Available	
Solubility (H20)	: Very slight	
Odor threshold	: Not Applicable	
Odor and appearance	: Odorless; colorless gas	

10. Stability and Reactivity

STABILITY:
Stable

INCOMPATIBLE MATERIALS:
Oxidizers

HAZARDOUS DECOMPOSITION PRODUCTS:
Carbon dioxide

HAZARDOUS POLYMERIZATION:
Will not occur.

11. Toxicological Information

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REPRODUCTIVE:
Inhalation of 150 ppm carbon monoxide for 24 hours by pregnant rats produced cardiovascular and behavioral defects in offspring. Toxic effects to fertility were observed in female rats exposed to 1 mg/m^3 for 24 hours. Similar effects observed in other mammalian species.

MUTAGENIC:
Genetic changes observed in mammalian cell assay systems at exposures of 1500 to 2500 ppm for 10 minutes.

OTHER:
Degenerative changes to the brain in rats chronically exposed to 30 mg/m^3.

12. Ecological Information

No data given.

13. Disposal Considerations

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED, WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to BOC Gases or authorized distributor for proper disposal.

14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Carbon Monoxide	Carbon Monoxide
HAZARD CLASS:	2.3	2.3 (2.1)
IDENTIFICATION NUMBER:	UN 1016	UN 1016
SHIPPING LABEL:	POISON GAS, FLAMMABLE GAS	POISON GAS, FLAMMABLE GAS

Additional Marking Requirement: "Inhalation Hazard"
Additional Shipping Paper Description Requirement: "Poison-Inhalation Hazard, Zone D"

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:
Acute Health Hazard
Chronic Health Hazard
Fire Hazard
Sudden Release of Pressure Hazard

16. Other Information

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Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

DISCLAIMER OF EXPRESSED AND IMPLIED WARRANTIES:
Although reasonable care has been taken in the preparation of this document, we extend no warranties and make no representations as to the accuracy or completeness of the information contained herein, and assume no responsibility regarding the suitability of this information for the user's intended purposes or for the consequences of its use. Each individual should make a determination as to the suitability of the information for their particular purpose(s).

APPENDIX II

Retail Display Life of Case-Ready Beef Steaks Enhanced by FMI Technology

A Report to Freezing Machines Inc.
891 Two Rivers Drive
Dakota Dunes, SD

Duane Wulf, Tanya Koger, and Robert Maddock
South Dakota State University

November 9, 2004

SDSU

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Materials and Methods

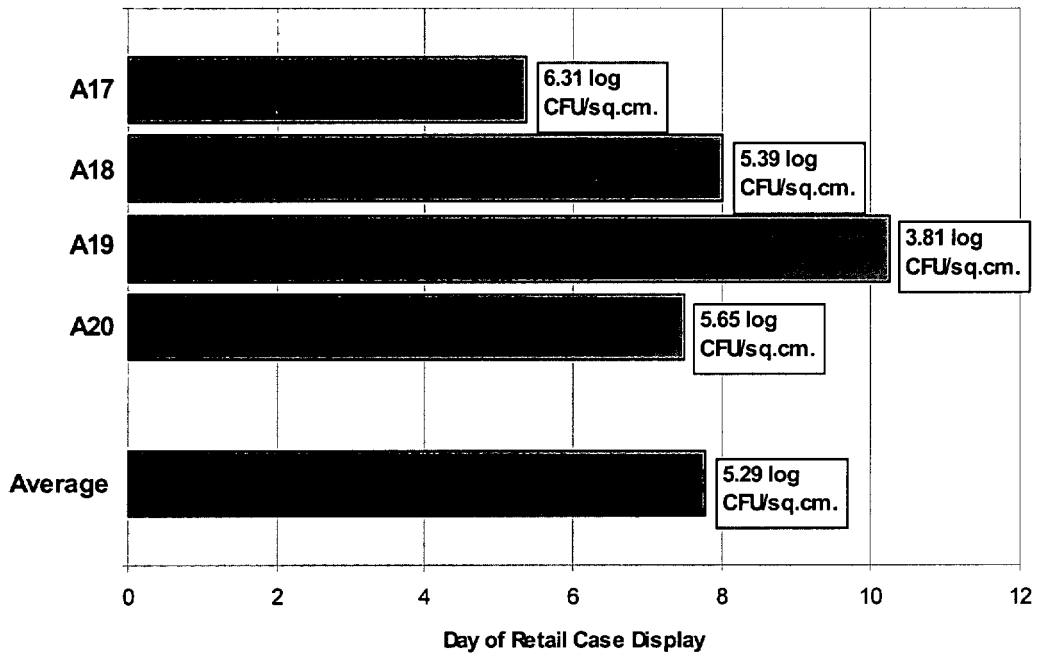
Retail Display. Upon arrival to the SDSU Meat Lab, all steaks were held in dark storage in boxes at 39°F. Steaks were removed from dark storage on d 7 after FMI enhancement, and assigned a random number within each subprimal (4 subprimals). Three of the subprimals had 12 steaks and one of the subprimals had 11 steaks. The steaks were randomly placed on tables in a cooler at 39°F under cool fluorescent lighting. The lighting was 1000 to 1800 lux at the steak surface level. Steaks were evaluated subjectively for color at approximately the same time each day for eleven days of retail display. Subjective evaluation was performed by a four-member trained panel. Panelists were trained using the process of open discussion. Evaluators assigned scores to the steaks for lean muscle color and percent surface discoloration. Lean muscle color (oxygenated pigment) was characterized on an 8-point scale (8 = bright cherry-red, 7 = moderately bright cherry-red, 6 = cherry-red, 5 = slightly dark-red, 4 = moderately dark-red or brown, 3 = dark-red or brown, 2 = very dark-brown, 1 = extremely dark-brown or green). Percent surface discoloration was characterized on an 8-point scale (8 = none, 7 = 1-5%, 6 = 6-10%, 5 = 11-25%, 4 = 26-50%, 3 = 51-75%, 2 = 76-99%, 1 = complete). At each evaluation time, the evaluators also answered yes or no to the question "Do you think that the average consumer would purchase this steak today?" Once three out of the four panelists indicated that the average consumer would not purchase that steak, it was considered "too discolored to sell" and removed from the retail display and frozen. The 5th, 6th, and 7th steaks to be considered "too discolored to sell" from each subprimal were used for microbial analysis, meaning that 12 steaks were used for microbial analysis (4 subprimals × 3 steaks per subprimal = 12 steaks).

Microbiological Analyses. Frozen steaks were kept in the original modified-atmosphere case-ready package and defrosted in a 113°F water bath for approximately 7 minutes. The package was opened with a sterile scalpel blade to expose the steak surface. A sterile scalpel blade and sterile template was used to cut around the edge of a 10-cm^2 (approximately 2-mm-thick) area. This area was then removed from the center of each steak using flame-sterilized forceps to hold the steak and a sterile scalpel to cut under the 10-cm^2 area. The 10-cm^2 sample was placed in a stomacher bag along with 100 mL of Butterfield's Buffer (Weber Scientific, Hamilton, NJ) and macerated in a stomacher for 2 min. Several 100-fold serial dilutions with 99 mL of Butterfield's Buffer were obtained for each sample. Plating was performed in duplicate with Standard Methods Agar (Becton, Dickinson, and Company, Sparks, MD). The plates were incubated at 95°F for 48 h. The plates were counted and the duplicate plates averaged. The number of CFU/mL in the stomacher bag were calculated, and then multiplied by 100 since there were 100 mL in the bag. We then divided that number by 10 to get CFU/cm^2. The counts were then converted to logarithms and then the three replications from each subprimal were averaged and reported as log CFU/cm^2. We analyzed for CFU per cm^2 versus CFU per gram because we were testing an intact muscle cut versus a ground meat product. Most of the data in the scientific literature for intact steaks are expressed on a per-cm^2 basis, whereas most of the data in the scientific literature for ground meat are expressed on a per-gram basis. Microbial data for intact steaks is typically presented on a per-cm^2 basis because we assume that the interior of whole muscle cuts is virtually sterile and bacteria are only present on the surface of the cut. Therefore, the bacteria counts presented in this report are probably slightly higher (expressed on a per-cm2 basis) than they would be if they were expressed on a per-gram basis.

Results

Based on visual appraisal, the Freezing Machines Inc. (FMI) steaks had an average retail caselife of 7.8 days, beyond the 7 days of dark storage, until the panelists determined the steaks were "too discolored to sell" (Figure 1). The length of retail caselife varied between subprimals; the steaks from subprimal A19 averaged 10.3 days of retail caselife, whereas the steaks from subprimal A17 averaged only 5.4 days of retail display. The average aerobic plate count at the end of visual caselife was 5.29 log CFU/cm^2 (Figure 1). Longer display times did not necessarily lead to greater bacterial counts; in fact, the steaks that had the longest caselife (A19) had the lowest bacterial counts. These plate counts were assessed when each individual steak was determined to be "too discolored to sell", because the objective was to determine if the visual caselife ended before or after the meat was spoiled by bacteria. Based on a review of scientific literature, aerobic plate counts of greater than 8 log CFU/g of meat would produce off-flavors (Walker, 1980), and aerobic plate counts of greater than 7 log CFU/g of meat are considered indicative of spoilage (Ayres, 1960; Branen, 1978). The microbial counts in this study were all less than 7 log CFU/cm^2, and because bacteria counts expressed on a per-cm^2 basis would be less if they were expressed on a per-gram basis (as described on page 2), we can conclude that these steaks had not reached the point of spoilage. Therefore, the steaks in this study discolored to the point of unacceptability <u>before</u> the meat was spoiled by bacteria. In other words, steaks enhanced by FMI technology were not spoiled at any time in the retail case while the color was still acceptable. Therefore, the enhanced caselife created from the application of FMI technology did <u>not</u> mask bacterial spoilage.

Figure 1. Retail caselife of steaks enhanced by FMI technology. Each bar represents the number of display days until the panel determined that the steaks were "too discolored to sell", averaged for each subprimal (A17 to A20) and overall. The bacteria counts represent the aerobic plate count on the day the steaks were determined "too discolored to sell".



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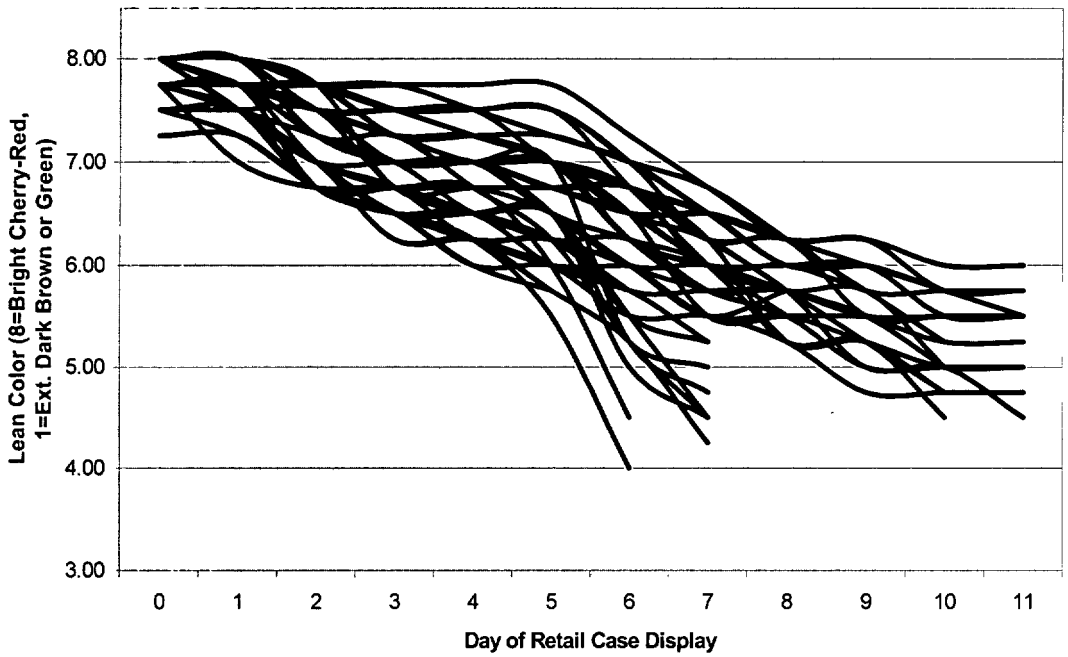
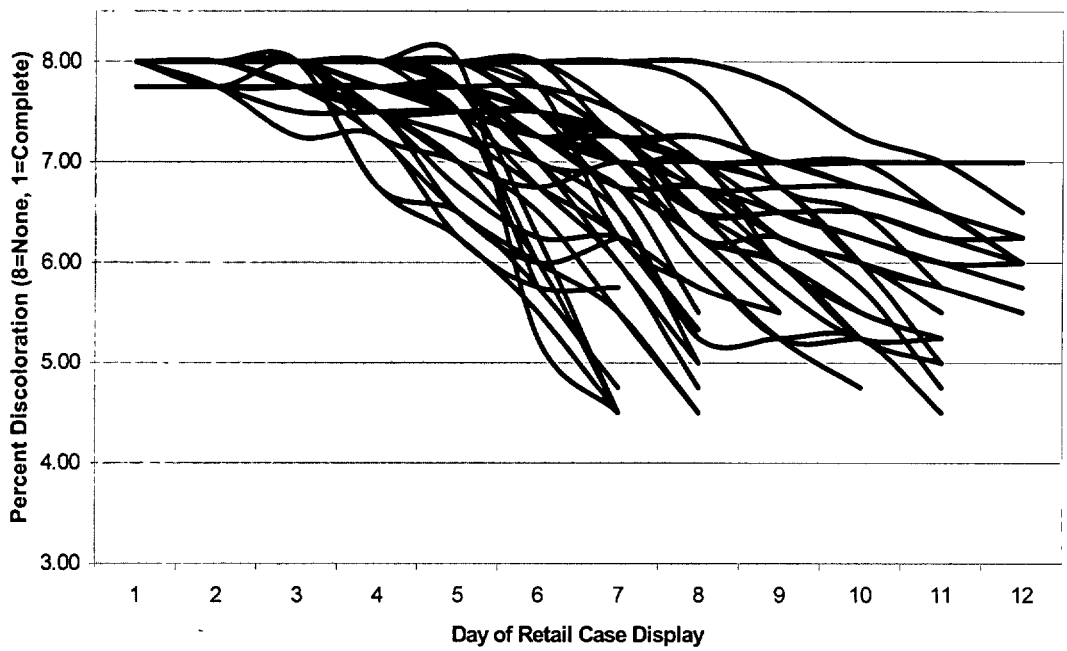
Lean color for each of the individual 47 steaks is shown in Figure 2. The color started to darken slightly on day 2 of retail display and continued to darken at a slow, but steady, rate through day 11 of retail display. These results indicate that case-ready steaks enhanced with FMI technology will gradually darken in color during retail display.

Figure 2. Lean color scores for 47 individual steaks enhanced by FMI Technology evaluated for 11 days of retail display. Each line terminates at the end of retail caselife for that particular steak, when the panel determined that the steak was "too discolored to sell".



Percent surface discoloration for each of the individual 47 steaks is shown in Figure 2. There was little to no surface discoloration on any of the steaks until day 4 of retail display. Most of the steaks showed their first surface discoloration on days 5 to 7 of retail display. One steak lasted 8 days and one steak lasted 9 days before any surface discoloration; however, all steaks eventually discolored. These results indicate that case-ready steaks enhanced with FMI technology will discolor during retail display.

Figure 3. Percent surface discoloration scores for 47 individual steaks enhanced by FMI Technology evaluated for 11 days of retail display. Each line terminates at the end of retail caselife for that particular steak, when the panel determined that the steak was "too discolored to sell".



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