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Improved quality of retail beef through control of bacterial spoilage

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Improved quality of retail beef through control of bacterial spoilage

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Prolifération des bactéries et qualité du boeuf au détail

SUMMARY

The retail case life of fresh beef is usually limited to 2 to 3 days due to the development of undesirable surface discoloration. This reduction in color acceptability has been shown to be related to the growth of psychrotrophic bacteria at the meat surface. The retailer can improve the keeping quality of beef by reducing the number of bacteria initially contaminating the meat and by controlling the growth of organisms which are present. Although the application of a rigorous program of retail sanitation will reduce the initial numbers of bacteria transferred to the meat surface the retailer has no control over the bacterial quality of carcasses or wholesale product received from the supplier. In this regard it has been shown that the level of contamination on wholesale cuts is more than one and one half times as important as retail sanitation in determining the case life of retail beef.

The nature of the retail display environment is such that beef is subjected to considerable temperature abuse resulting in limited case life. The following two practical methods of retail temperature control have been proposed 1) removal of beef from the retail case at the end of each work day and storage in a walk-in cooler overnight 2) a reduction in retail case temperature to maintain meat surface temperatures just above the freezing point. The application of these methods has been shown to result in a substantial increase in retail case life which would be economically beneficial to the retail beef industry. Also, proper retail temperature control should increase consumer satisfaction following meat purchases due to improved keeping quality in home refrigerators.

RÉSUMÉ

La durée de conservation du boeuf frais en étalage chez le détaillant se limite habituellement à deux ou trois jours en raison du brunissement progressif de la viande en surface. Il a été démontré que cette altération de la viande est causée par la prolifération de bactéries psychrotrophes en surface. Le détaillant peut accroître la durée de conservation du boeuf en réduisant le nombre initial de bactéries qui contaminent la viande et en freinant la croissance des organismes présents. Cependant, bien qu'il puisse réduire le nombre de bactéries transmises à la surface de la viande en appliquant un programme d'assainissement rigoureux, il ne peut exercer aucun contrôle sur la qualité bactériologique des carcasses ou des produits de gros qu'il reçoit du fournisseur. Il a été démontré qu'à l'égard de la détermination de la durée de conservation du boeuf en étalage le degré de contamination des morceaux de gros est plus d'une fois et demie plus important que les mesures sanitaires appliquées chez le détaillant.

Le mode d'étalage des viandes chez le détaillant est tel que le boeuf est exposé à des excès de température qui réduisent sa durée de conservation. On propose deux méthodes de contrôle de la température à laquelle est exposée la viande: soit retirer la viande du comptoir à la fin de la journée et la conserver dans une chambre froide au cours de la nuit, soit réduire la température des comptoirs à viande de façon à maintenir la surface de la viande à des températures juste au-dessus du point de congélation. Il a été prouvé que l'application de ces mesures entraîne une augmentation substantielle de la durée de conservation de la viande au comptoir ce qui serait économiquement profitable au secteur du boeuf au détail. En outre, le contrôle adéquat des températures de la viande vendue au détail devrait accroître la satisfaction des consommateurs, ces derniers obtenant en effet des viandes se conservant plus longtemps.

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INTRODUCTION

Fresh, retail beef is conveniently displayed in illuminated, self-serve, refrigerated cabinets to facilitate consumer evaluation prior to purchase. Under these conditions, however, the quality of beef rapidly deteriorates and seldom remains acceptable for more than 2 to 3 days. It is the growth of bacteria on the meat surface which produces undesirable odors, slime, and surface discoloration making the product unacceptable to the consumer. As a consequence, if retail beef is not purchased within a relatively short time the retailer suffers considerable spoilage losses. It has recently been estimated that losses due to bacterial spoilage can be in excess of $24,000 per year for a single retail store. In view of the magnitude of these losses methods of controlling these detrimental spoilage bacteria are of prime importance to the retailer.

Although the retailer has no control over the level of contamination which accumulates during the pre-retail, primary, meat processing stages he has the potential to exert the final control on quality. Since the retailer occupies this key position it is necessary that he be knowledgeable of bacterial-induced spoilage and measures which can be applied to improve the keeping quality of retail meats. The intent of this overview is to outline the characteristics of bacteria relevant to beef spoilage and to recommend practical procedures by which bacterial growth can be retarded and retail case life substantially extended.

SOURCES OF BACTERIAL CONTAMINATION

There is sufficient evidence to conclude that the unexposed muscle tissues of healthy beef cattle are free from spoilage bacteria. However, the soiled hides, hooves and expelled faeces of slaughtered animals are the initial sources of carcass contamination throughout the various primary processing stages at the abattoir. Bacterial contamination from these sources is spread to the carcass surface via contact with knives, saws and meat handlers during carcass dressing and cooling. Increased handling during carcass breaking, the fabrication of primal and subprimal cuts and transport contributes significantly to the level of contamination. Thus, the ultimate bacterial quality of carcasses or wholesale cuts received by the retailer reflects the cumulative effects of processing contamination from slaughter to receipt at the retail store.

At the retail store, the retailer must contend with carcasses or wholesale product of unknown bacterial quality. It is unfortunate that the degree of contamination on the surface of this starting material provides a major reservoir for the bacterial contamination of the freshly exposed surfaces of retail beef. However, the retailer can, through frequent sanitization, reduce the levels of bacteria contaminating work surfaces, and the hands and apparel of meat cutters. In this regard, it has been shown that the implementation of a rigid retail sanitation program can result in an economically beneficial extension of beef retail case life. The relative contribution of wholesale and retail contamination to beef case life will be discussed further in a subsequent section.

BACTERIA AND RETAIL BEEF SPOILAGE

The presence of glucose, soluble nitrogen-containing compounds, vitamins, minerals and a high moisture content makes fresh beef a highly nutritious medium readily supporting the growth of a number of bacterial species. From the standpoint of spoilage, the bacteria of concern to the industry are those whose growth results in esthetically undesirable changes in product quality. Since fresh beef is subjected to continuous refrigeration during processing and throughout retail display, these spoilage organisms must be able to survive and grow at low temperatures. Appropriately, the term psychrotroph, meaning "cold-thriving" or "cold-increasing" has been adopted to describe species of bacteria capable of growth at 5°C and below. The predominant psychrotrophic bacteria associated with aerobically spoiled beef, other red meats and poultry are members of the genus Pseudomonas. These small rod-shaped bacteria (Fig. 1) are not harmful to man but their growth and metabolic activities at the meat surface results in discoloration, off-odors, slime formation and undesirable flavors. It should be stressed, that with the exception of extremely advanced stages of beef spoilage bacterial growth is restricted to the outer few millimeters of the meat surface. In the case of ground beef, however, spoilage bacteria are distributed throughout the product during grinding.

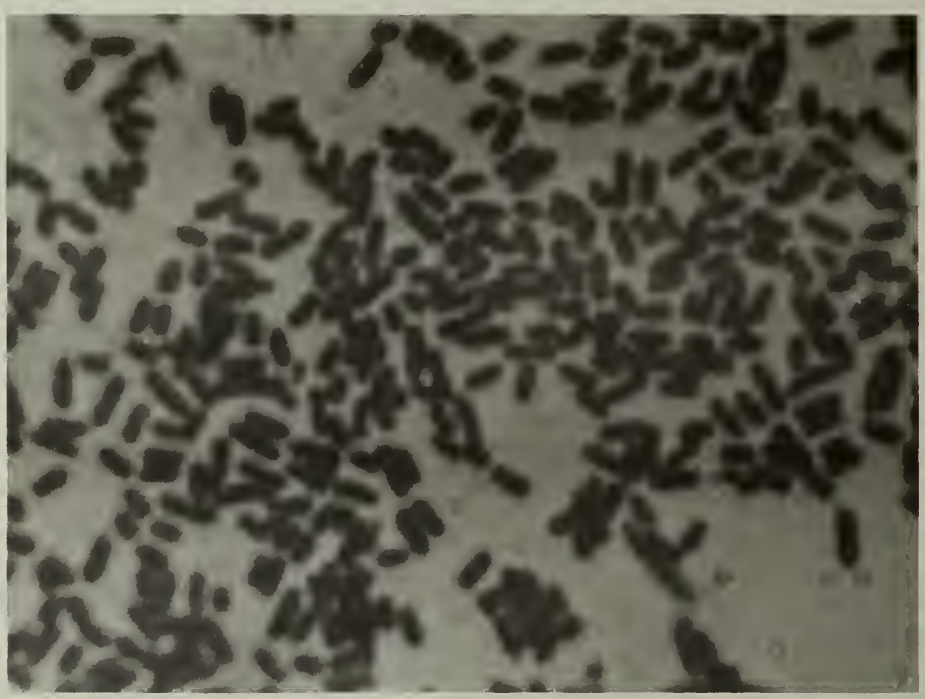

Fig. 1. These small bacteria growing on the surface of beef reduce retail case life. Bacteria were isolated from the surface of spoiled rib-eye steaks, stained and magnified 3,000 x using a light microscope.

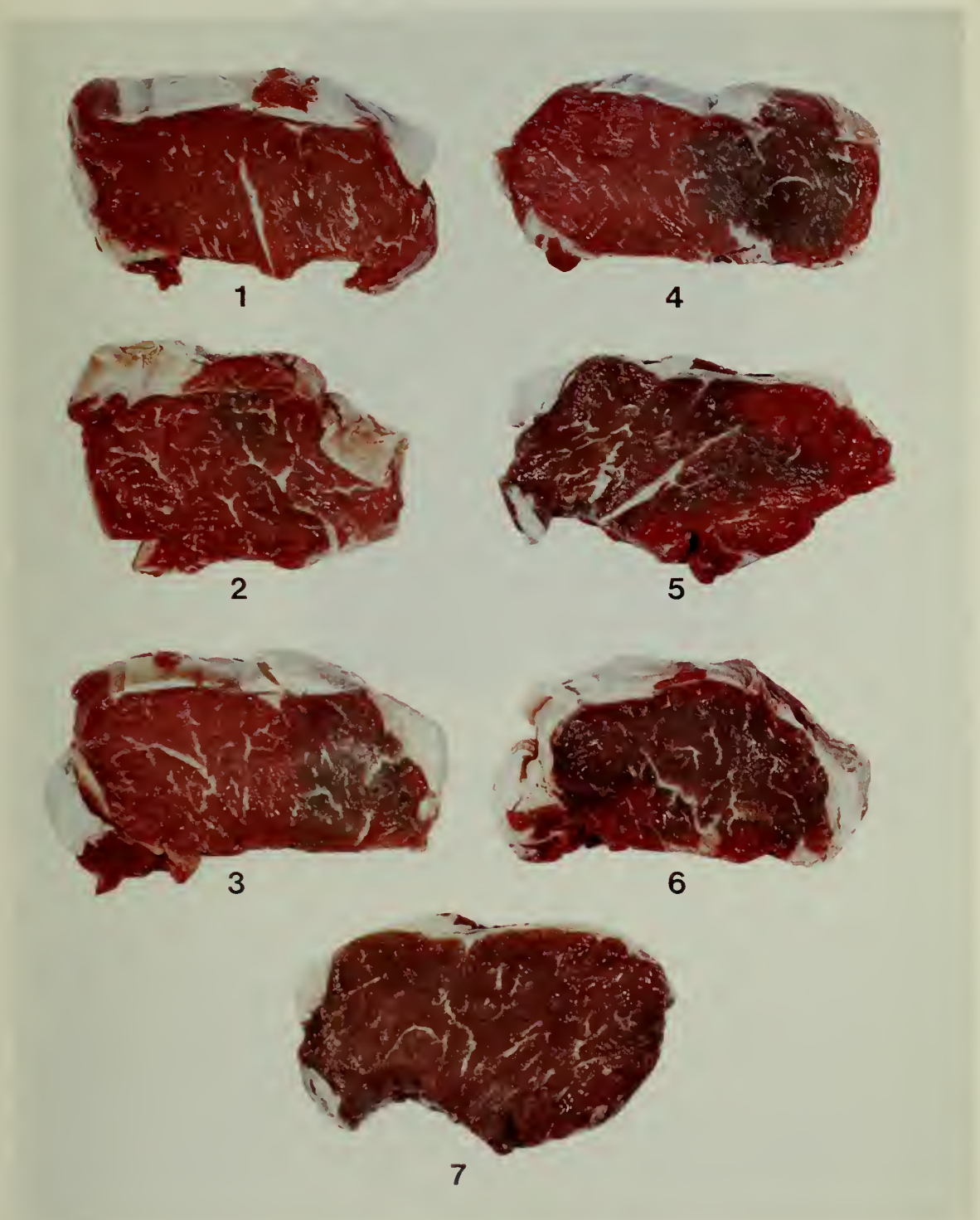

Fig. 2. The progressive increase in the undesirable brown surface discoloration on steaks results in spoilage losses.

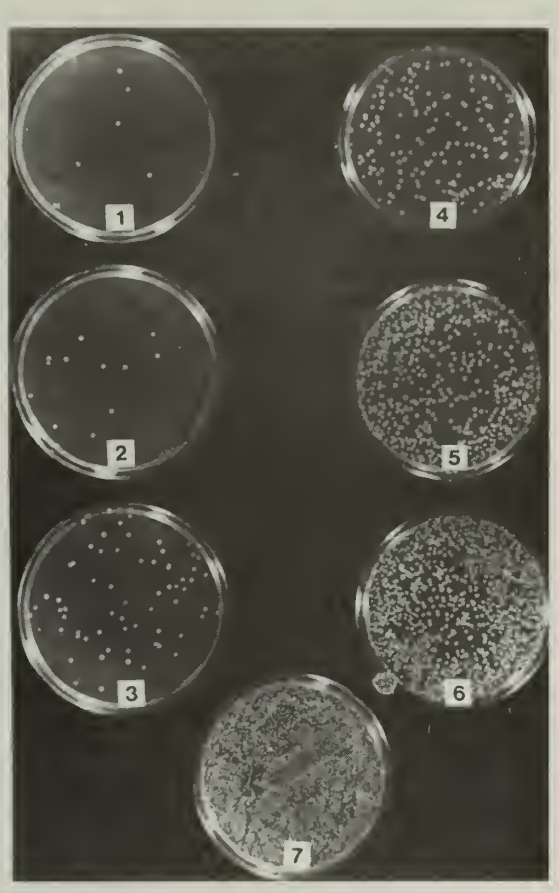

Fig. 3. The amount of steak surface discoloration is dependent upon the number of bacteria growing on the meat surface. Bacteria appearing on the culture plates 1 to 7 were isolated from the steaks depicted in Fig. 2.1 to 2.7, respectively.

Of the bacteria-related sensory changes occurring in overwrapped, retail beef cuts, surface discoloration is the most relevant. Relative to this, it is the first alteration in product quality which becomes evident in the time course of spoilage. Off-odors, objectionable flavors and slime are not apparent until much later and odors and flavors cannot be evaluated until the meat has been purchased, opened and/or prepared for consumption in the home. Furthermore, studies have shown that color is one of the major quality attributes influencing consumer selection of retail beef. If there are significant deviations from the acceptable color of fresh beef, the meat becomes unacceptable to the consumer and the retailer incurs losses.

BACTERIAL GROWTH, BEEF SURFACE DISCOLORATION AND RETAIL CASE LIFE

In view of the importance of color to beef acceptability, the extent of bacterial-induced surface discoloration can be used as a measure of retail beef case life. As bacteria grow on the meat surface they accelerate the oxidation of meat pigments which results in a progressive deterioration of the

acceptable red color (Fig. 2.1) and the appearance of varying degrees of brown surface discoloration (Fig. 2.1 to 2.7) until the steak is completely discolored (Fig. 2.7). When the rib-eye steaks depicted in Fig. 2 were sampled, and cultured on a suitable nutrient medium and incubated for a specified period of time, small colonies of bacteria appeared (Fig. 3). Although the steak exhibiting no surface discoloration (Fig. 2.1) contains relatively few bacteria (Fig. 3.1) as the extent of steak surface discoloration increases (Fig. 2.2 to 2.7) there is a substantial increase in the number of bacteria which can be isolated from the steak surface (Fig. 3.2 to 3.7). It should be re-emphasized that the relationship between bacterial numbers and surface discoloration is based upon psychrotrophic counts obtained following incubation at 7°C for 10 days.

The number of bacteria present on the meat surface can be estimated by counting colonies on culture media such as those depicted in Fig. 3. By sampling steaks on a daily basis and determining bacterial numbers it is possible to construct a bacterial growth curve. At the same time the appearance of steaks can be evaluated by a sensory panel and scored for the extent of surface discoloration and overall retail acceptance. In the laboratory, 7-point sensory scales are routinely used to evaluate both discoloration (1 = no discoloration, 7 = complete discoloration) and retail acceptance (1 = extremely undesirable; 7 = extremely desirable). The data presented in Figs. 4 and 5 show bacterial growth, steak surface discoloration and retail acceptance for 50 rib-eye steaks displayed for up to 4 days under simulated retail conditions. Initially, it is evident that the onset and rate of steak surface discoloration closely parallels that of bacterial growth (Fig. 4).

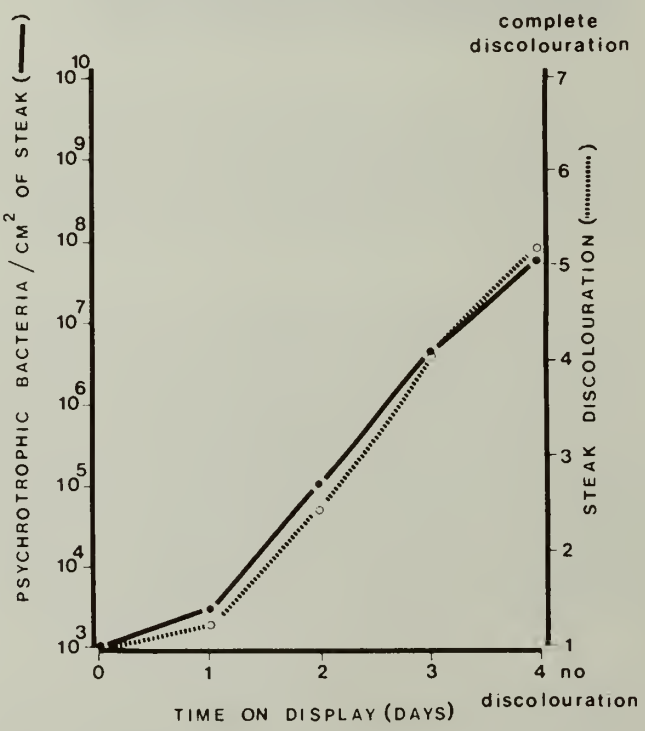

Fig. 4. The increase in the extent of steak surface discoloration (▮▮▮▮▮▮▮▮▮▮) closely follows the growth of bacteria on the steak surface (▬▬▬▬) during retail display.

Furthermore, as the degree of steak surface discoloration progressively increases there is a concomitant decrease in the acceptability of retail steaks (Fig. 5). Thus, the extent of psychrotrophic bacterial-induced surface discoloration is the major factor limiting the shelf life of retail beef. Additional analyses of the data in Figs. 4 and 5 showed that if retail steaks have an initial bacterial load of about 1,000 bacteria/cm^2 they will become visually unacceptable within 2.5 days of retail display at which time bacterial numbers would approximate 1,000,000/cm^2 on the meat surface. It is noteworthy that this retail case life, determined in the laboratory, is in accordance with the 2 to 3 day case life reported under actual retail conditions.

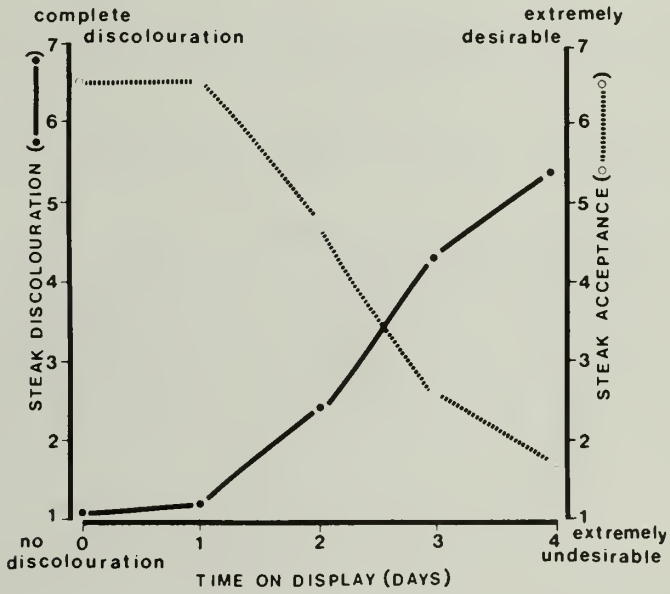

Fig. 5. The progressive decrease in the retail acceptance of steaks (▪▪▪▪▪▪▪▪▪▪▪) is due to increased surface discoloration (▬▬▬▬▬).

CONTROL OF RETAIL BEEF SPOILAGE

Sanitation

The case life of fresh beef is directly related to the initial number of psychrotrophic bacteria associated with the surface of retail cuts when they are first wrapped and placed in the retail display case. At low levels of contamination (10 bacteria/cm^2) case life will exceed 3 days, but with every 10-fold

increase in the initial bacterial load there is a corresponding two-fifths of a day decrease in case life and at bacterial loads approaching $10^8/cm^2$, case life is less than 1 day (Fig. 6). In view of this, the retailer must frequently sanitize knives, saws, cutting tables, grinders and the floors and walls of the cutting area to reduce the numbers of bacteria, transferred to the meat during the processing of retail cuts. The repeated use of suitable germicidal hand washes is also recommended to reduce the microflora associated with the hands of meat cutters. Actual retail store case studies have shown that an economically beneficial increase in meat case life can result from the application of a rigid sanitation program at the retail level.

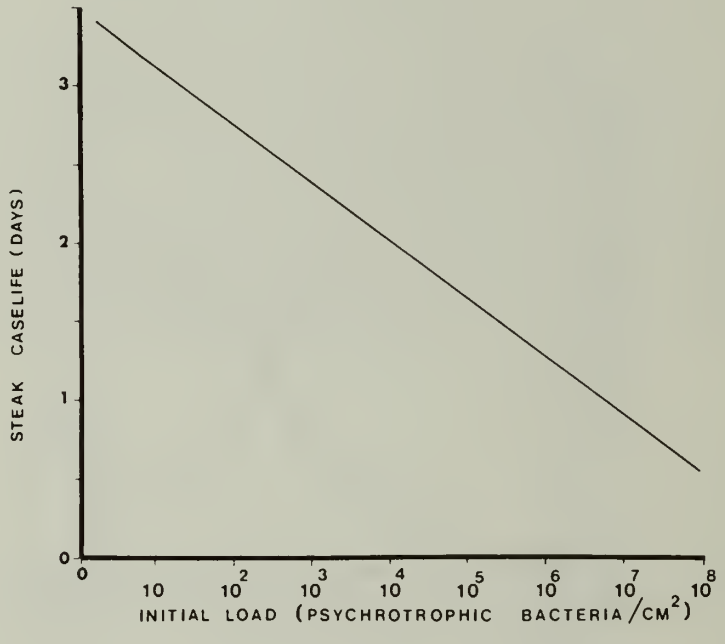

Fig. 6. As the number of psychrotrophic bacteria initially contaminating steaks increases there is a decrease in retail case life.

As cited earlier, an additional source of contamination for retail beef cuts is the surface of carcasses and wholesale product received by the retailer. The retailer has no control over the bacterial quality of this starting material and bacteria are readily transferred to the freshly cut meat surfaces during the fabrication of retail cuts. In the laboratory, studies were designed and conducted to determine the relative contribution of wholesale and retail contamination to the retail case life of rib steaks. This was accomplished by selecting wholesale ribs with varying degrees of surface contamination and fabricating rib-eye steaks using extremes of retail processing sanitation. The results

showed that a much greater amount of the variability in steak case life could be attributed to wholesale rib bacterial counts (45%) than the level of bacterial contamination on retail processing equipment (25%). In addition, wholesale rib contamination was found to be more than one and one half times as important as retail sanitation in determining retail beef case life. These findings do not negate the necessity of hygienic retail processing, but rather stress the need for improved sanitation throughout all levels of pre-retail processing. Conceivably, a conscientious retailer, employing strictly hygienic processing procedures, could fabricate retail cuts of inferior bacterial quality and reduced case life as a consequence of highly contaminated wholesale product.

The results of these laboratory simulated retail processing experiments also allows the derivation of an equation which should have practical application in predicting the retail case life of beef:

Retail Case Life = 3.97 - 0.19 (log bacteria/cm^2 on wholesale ribs)
-0.14 (log bacteria/cm^2 on retail processing equipment)

The numbers of bacteria determined on the surface of ribs and retail equipment are converted to common logarithms prior to applying the equation.

With knowledge of the level of retail sanitation and the bacterial quality of meat received by the retail outlet, retail case life could be predicted. Furthermore, this predictive equation would give the retailer some basis for quality control. Relative to this, by determining the retail case life of beef and the level of retail processing sanitation the above equation could be used by the retailer to assess the bacterial quality of product received from different suppliers. Subsequent beef purchases could then be directed towards suppliers providing product with lowest bacterial counts.

Temperature

Once retail beef cuts are overwrapped in the routinely used polyvinyl films and placed on display in the retail case, no further bacterial contamination is possible. At this point, it is the rate at which the resident bacteria grow that determines case life. Of the factors influencing bacterial growth, temperature is the most critical. Although beef spoilage bacteria are capable of growth, at a limited rate at 0°C, their growth rate increases rapidly with small increments in temperature and becomes optimal at about 25°C. The growth rate of a typical beef spoilage bacteria can double as the temperature of incubation increases from 1 to 5°C and can triple with a further increase to 10°C. Increased bacterial growth means reduced case life. In Fig. 7, the importance of temperature to the retail case life of rib steaks is clearly illustrated. Although at steak temperatures approaching 0°C a retail case life of about 8 days can be achieved, for each 1°C increase in temperature there is a coincident 0.63 day decrease in case life.

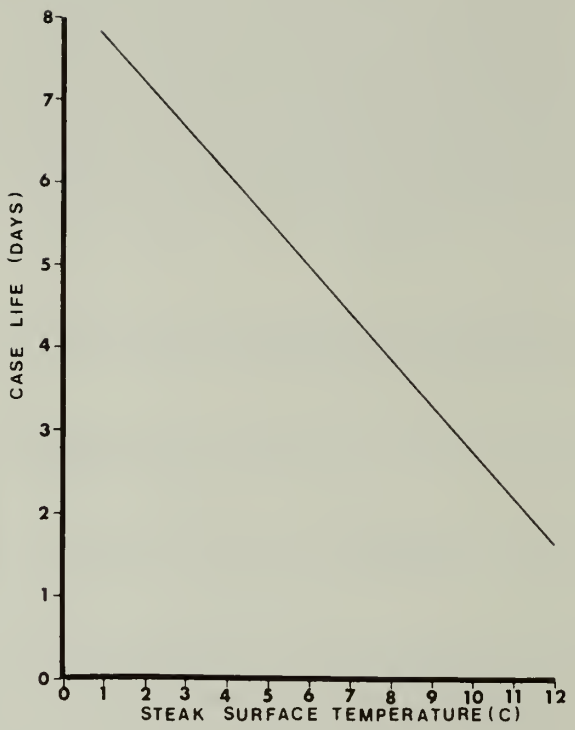

Fig. 7. The retail case life of steaks is directly related to the steak surface temperature.

Since the retail case life of beef is directly related to storage temperature a means of display is necessary which maintains low temperatures but at the same time allows visual evaluation of the cuts by the consumer. This is accomplished in most retail outlets by overwrapping beef in an oxygen permeable, polyvinyl wrap and displaying in open, refrigerated cases illuminated with sufficient lighting to enhance the meat appearance. Most display cases are horizontal or vertical, fan-assisted, convection type cabinets where air is cooled by passage over evaporator coils and then blown over the display case through ducts. The temperature of the display case is monitored by thermometers situated directly in front of the incoming blower air. In our laboratory, a commercially available, horizontal fan-assisted convection type retail case is used in studies of retail beef case life. The retail case operates at a mean blower temperature of -0.5°C and a case life of 2-3 days is usually observed for steaks on display. This temperature and case life are close to average values reported from surveys of retail outlets. Although this retail display temperature should be more than adequate for the preservation of beef quality it was noted that when steaks were stored in a walk-in cooler at a slightly higher temperature (1°C), case life was substantially extended to more than 9 days. The

deterioration in retail acceptance of steaks on retail display is compared to that of steaks stored in the cooler in Fig. 8. Clearly, the acceptability of steaks on retail display deteriorated much more rapidly when compared to those stored in a walk-in cooler. Although the appearance of steaks on display remained acceptable for only 3 days, those in the cooler were still visually acceptable after 9 days of storage. The reduced case life of retail displayed steaks was found to result from a more rapid growth of psychrotrophic bacteria on the steak surface.

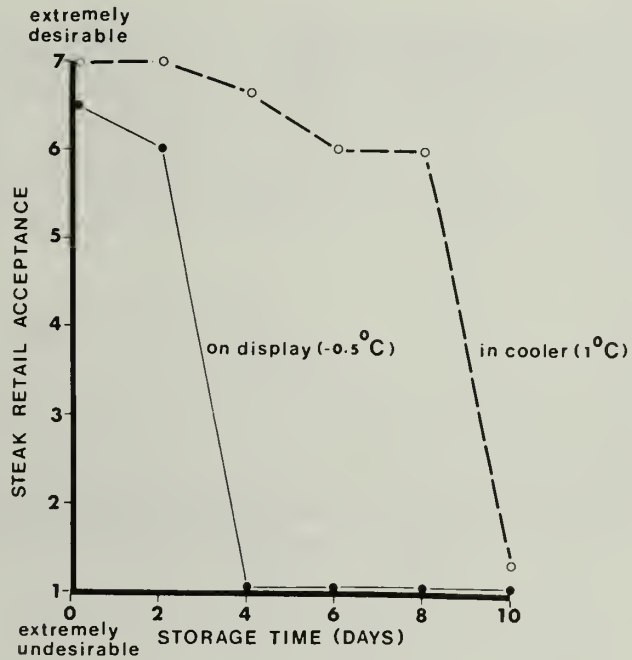

Fig. 8. When steaks are stored in a walk-in meat cooler (·▬▬▬·) they remain acceptable for a longer period of time when compared to steaks in a retail display case (▬▬▬).

These findings, at first glance, seem somewhat surprising since the actual temperature recorded at the retail case blower was slightly lower than that of the cooler. However, it should be stressed that retail case thermometers are a measure of the incoming blower air and do not necessarily reflect the temperature of the displayed meat. To establish the temperature of steaks, thermocouples can be used to continuously monitor fluctuations in steak surface temperature during retail display. A typical steak surface temperature profile for a 24 hour period of retail display is depicted in Fig. 9. It is immediately apparent that the actual surface temperature of steaks on retail display is

much higher than that recorded at the blower thermometer. In this particular case, the blower thermometer indicated a temperature of -0.5°C while displayed steak surface temperatures were on the average about 8°C higher (7.3°C). However, steaks stored in the walk-in cooler at 1°C did maintain a temperature of 1°C throughout the storage interval. These observations elucidate the unusual nature of the findings reported in Fig. 8. That is, the steaks stored in the walk-in cooler remained acceptable for a much longer period of time since they were maintained at a substantially lower temperature than steaks in the retail cabinet.

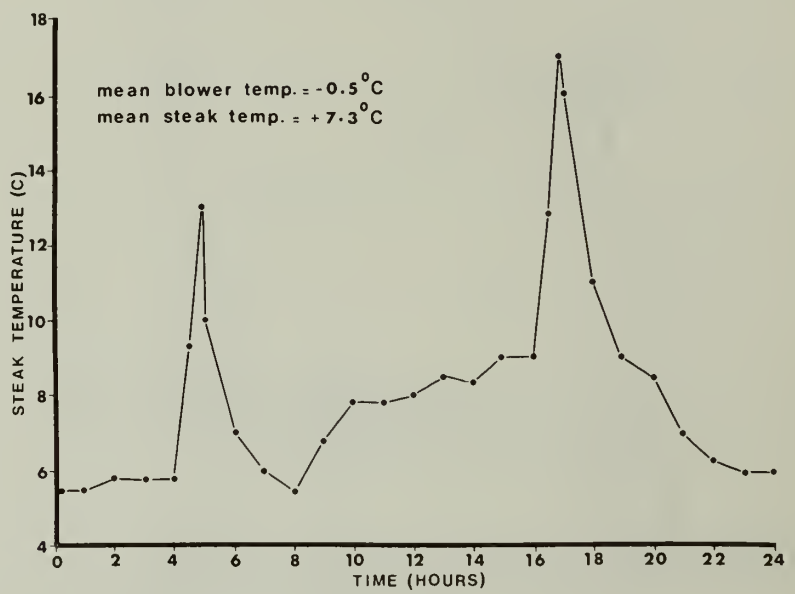

Fig. 9. The actual temperature at the surface of steaks on retail display exceeds that measured by the retail case thermometer.

In consideration of these findings one wonders as to why the temperature of beef in the retail case is excessively high and exceeds that measured by the blower thermometer. Part of the reason can be found in Fig. 9. At regular 12 hour intervals the retail case automatically defrosts and at this time steak surface temperatures can approach 17°C. Another important consideration is the intensity and duration of display illumination. The display case in the studies described herein was illuminated with 150 watt incandescent, cool-beam floodlights to give a light intensity of about 80 foot-candles at the meat surface. Lighting was automatically timed to illuminate the display case for 12 hours/day. In Fig. 9, the display case lighting was activated at hour 8 and the display case remained illuminated until hour 20. During this 12 hour period of illumination steak surface temperatures were found to be higher than in the absence of illumination. This is a type of "greenhouse effect" in that the heat produced by radiant energy is absorbed by the meat and trapped

between the polyvinyl wrap and the meat surface. Thus, although display illumination enhances the appearance of beef it is detrimental to keeping quality.

Apart from defrost cycles and illumination, other factors influencing the temperature of beef on display include fluctuations in room temperature, display case design and the position of meats within the case. For example, products located near the blower or at the bottom of a horizontal case will be cooler than those displayed farther from the blower and nearer the load line. The combined influence of these factors accounts for the large discrepancy between retail display temperature and that recorded at the surface of beef on retail display.

Although the temperature of retail beef should be maintained as close to 0°C as possible for maximum keeping quality, displayed steaks are subjected to relatively abusive temperatures and under these conditions case life rarely exceeds 2 to 3 days. Some believe, that as a result of display case design and environment it may not be possible to maintain lower storage temperatures. However, in the laboratory, two studies were conducted to evaluate methods of increasing bacterial quality and beef case life through improved temperature regulation.

Methods of Retail Temperature Control

As shown earlier, bacterial growth can be reduced and steak case life can be extended by 6 days if the meat is stored at 1°C in a cooler. However, this is not a practical method of storage since it precludes consumer evaluation of appearance which is a necessary prerequisite to purchase. The possibility of reducing the time of retail display was therefore considered. This was accomplished by removing steaks from display at the end of each work day, placing them in a cooler at 1°C and then returning product to the retail case each morning. In this manner, retail case defrosting was avoided and steaks were only subjected to the detrimental influences of the display environment for 8 hours/day. The results of these investigations are shown in Fig. 10 and 11. Initially, bacterial growth on steaks continuously displayed was compared to that on steaks limited to 8 hours of retail display/day (Fig. 10). The results showed that reducing the time of retail display reduced the rate of bacterial growth and resulted in a 100 to 1,000 fold reduction in the bacterial load. Consequently, steaks with limited periods of retail display remained acceptable for a longer period of time than steaks held continuously in the retail case (Fig. 11). Retail case life determinations revealed that case life could be extended by 2 days by overnight refrigeration in a walk-in meat cooler. These results establish a practical method by which a retailer could improve beef case life and reduce spoilage losses.

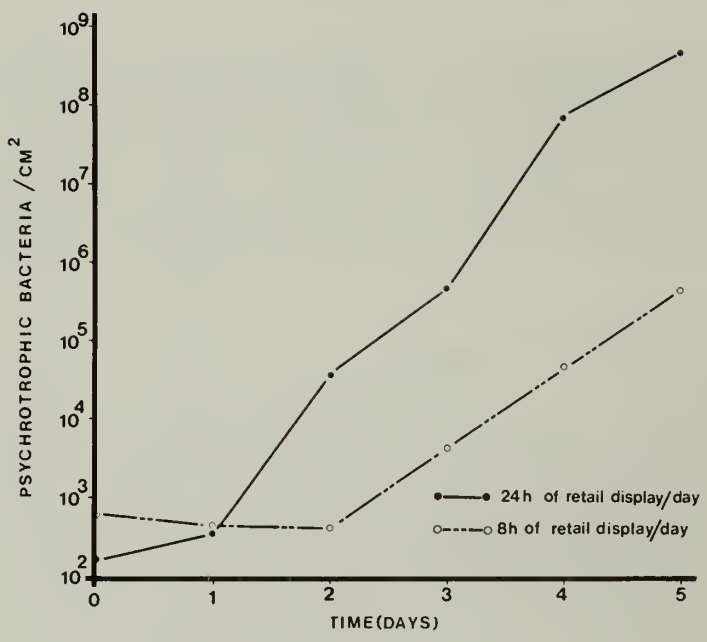

Fig. 10. When steaks are limited to 8 hours of retail display per day (- - - ———) by storage in a meat cooler overnight, psychrotrophic bacterial growth is retarded when compared to steaks remaining in the retail case (———).

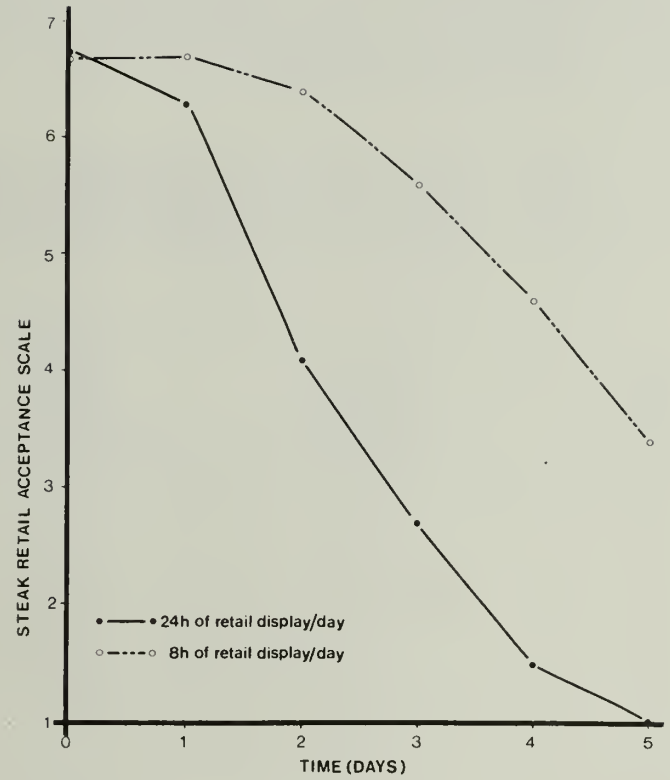

Fig. 11. When steaks are limited to 8 hours of retail display per day (•--•) by storage in a meat cooler overnight, they remain acceptable for a longer period of time when compared to steaks remaining in the retail case (•—•).

A second approach taken was to investigate the relationship between retail case temperature, bacterial growth and steak case life in attempt to determine a retail temperature setting which would improve product quality. In this regard, it was felt that retail cases may not be operating at levels which would provide adequate temperature control of displayed product. The results of this investigation are presented in Table 1. Retail case blower temperature and corresponding steak surface temperatures were monitored at 5 distinct retail case temperature settings. Initially, it is evident that the actual retail case temperature setting is somewhat lower than that indicated by the blower thermometer (Table 1). Of more importance, the surface temperature of retail displayed steaks was on the average about 9°C higher than the temperature recorded by the blower thermometer.

Table 1. The effect of retail case temperature on bacterial growth and steak case-life. A simple adjustment of the retail case temperature setting can reduce bacterial growth and substantially improve keeping quality

Case Temperature Setting (C)	Blower Temperature (C)	Steak Temperature (C)	Bacterial Growth Rate (Generations/h)	Steak Shelf Life (Days)
-9.4	-8.6	1.9	0.09	8.2
-6.7	-5.7	4.2	0.11	6.0
-3.9	-3.6	5.3	0.14	5.6
-1.1	-0.5	7.3	0.17	3.8
+1.7	+2.0	11.8	0.28	1.9

It should be stressed, that although the retailer may maintain a completely acceptable blower temperature of 2°C, the actual temperature of the product is closer to 12°C. As the temperature of the blower air is reduced from +2°C to -8.6°C there is a concomitant reduction in steak surface temperature, bacterial growth and consequently a more than 6 day increase in steak case life. These results indicate that a relatively simple adjustment of blower temperature by the retailer can result in a retail case life for beef which exceeds one week. Further studies are necessary to determine whether the economic benefits of reduced spoilage losses would compensate for increased refrigeration costs.

This review has summarized the results of current research on the growth and spoilage potential of bacteria and the importance of sanitation and temperature to the bacterial quality of retail beef. The two practical methods of retail temperature control described should be of direct economic benefit to the retail beef industry by reducing spoilage losses.