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I am submitting herewith a dissertation written by Eugenia Malone Zallen, entitled "Quality Characteristics of Precooked Meat Loaf Stored at Refrigerated Temperatures." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Food Science.

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QUALITY CHARACTERISTICS OF PRECOOKED MEAT LOAF STORED AT REFRIGERATED TEMPERATURES

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee

Eugenia Malone Zallen

August 1974

This Dissertation is Dedicated

To Mrs. Elsie Martin, Professor Emeritus

Duke University Medical Center

and

To the Memory of Professor Ruth Jordan

Purdue University

They were women whose minds led them far in advance of their time and they shared their vision with their students. Thus, they changed thought patterns and processes.

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ABSTRACT

Introduction of cooked food storage for an interval of time between preparation and service has been a frequent innovation in quantity food systems. The effects of refrigerated storage at 32°F. and 42°F. ± 1°F. upon selected quality related properties of cooked meat loaf were evaluated. Ground beef loaves prepared by generally accepted techniques were handled in one of three procedures prior to refrigerated storage in an environmental chamber. Handling procedures were: immediate refrigeration of the cooked loaf, pasteurization of the loaf followed by refrigeration, and freezing, then thawing of the cooked loaf as a part of refrigeration. A freshly fabricated loaf cooked immediately prior to evaluation was used as a reference.

Over a nine day storage period, loaves were removed from storage at six intervals and reheated prior to being subjected to various tests. For handling procedures and days in storage, reference loaves were found to be significantly different ($P < 0.01$) by all criteria used from loaves which were stored. The freshly prepared loaf cooked immediately prior to evaluation statistically had a shorter heating time, less cooking losses, higher moisture content, lower Thiobarbituric Acid (TBA) numbers and higher taste panel scores for odor, juiciness, flavor and appearance. These differences were indicative of higher quality.

Pasteurized loaves were not found significantly different from refrigerated loaves. Thus the value of pasteurization for quality maintenance is in question. Frozen, thawed loaves had significantly

different values ($P < 0.01$) values for TBA numbers and all taste panel scores. There was a significantly lower ($P < 0.01$) heating time for frozen, thawed loaves, but the difference was not of practical value. Cooking losses and moisture content were not different in frozen, thawed loaves. From these comparisons, quality deterioration in frozen, thawed loaves was judged more extensive than in the other stored loaves.

Standard plate counts for aerobic bacteria indicated extremely low counts when samples were taken after storage and after reheating. Only two loaves sampled had counts above 100 colonies per gram. Increases in counts did not occur over the nine days of storage. The absence of a microbial growth pattern would tend to indicate that increases in TBA Numbers and decreases in odor and flavor scores were produced by autoxidations of lipids.

The only significant difference noted for the two storage temperatures was for total heating time. Over nine days of storage and under procedures and conditions of the present study, four days appear to represent a maximum storage time for refrigerated, cooked ground beef loaves to remain acceptable. It should be noted that linear decreases in quality related properties began to occur upon initiation of storage and determination of unacceptability was not a precise point in time.

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CHAPTER I

INTRODUCTION

The past several years have been notable for extensive changes which have characterized production and delivery of food prepared in volume for institutional service. One frequent innovation in quantity food systems has been in the introduction of temporary storage or holding of prepared food for an interval of time between preparation and service. Utilization of a holding period for cooked food prior to service represents a distinct change from quantity food production systems of previous generations. Fifteen years ago, it was recommended that quantity food systems emphasize immediate service of prepared food to insure maintenance of quality from time of production to point of service (Fenton, 1960; Harris, 1960).

Several commentators have expressed their belief that holding systems are or will be a dominant characteristic of today's and tomorrow's food service systems. Willett (1971) has viewed the deliberate delay in time of service from occasion of preparation as the one common feature of today's new food service systems. In Livingston's (1968) opinion, the major trend for food service systems has been the separation of preparation from service, both in time and place.

The process of holding food between preparation and service is described as occurring in a variety of temperature zones including frozen, refrigerated, ambient and hot temperatures (Willett, 1968;

Longrée, 1972). Dependent upon the holding conditions, the length of time that food is held in temporary storage ranges from minutes to months. The handling and reheating of food which has been held in storage may constitute a complex system involving acquisition of new equipment and implementation of recently developed technology, or it may be initiated in a food service operation traditionally equipped which has been functioning for years.

Reasons for the movement toward food holding systems are shortages and costs of skilled personnel as well as efficiency in time and space utilization (Livingston, 1968; McIver, 1970; Kaiser and McFarland, 1971). Because the entreé component of the menu represents both a major economic factor for the system and a skilled personnel requirement for food preparation, holding systems have predominantly focused upon development of precooked entreé items (Bjorkman and Delphin, 1966; Rappole, 1971). Descriptions of the initiation of quantity food holding systems have emphasized economic and personnel features. Developmental and feasibility aspects which relate to the noted components of food holding systems dominate the literature (Sayles and MacLennan, 1965; Kooser, 1969; McGuckian, 1969; Beyer, 1971; Amer. Hosp. Assoc., 1973).

Donaldson (1971) has expressed concern for the temperature and quality of food delivered from quantity production systems which incorporate holding of cooked food, even though the techniques may demonstrate savings in labor and space. She has stated:

> Although many aspects of food service are being evaluated, the quality of the food and patient tray service are frequently

> overlooked. In the literature reviewed, there is little evidence of concern for the effects of changing preparation, assembly and delivery methods on esthetic, nutritional, and microbiological quality of meals at point of service.

The Symposium on Ready-Service Food (Anon., 1972) at the University of Wisconsin sought to define unresolved problems in pre-prepared food. As defined by the Symposium, such food may involve holding at frozen or refrigerated temperatures. Seven of the nine discussion groups at the Symposium listed food quality as one of the five priority problems. Questions asked by participants frequently related to the effects of holding and reconstitution of ready-service food upon its quality characteristics.

There are indications that systems for quantity food production are currently in the process of change and that alterations frequently are being instituted without evidence as to the effects of system modifications upon food quality characteristics. West, Wood and Harger (1967) have stated:

> In an institution of any type the food service has for its goal the maintenance of acceptable standards of food preparation that will result in a product of high quality, served in the best condition and manner possible.

If such a goal is to be affirmed on a continuing basis for the evolving food service systems of today and of the future, knowledge of effects resulting from holding prepared food in storage upon its quality characteristics is necessary for control of the system by its management. The maintenance of quality, food acceptance and client satisfaction are vital components of all food service systems. Without input as to acceptable levels of food quality and changes in quality which occur

within a system, it would be difficult to effectively accomplish system objectives while utilizing a quantity food holding system.

In response to recognition that knowledge is needed concerning quality of food being produced from innovative food holding systems currently utilized by the food service industry, this research study was developed. The present project was undertaken specifically to examine the effects of refrigerated storage or holding upon precooked meat loaf. The objectives of the research were:

1. To measure selected quality characteristics of precooked meat held in refrigerated storage by sensory and objective evaluations.

2. To examine the influence of refrigerated storage over a selected time frame upon the microbial population of precooked meat loaf.

3. To relate the effects of selected handling procedures prior to refrigeration to quality related properties of precooked meat loaf.

4. To ascertain if precooked meat loaf remains an acceptable food for service in quantity food systems within the selected time parameters of refrigerated storage.

5. To study the relationships of quality related characteristics of precooked meat loaf with selected time and temperature variations.

CHAPTER II

REVIEW OF THE LITERATURE

Food service systems for many years directed their interest in holding of prepared food prior to service toward unintentional holding and storage of leftover food (Sayles and Wanderstock, 1963). More recently, emphasis has shifted to deliberate holding of prepared food as it is designed into the food production and service system. Longrée (1972) has described general temperature ranges in which food may be held (Table 1), whether it is unintentional or deliberate holding. While there could be disagreement with the demarcation and description of the environmental zones as listed by Longrée, a grouping of holding temperatures into separate categories provides a basis of commonality for discussion purposes.

I. HOLDING SYSTEMS

The commonly reported procedure in development of a holding plan for food service systems is selection of one of the refrigerated zones or the hot zone as the primary mode of storage. Selection of one zone is followed by the storage of as many menu components as is feasible within the chosen temperature range. A major exception to the specification of one primary holding zone for a system is the United States Army Centralized Army Feed System (CAFÉ) (Bustead et al., 1972) which holds and transports food at frozen, chilled and ambient temperatures. Since in other described holding systems, a single temperature

Table 1. Environmental Zones for Holding Food[a]

Recognized Temperatures for Holding Food	Internal Temperature of the Food
1. Refrigeration	40°F. and below
A. Freezing: 20°F. and below	
B. Defrosting: 20° to 30°F.	
C. Chilling: 30° to 40°F.	
2. Temperatures Involving Major Bacterial Growth[b]	45° to 140°F.
3. Hot Holding: 140° to 180°F.	145° ± 10°F.
4. Cooking	150°F. and above

[a]Adapted from: Longrée, K. 1972. "Quantity Food Sanitation," 2nd Ed., Wiley-Interscience, New York.

[b]Considered danger zone for holding food and is to be avoided.

is utilized, it is possible to examine various system designs related to the holding zone.

Frozen Holding Systems

Livingston (1972) has described two European systems which he considered to be nearest his concept of an "ideal" holding system. In the University of Berlin and the Swedish Automatic Food systems, precooked food was frozen in individual portions. The frozen portions were stored in computer-controlled automated freezers from which portions were discharged upon computer demand. Portions released from storage were transported by a tunnel to a microwave oven where they were reheated from the frozen state to the desired temperature. For the

described systems, no information was given as to freezing and holding temperatures, length of storage and types of food items prepared and frozen.

The University of Leeds, England Cook-Freeze system (Amer. Hosp. Assoc., 1973) was much less automated than the previously described system. Precooked food was placed in plastic molds and blast frozen at -31°F. After the freezing process, the food was removed from the mold, packaged in plastic bags and stored at -4°F. The unit volume of food frozen and its degree of "doneness" in initial cooking were based on a standard time of 25 minutes in a convection oven for reheating.

A system utilized at the Tuscon Medical Center (Kooser, 1969) contrasts with the European patterns in that frozen food was thawed prior to reheating. A six week supply of frozen food was maintained in storage on premises. The frozen items to be used were defrosted under refrigeration until the internal temperature of the food was between 35°-40°F. The defrosted food was portioned and placed on plates for service. Patients' trays were assembled and transported over a 40 acre hospital site in insulated cold carts. Trays might remain in refrigeration at point of service for a day. At the time of service, the food was reheated for 60-90 seconds in a microwave oven.

Other frozen holding systems were described in the literature (Rappole, 1971; Beyer, 1971), but the plans which were defined above incorporate possible variables of the concept. In the frozen food systems, variations may be noted as to unit volume of food frozen, handling of frozen items, length of frozen storage and thawing of

products prior to reheating. Complete data on the described systems were not always reported, making difficult comparisons among plans or experimental duplication of the designs. Negligible data were reported relative to the quality of food in frozen holding systems. For example, the University of Leeds Cook-Freeze system was proclaimed as a thoroughly researched plan. Published information of the Leeds system consists primarily of feasibility studies on equipment and comparative costs in money, staff and equipment utilization (Amer. Hosp. Assoc., 1973). Glew (1973) reported on a food acceptability questionnaire which asked patients to evaluate food in a non-selective conventional system, a selective conventional system and the Cook-Freeze system. The same patients did not evaluate all systems and statistical analyses were not reported. From bar charts, there was little difference indicated in acceptance between the selective, conventional plan and the Cook-Freeze system which also included the selective feature.

A "rosteak" method for preparing meats involved frozen storage of partially cooked products (Baldwin and Korschgen, 1968; Korschgen and Baldwin, 1971a and 1971b). Roasts and steaks were partially cooked, refrigerated overnight, sliced, packaged and frozen. At various times of sampling up to one year in storage, the meats were heated again and served. Although all products prepared by this method were acceptable to a taste panel, total cooking losses were higher in "rosteak" prepared meats as contrasted to a single cooking procedure.

Refrigerated Holding Systems

The two refrigerated holding systems most frequently described in the literature have incorporated an additional step prior to refrigeration referred to as "pasteurization." This step consisted of a heat treatment after the prepared food product was packaged.

The Nacka system (Bjorkman and Delphin, 1966; Livingston, 1972), used in a Swedish hospital, prepared entreés by conventional processing methods. In the initial cooking process, an internal end point temperature of 176°F. was sought in all foods. Five portions of hot food were placed in polyethylene bags, a vacuum was created and the bag was sealed. The sealed bag was immersed in 212°F. water for three minutes to "pasteurize" it. The hot bag of food was cooled with running cold water to 50°F. The food was then held in storage at 37°F. For reheating purposes, the sealed bag was immersed in 212°F. water for 30 minutes.

The Anderson-Greenville-Spartanburg (AGS) system (McGuckian, 1969; Montague, 1972) processed all entreés and vegetables for regular and modified hospital diets by use of a plan similar to Nacka. Variations from the Nacka system included packaging in one portion, five portions or bulk amounts; storage at 28° to 32°F.; reheating in hot (not boiling) water until the internal temperature was 160°F. and placing portioned food in a microwave oven for 10 to 20 seconds just prior to service. Shelf life of the food in the AGS plan was stated to be 60 to 90 days, but the food generally was held for 21 to 30 days before use. Quantitative data were not reported on quality of food processed in the AGS system.

Refrigerated food in the Army's CAFÉ system was not subjected to any heat treatment similar to "pasteurization." The Army planned to serve the refrigerated food in its system within four days from production (Bustead, 1972). The feasibility study for the Army's plan had a taste panel consisting of five persons who were unit supervisors in the food service. The panel failed to report data, since when workloads were heavy, it did not meet.

Kaud (1972) reported on implementation of a chilled food plan at the University of Wisconsin Hospital. At this hospital, most food was prepared on-premise, stored and transported in the refrigerated state. Kaud stated that when compared to hot-held food, refrigerated food was less perishable and retained more nutrients. This would not be in question when equivalent time frames for chilled and hot food were compared. It was further noted that holding time for refrigerated food was not critical as affecting food quality. The ultimate conclusion was drawn that patient food was improved, the number of employees were reduced and costs were decreased when the chilled food system was adopted.

Holding Food at Temperatures Above Refrigeration

Holding food at temperatures above refrigeration include the actions of unintentional holding within the 45° to 140°F. range (Sayles and Wanderstock, 1963; Willett, 1971; Bryan and Kilpatrick, 1971), holding which constitutes a cooking process (Bramblett et al., 1959; Funk et al., 1966), and holding prepared food at service temperatures on premises or for transportation purposes (Yergler, 1966; Bates, 1966).

Generally, in these variations, the holding times involved were for periods of 24 hours or less.

II. EFFECTS OF HOLDING ON COOKED FOOD QUALITY

When food quality is defined, it is usually stated to have three major components. These factors are wholesomeness related to microbial condition, nutrient retention and organoleptic characteristics such as aroma, color, flavor and texture (Kramer and Twigg, 1970).

One of the most extensive research studies which has been conducted related to the effects of storage upon food quality was that of the Western Regional Laboratory of the United States Department of Agriculture. It focused solely on frozen food found in the market channels of the 1950's, mostly raw or blanched food. For cooked food, poultry pies were among the few products on which reports were found from the study. Using frozen, fried chicken, Hanson et al. (1959) reported that a taste panel noted a more rapid onset of stale and rancid flavors as the storage temperature was increased from 0°F. to 20°F. Hanson and Fletcher (1958) found that off-flavors in turkey pies and turkey dinners in frozen storage were first noted by a panel between three and four months and 1.5 and 2.0 months respectively when the temperature was a constant 20°F. Peroxide values did not correlate well with the judges' scores. In comparing poultry stored at fluctuating temperatures between 0°F. and 20°F. and a constant storage temperature of 20°F., significant differences in flavor were not found. This milestone study was completed nearly 20 years ago and frozen storage technology has advanced in the intervening years.

Effects on Odor and Flavor

The measurement of odor and flavor changes occurring in stored meats has been approached both objectively and subjectively. Two general views of development of off-odors and off-flavors during refrigerated storage of meats have appeared in the literature. Watts (1954) attributed odor and flavor changes in meats to rancidity development resulting from oxidative decomposition of unsaturated fats. Younathan and Watts (1960) concluded that oxidation of tissue lipids such as phospholipids and proteolipids were involved in development of rancidity. Hornstein et al. (1961), in examining fatty acid composition of meat tissue lipids concluded that phospholipids do not contribute to desirable meat flavor and in excessively lean meat the component could contribute to poor flavor. Lea (1962) did not consider it necessary for the proportion of lipids in meat to be high before oxidation resulted in serious flavor change. His reason was that all foods contain cellular lipids necessary for cell metabolism. Chang et al. (1961) compared cooked beef stored with and without an antioxidant (sodium polyphosphate and sodium ascorbate) and found highly significant differences in odor scores between the treatments. They concluded that the antioxidants were preventing oxidative rancidity from occurring in the meat.

Sato and Hegarty (1971) characterized the off-flavor of cooked, stored meats as Warmed Over Flavor (WOF). They postulated that the substance which initiates WOF is an unknown water-soluble component of meat catalyzed by ferrous iron and ascorbic acid. According to Sato

and Hegarty, the cooking process disrupts the muscle membrane system, exposing the lipid component to oxygen as well as to the initiating agent for WOF. Thus the lipid component is involved in off-flavor of cooked, stored meats, but the presence of an intermediate initiator is required to induce WOF. Sato et al. (1973) reported the inhibition of WOF in ground beef by addition of 4 percent non-fat dry milk. These authors concluded that inhibition of WOF occurred as a result of an interaction between proteins or amino acids and carbohydrates during the heating process.

Regardless of which view has been taken by researchers as to the immediate effecting agent in odor and flavor changes during cooked meat storage, the chemical measurement for evaluation of the alterations has been the same test. The determination commonly in use has been the Thiobarbituric Acid (TBA) Test. For a number of years, the measurement of choice was to ascertain the increase in peroxides as an indicator of rancidity in meats. As Watts (1954) noted, peroxides are intermediates in the oxidative process involving fats. The peroxide value is still listed in the Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC, 1970). The TBA Test was actually applied to food to replace the Kreis Test for determining the rancidity of milk fats (Josyln, 1970). Sidwell et al. (1955) developed the techniques to utilize the formation of a pink color resulting from an interaction of TBA with a decomposition product of milk fats when autooxidation occurred. Sinnhuber and Yu (1958) further refined the TBA method, using fish products, and suggested the use of 1,1,3,3-Tetraethoxypropane

as a standard by which to compare the food product color reaction. Tarladgis et al. (1960) adopted the TBA method to meat products by use of a distillate from a meat-acid slurry.

The peroxides, a primary decomposition product of fats, previously were used to indicate development of rancidity. The TBA Test utilizes a secondary decomposition product, malonaldehyde, as the indicator compound. As Keskinel et al. (1964) described the reaction, malonaldehyde is formed during the oxidative decomposition of highly unsaturated fatty acids. It will react with 2-Thiobarbituric Acid to give a compound which has a pink color. This compound has a maximum light absorption in the range of 530-538 nanometers. Tarladgis et al. (1960) reported that malonaldehyde appears to contribute a relatively small fraction to the odor complex of rancid meats, but its presence does accompany off-odor development.

Younathan and Watts (1960) compared TBA values and peroxide numbers of refrigerated pork. In cooked pork, peroxide numbers of extracted fat were 10.2 after two days of storage and 12.9 at seven days of storage. At these points in storage time, TBA values of the fat were 0.14 and 0.35. TBA values of meat tissue rose from 0.2 on day zero to 2.3 on day 2 and 2.5 on day 7. It was concluded that TBA values measured tissue rancidity. With the tissue samples, the TBA response indicated a more rapid rise over seven days than did the peroxide numbers. Additionally, the TBA values leveled off about the fifth day of storage.

The use of TBA values as an indicator of rancidity development in stored meat has been utilized since Tarladgis et al. (1960) developed the distillation method for meats and adopted the TBA number which equals the milligrams of malonaldehyde per 1000 grams of meat. A single report by Bramblett et al. (1965) was found from the 1960's which used peroxide numbers as an indicator of rancidity. In this study, peroxide numbers did not indicate development of any rancidity during 12 months of frozen storage. Over this same period, taste panel flavor scores significantly decreased. Results such as from this study in which chemical values and taste panel scores did not significantly correlate, led to the use of the TBA test as a measure of odor and flavor in stored meats. As Sidwell et al. (1955) noted, peroxide values may not correlate with flavor scores because of simultaneous formation and decomposition of the peroxides.

In the years since Tarladgis et al. (1960) adapted the method of Sidwell et al. (1955) for measurement of lipid oxidation, a number of publications have discussed the TBA method. Initially, it was uncertain as to the identity of the compound with which TBA combined to form a chromagen. Kwon and Olcott (1966) fractionated water-soluble, TBA reactive substances from fatty acids by gas chromatography. The substances were characterized by elution volume, ultraviolet absorption and thin layer chromatography. By all these criteria, malonaldehyde was identified as the main component. Braddock and Petrus (1971) obtained three colored bands on a gel filtration column after filtering the pink colored liquid derived from the reaction of TBA reagent

and orange juice essence. A relatively pure malonaldehyde was isolated from a bright pink band. The researchers were unable to find malonaldehyde in fresh orange juice essence.

Kwon et al. (1965) reported that malonaldehyde in water exists primarily as a nonvolatile enolate anion and in this form in food, malonaldehyde is bound to amino acids, proteins, glycogen and other food constituents. When nonvolatile malonaldehyde was acidified, it was converted to its volatile isomer. Only when heat was applied to the acidified product was malonaldehyde released from protein. Thus, as stated by Kwon et al. (1965), the water extraction of malonaldehyde was unsatisfactory as an analytical technique. Water extraction yielded only free, non-bound, thiobarbituric acid reactive substances. Kwon and Norgaard (1966) used gas chromatography to determine that the lipoprotein fraction of dry whole eggs contained more thiobarbituric reactive substances than any of the other identified peaks. Kwon and Watts (1964) had previously verified that maximum volatization of malonaldehyde occurred at pH values below 3.0.

Attempts have been made by Tarladgis et al. (1964) and by Witte et al. (1970) to develop a thiobarbituric acid test based on aqueous extraction rather than distillation. Both concluded that although that their methods were simpler, they were less sensitive. The reasons for the lack of sensitivity of aqueous extraction is shown in the preceding paragraph.

It may be concluded that although the mechanism for formation of malonaldehyde has not been characterized (Lea, 1962), this product

has been shown to exist in stored food. Further, the TBA-malonaldehyde reaction yields a pink chromagen which has maximum absorbance in the range of 530 to 538 nanometers. TBA values correlate with odor and flavor scores (Tarladgis et al., 1962). Thus, in spite of some unanswered questions and a somewhat empirical basis for use, the TBA Test has merit as an indicator of the development of oxidative rancidity in stored food products.

Several reported studies correlate TBA scores and sensory evaluations for odor and flavor. Chang et al. (1961) held precooked longissimus dorsi muscle from beef at room temperature (25°C.), under refrigeration (1 to 4°C.) and in frozen storage (-26°C.). Flavor scores for cooked, sliced beef which was held at 25°C. dropped from 5.7 to 2.9 on a six point scale over a four hour period. TBA values for the samples stored at 1 to 4°C. and -26°C. increased over 11 days and 164 days respectively, while taste panel ratings declined. Chang et al. found that the use of sodium polyphosphate and sodium ascorbate minimized changes in TBA numbers and taste panel odor scores in products held in refrigerated and frozen storage.

Jacobson and Koehler (1970) compared flavor of turkey and chicken which was either freshly cooked, refrigerated after cooking or frozen after cooking. The TBA Test used was the modified Tarladgis et al. (1960) method, holding meat samples for 16 hours at 22°C. in the dark rather than using the distillation method. No significant differences in flavor were noted by a taste panel after three days of frozen storage, while significant differences in flavor were noted by the

taste panel in the refrigerated product. Significant differences also were noted in TBA values, but increases in TBA values were not as pronounced as were decreases in flavor scores. This fact might have been influenced by the water extraction method used. Jacobson and Koehler concluded that refrigeration might be effective in insuring microbiological safety, but it was ineffective in maintaining a characteristic fresh cooked flavor of chicken and turkey.

Harris and Lindsay (1972) prepared chicken thighs dipped in milk and coated with flour and salt. They either fried chicken in oil or cooked it in an electronic oven. Cooked chicken was held for five days at 6°C. ± 1°C. and was reheated prior to tasting. All stored samples were significantly different in flavor scores from freshly prepared samples. Freshly cooked deep fat fried chicken had a TBA number of 1.00. After one day of storage, the value was 2.7 and after five days, it was 4.4 for fried chicken. The largest change occurred in flavor of samples which were rapidly cooled and rewarmed within two hours of original preparation. A rapid initiation of off-flavor in stored chicken was indicated.

Several research studies have evaluated the effects of holding on cooked turkey without the use of the TBA Test. Town (1964) stored deboned turkey at 34°F. for up to 24 hours. Significant differences in aroma, juiciness, flavor and tenderness were not found by a taste panel over this period of time. Cipra and Bowers (1970) stored pectoralis major muscle from turkey which had been cooked to 85°C. internal end point temperature and then cooled at 25°C. to an internal

temperature of 50°C. When the 50°C. temperature was reached, the muscle was wrapped in plastic and held at 6°C. for 24 hours. The muscle was reheated in aluminum foil to an internal temperature of 60°C. Flavor and aroma of freshly braised turkey were rated as being superior by a taste panel. Twenty-four hour storage at 6°C. produced highly significant increases in stale, acid, bitter and salty flavor components.

Other research in holding of cooked food used beef as the experimental material. Keskinel et al. (1964) studied oxidative changes in storage of raw and cooked meats including beef, lamb, pork and turkey. Cooked meat samples were roasted in aluminum foil, cooled one hour in the refrigerator and ground. The ground meat then was stored in the refrigerator for three weeks at 5° ± 1°C. Oxidation deterioration as measured by TBA values was more rapid and ultimate values were higher in cooked meat. Major oxidative changes occurred in the first day of storage as evidenced by TBA in beef of approximately 0.5 at zero hours and 8.0 at one day.

Sato and Hegarty (1971) and Sato et al. (1973) have sought to minimize Warmed Over Flavor (WOF) in cooked beef. In beef stored at 4°C. for 48 hours, they reported that polyphosphates and sodium nitrite were effective inhibitors of WOF flavor. At 50 to 300 parts per million of ascorbate, development of flavor change was accelerated, while at 1000 parts per million, it was inhibited. Sato et al. (1973) found the best inhibitors among non-meat protein products to be non-fat dry milk. TBA scores and odor and flavor ratings were related in these studies of WOF in beef.

Jakobsson and Bengtsson (1972) fried sliced beef in margarine, packaged it in laminated pouches, pasteurized it for nine to 12 minutes in a convection oven at 105°C., cooled it to 10°C. by placing it in a -20°C. environment, and stored it in the dark at 3°C. and 8°C. for three weeks. Refrigerated products were compared to a product similarly handled prior to storage at -20°C. for two months. The reference sample was freshly cooked prior to each sampling. Other variables in the study were amount of head space volume and packaging atmosphere. Significant differences were noted in flavor between the products stored at the two refrigerated temperatures when the larger head space volume was considered. It was not until after two weeks of storage at refrigerator temperatures that products which were vacuum packaged were found to be significantly different from frozen stored beef. Freshly prepared products always were rated highest by the panel for the quality characteristics of flavor, juiciness and tenderness. These authors did not report TBA values over time of storage. They did have figures demonstrating the correlation between flavor scores and TBA which was good.

The study of Jakobsson and Bengtsson (1972) sought to compare the Nacka holding system (Bjorkman and Delphin, 1966) with frozen storage. Only a few other research studies reported were related to food quality in quantity food holding systems. Kossovitas et al. (1973) have evaluated the "pasteurization" treatment of the Nacka system. They compared pasteurized products to frozen, stored products. After 15 days of storage at 2°C., a taste panel did not detect significant differences

in appearance, flavor and consistency between frozen and refrigerated food. Products tasted included chicken á la king, codfish in cream sauce and broccoli in cream sauce. After the next storage period, at 30 days, refrigerated samples were no longer acceptable to the panel. No chemical evaluation of flavor change was made in this study.

Rappole (1971) conducted triangle tests with samples of fresh and frozen, stored shrimp creole. A significant number of the taste panel were not able to distinguish the odd sample of the three presented to them. The panel commented that there was no difference in odor and color between the samples, but were inconsistent in their response to whether there was a flavor difference. Patrons in the university food service who received the 15 products in the Rappole study rated the acceptability of precooked frozen entreés. On a one to 10 rating scale, scores for 15 entreés ranged from 8.73 for chicken normandy to 5.91 for beef stroganoff.

In development of the Leeds Cook-Freeze holding system, Hill et al. (1970) compared white sauce and six vegetables which were available in fresh, canned, dehydrated and precooked frozen forms. The taste panel in the study preferred fresh over precooked frozen vegetables, but the differences were not statistically significant. Frozen white sauce was preferred to the fresh product. Further, Hill and Glew (1970) studied the effect of delaying the freezing of food after it was cooked. When freezing was delayed for 60 minutes, significant differences were not noted in flavor from products which were immediately frozen after cooking for the following products: minced

beef, sole in wine sauce, chicken in veloute and lamb stew. When delay between preparation and freezing was only 15 minutes, there was a significant difference noted in omelette. The only data collected for the Leeds Cook-Freeze systems food studied were taste panel scores. Data from the Leeds system was developmental for specific menu items in the plan rather than research oriented data.

In summary, data regarding quality of precooked meat held in refrigerated storage were limited. A summary of TBA values reported for meats is found in Table 2. Correlation of these data with flavor and odor scores was present in about half the reported studies and was generally found to be significantly correlated. TBA scores for refrigerated cooked meat have been demonstrated to rise rapidly over the first five to seven days and then to level. In regard to evaluation of storage systems, again, food quality evaluation was sparse. Information which was reported in the literature was directed primarily at frozen food holding systems. In studies which did evaluate refrigerated food, such as Jakobsson and Bengtsson (1972) and Kossivitas et al. (1973), comparison was made to frozen food rather than freshly prepared products.

Microbial Aspects of Refrigerated Storage

Considerable literature exists on refrigerated storage of food as it relates to microbial factors. The vast majority of information presented in the literature referred to raw food with little attention given to cooked food storage. Ingram and Dainty (1971) have reported:

Table 2. Summary of Thiobarbituric Acid Values Reported in the Literature for Stored Meat

Literature References	Components of Obtaining the TBA Values: Meat	Temperature	Other Conditions	Days in Storage	Procedures for Reporting Results
				0 7 9	
Timms and Watts (1958)	Ground Beef	5-7°C.	Raw Cooked	0.516 0.627 Spoiled 0.878 4.59 4.59	Absorbance x 7.8
				0 2 4 7	
Younathan and Watts (1960)	Ground Pork	5-7°C.	Raw Cooked	0.20 0.21 0.23 0.23 1.9 4.4 4.5	Absorbance x 7.8
				1 2 4 7 10	
Watts (1962)	Sliced Beef	Refrig.	Cooked	3 8 15 20 21	Absorbance x 7.8
				0 1 2 6 12 15 21	
Keskinel et al. (1964)	Beef	5°C.	Raw, unground Cooked, ground	0.5 0.6 0.4 0.2 0.4 0.5 8 16 17 17.5 17 17	Absorbance x 7.8
				0 1 2	
Sato and Hegarty (1971)	Ground Beef Round	4°C.	Raw Cooked to 70°C.	0.023 0.026 0.044 0.048 0.061 0.113	Absorbance
				0 Pooled 21 Days	
Jakobsson and Bengtsson (1972)	Sliced Beef	3°C. 8°C	Cooked 9 ml. headspace	0.0 1.5 0.0 1.5	Absorbance/Sample Wt. of Fat

> The spoilage of cooked meats is little investigated and is frequently due to what is almost a haphazard monoculture of the few organisms which happen to survive cooking or gain readmittance to the cooked product.

Nickerson and Sinskey (1972) have estimated that 85 percent of all food is refrigerated at one point in the chain of marketing between harvest and consumption. They considered that refrigeration may be the most important method of preserving food. Elliott (1963) noted that while food poisoning bacteria do not grow at refrigerator temperatures, spoilage of food held under refrigeration is accompanied by bacterial growth to millions of colonies per gram. Michener and Elliott (1964) have summarized the lowest reported temperatures for growth of pathogenic bacteria (Table 3).

Table 3. Summary of Lowest Reported Temperatures for Growth and Toxin Production by Food Borne Illness Causing Bacteria

Type	Growth Ceases °C.	Toxin Production Ceases °C.
Staph. Aureus	6.7	18
Salmonella	6.7	--
Fecal streptococci	5.6	--
Clostridium Botulinum		
Type A	10	10
Type B	10	10
Type C	15	10
Type E	3.3	3.3
Clostridium Perfringins	15	--

--Organism does not produce toxin.

From: Michener and Elliott. 1964. Adv. in Food Res. 13: 349.

Temperatures reported in Table 3 do not represent survival temperatures or death temperatures, but points at which growth has ceased. Thus, if present in refrigerated food, pathogenic bacteria will survive and may grow if actual temperatures within the food are not below those reported. If handling of food after removal from the refrigerator allows growth or if a heat treatment does not kill, pathogenic organisms may become a health hazard. For these reasons procedures for preparing and processing food to be stored under refrigeration should minimize the presence of bacteria, pathogenic or otherwise.

Elliott and Michener (1965) have stated that psychrophilic organisms are of major importance in modern food technology because their activities limit the time that food can be stored at refrigerator temperatures above freezing. The psychrophiles are not pathogenic to man, but their growth and enzyme production produce spoilage of food. There are various definitions for the psychrophilic bacteria. Elliott and Michener (1965) considered them to be bacteria which would grow relatively rapidly at 0°C. Within this group are bacteria whose optimum growth temperatures are 20-30°C., 30-45°C. and 15°C. Ingraham and Stokes (1959) have added to the above definition that the organisms grow well at 0°C. within two weeks. Species of bacteria commonly effecting spoilage of food at refrigerator temperatures are Pseudomonads, Achromabacter and Lactobacteriacae (Nickerson and Sinskey, 1972). Microorganisms usually produce a greater quantity of extracellular enzymes at a low temperature rather than at optima or at a higher temperature (Elliott and Michener, 1965). Spoilage while bacterial counts are still low

could result from high enzyme production by bacteria alive at low temperatures. Peterson and Gunderson (1960) stored frozen chicken pies at 41°F. for up to 14 days. The product was innoculated with Pseudomonas fluorescens and proteolytic enzyme activity was measured. The activity reached a maximum peak after one to two days of storage. Off-flavors and odors developed within three days of storage while bacterial load was still under 10,000 bacteria per gram.

Elliott and Michener (1965) have reviewed factors which influence growth of psychrophilic microorganisms in food. The term microorganisms was used since there was some psychrophilic molds and yeast.

Water activity. Food usually contains collodial matter that binds a part of its water content, thus the Water Activity (A_w) of a food system is not equal to its water content. As the A_w of a food is lowered, bacterial activity is inhibited first, then yeasts and finally molds. As temperature is reduced, a higher A_w is required for bacterial growth. The lowest reported A_w of nonhalophilic bacteria on food is 0.86.

Temperature. All data point to the advantage of storing chilled flesh-type food at as low a temperature as possible without actually freezing it to extend the shelf life of the product. Nickerson and Sinskey (1972) reported a greater advantage to lowering the temperature of storage from 4.4°C. (40°F.) to near 0°C. (32°F.) than from

10°C. (50°F.) to near 4.4°C. (40°F.). The effect produced by the lowering of the temperature from 10°C. to 0°C. involved extension of the lag phase.

Type of surface. An unbroken surface acts to deter bacterial activity, thus an animal carcass would be more impenetrable than ground meat.

Innoculum size. A high initial count will result in a more rapid spoilage of chilled food. If initial contamination consists largely of mesophiles, and not psychrophiles, their number will not affect the spoilage rate.

Air movement. At low humidity, movement of air over the surface which is necessary to achieve reduced moisture in a refrigerator acts to reduce A_w of meat enough to prevent or slow microbial growth. Most references to desirable relative humidity of food in chilled storage are suitable for raw products. In recommendations for raw food, relative humidity values of 80 percent and above are commonly cited (Wright et al., 1954).

Oxygen. Psychrophilic bacteria are aerobes. Some are facultative anaerobes and will grow in food in the absence of oxygen, but the rate of growth is slower.

Acid. Psychrophilic food spoilage bacteria do not grow readily at low pH values. Nickerson and Sinskey (1972) reported that they do not

grow well at a pH less than 6.0.

Heat. Most psychrophiles are easily destroyed by relatively mild heat. This is evidenced by the report that psychrophiles in pasteurized milk were due to post-pasteurization contamination. Nickerson and Sinskey (1972) discussed food which had been processed by heat and stored at refrigerator temperatures by stating:

> It is usually the case that cooked-type foods which are held under refrigeration after heat treatment is applied contain few viable bacteria, and few, if any, psychrophilic bacteria. The recontamination is due to post-handling such as . . . slicing of meat loaf.

Thawing of Frozen Food

Elliott and Michener (1965) reported that frozen food thawed at refrigerator temperatures and remains in storage spoils at about the same rate as food which has not been frozen before refrigeration. Fennema (1973) suggested more knowledge is needed concerning optimum thawing procedures. Fennema further stated that during thawing, food is damaged chemically, physically and by microbial means. Proper handling of food could minimize microbial problems in thawing. Statements from users of frozen food in quantity food systems revealed that thawing is a confused issue. Harder (1973) reported that a fast rate of thawing prevented loss of water holding capacity and thus minimized drip. The view was expressed that drip was related to dryness, toughness and loss of flavor in meats. In contrast, Pedderson (1972) noted that food thawed more slowly over two to three days retained more stability and had better eating quality than that which was thawed quickly.

Bacterial Growth in Precooked Food

Ice et al. (1952) thawed frozen, cooked meat loves and then either reheated the loaves or exposed them to room temperature. All frozen, thawed loaves were acceptable to a taste panel when reheated and 33 of 36 loaves held at room temperature were acceptable. Total plate counts were performed on loaves immediately after they were baked and cooled in ice, after holding at room temperature for five hours and after reheating. One loaf held at room temperature had a count of 2,450; all others had counts of less than 1,500 count per gram.

Husseman (1951) observed the bacterial flora of frozen, precooked food after thawing it in a 6°C. refrigerator, after heating food from the frozen state, after storing it for 48 hours in refrigeration following reheating, and after reheating it the second time following 48 hour refrigerated storage. The following total counts were found:

Condition	Chicken a la King	Beef Stew	Creamed Seafood
	Counts Per Gram		
After thawing	2,310,000	4,400	3,400
After heating	340,000	100	720
48 hour refrigeration	815,000	250	430
Reheated after refrigeration	497,000	40	330

Refrigerated storage for 48 hours doubled the counts in the chicken and beef products, and the cooking process markedly reduced bacteria, but did not eliminate them. The extremely high counts in the chicken á la king were likely due to the handling of cooked chicken which then became a component of the product.

Felstehausen et al. (1963) innoculated chicken gravy with E. coli, Proteus vulgaris and three strains of Pseudomonas at a level of 100 cells per gram. Change in the flavor of the gravy was detected by a taste panel at the end of four hours of holding. As microbial load increased over the range from 10,000 to one million counts per gram, flavor scores decreased. Frozen storage did not have an observable effect on flavor scores except in those products innoculated with Pseudomonas fluorescens. In these, a flavor score decrease was noted. Dalton and Strong (1967) illustrated that flavor and aroma of frozen food held for three to four hours in the thawed state were little affected by innoculates of the same organisms as used by Felstehausen (1963). Factors which would permit these organisms to influence flavor and aroma were time lapses during processing prior to freezing and prolonged thawing periods.

Rey and Kraft (1971) studied the effects of freezing, thawing and holding of chicken at 5°C. on survival and growth of aerobic bacteria. Increases in bacterial numbers were found to parallel biochemical indices of deterioration, but no comparison was made between chemical determinations and flavor evaluations. The researchers concluded that frozen storage caused a change in the microflora of poultry meat which resulted in a proportional increase in biochemically active psychrophiles.

Food service systems which incorporate holding of precooked food generally have included generalized statements as to effects of the plan for storage upon microbial condition of food prepared.

McGuckian (1969), in describing the AGS system, reported that growth of any harmful bacteria was inhibited from time of processing to consumption. The planned shelf life of the AGS system food was 60 days.

Each batch of food in the Nacka system (Bjorkman and Delphin, 1966) was sampled for bacteriological tests on the day it was cooked and at the end of the refrigerated storage period. The general statement was made that the microbial condition of the stored food was the same as freshly prepared food. Microbial standards were not stated. Kossovitas et al. (1973) found that the pasteurization treatment of the Nacka system killed innoculates of Clostridium perfringens and Salmonella. In frozen samples, Clostridium perfringens were killed and Salmonella survived. For all samples which were pasteurized and refrigerated for up to 45 days, results of the presence of the innoculates were negative when the food was examined unheated and heated to 93.3°C.

Reports of the Leeds Cook-Freeze system (Amer. Hosp. Assoc., 1973) simply concluded that products from the plan were microbially safe. The development of the Leeds system as a frozen storage concept was probably influenced by the English government's emphasis on the safety of frozen food. The Department of Health and Social Security (1970) of the United Kingdom stated that chilled precooked food should not be used routinely to feed a group because of enhanced risks from bacterial growth. The Department's report stated that if precooked refrigerated food was to be used, storage should be at temperatures between 1°C. (33°F.) and 5°C. (41°F.) for less than a day, and in small quantities. If transported, the storage temperature should be below 0°C. (32°F.).

Rappole (1971) conducted a feasibility study of on-premise produced frozen entreés. Over a period of two semesters' production of frozen entreés in a college food service unit, the standard plate count of all items tested was under 50,000 colonies per gram. A conclusion was reached that it was not possible to produce sterile or pathogen-free precooked frozen foods. Two production runs which were tested had coliform counts higher than 10 colonies per gram and no Clostridium perfringens were found in the food. Rappole selected one sample of turkey á la king which was considered highly contaminated in production and three samples of the product which had very low microbial counts. He incubated these for 48 hours at 0°, 40°, 66° and 86°F. There was no bacterial growth over the 48 hour period. Microbial data from Rappole's study were difficult to decipher due to the reporting system and the organization of the report. Because of this difficulty, conclusions from the dissertation were of limited value.

The United States Army (Bustead, 1972) tested its CAFÉ system at Fort Lewis, Washington for 11 weeks in 1971. Aerobic plate counts were taken after zero and five days of storage at 40°F. For 12 meat items which had been cooked to 165°F. and chilled, eight had counts of 100 colonies per gram at both zero and five days. The counts for the other four products on the two days tested ranged from 310 to 5100 colonies per gram and 450 to 6600 colonies per gram respectively. Only one product showed a decrease in colonies. The microbiological criteria established for the CAFÉ project included a total count of less than 100,000 colonies per gram for cooked meat items.

Constraints for transporting and storing of cooked food were established by the Army for the project. They included a temperature of 40°F. for chilled food if the food was stored over eight hours and 45°F. if it was used within eight hours. The temperature range of 0 to 10°F. was the criteria for holding in frozen storage up to 24 days. Products in chilled storage were to be used within two to four days of production and within three days if thawed and held in refrigerated storage. One of the evident problems in implementing the CAFÉ system was an inability to hold food within desired refrigeration temperatures. During the test period in August 1971, 42 percent of all food held chilled in the central production facility was in non-compliance of the temperature constraints; in September, 39 percent was in non-compliance and in October, 13 percent. Although during the test period failures to comply with temperature limitations in chilled storage appeared to have little effect on microbiological quality, a point of vulnerability in an on-going system was indicated which would not be under as close supervision as a feasibility study.

The role of psychrophilic bacteria in the spoilage of raw, refrigerated food has been well established. Factors which affect the growth of psychrophilic organisms have been defined for raw food. Assumptions are that cooked food which is refrigerated would be similarly influenced by water activity, storage temperature, innoculum size, oxygen, acid and heat treatment since these are parameters for bacterial growth.

There are few reported studies of bacterial populations in precooked food and the most recent publication for bacterial counts in meat loaf was that of Ice et al. (1952). In this study, low total counts were reported in all loaves tested. Microbial data from refrigerated storage systems are limited to Kossovitas et al. (1973), who reported that Nacka's pasteurization killed innoculates and Bustead et al. (1972) who noted total counts for several products in the Army CAFÉ system.

CHAPTER III

PROCEDURES

Ground beef from a common source was used to fabricate 144 meat loaves. The loaves were prepared and processed under conditions generally recommended for quantity food production. Thirty-six loaves, comprising three replications, were cooked, frozen, then thawed in refrigerated storage. Thirty-six loaves were cooked, sealed and "pasteurized" by a second heat treatment before refrigeration. Thirty-six loaves were cooked, sealed and immediately refrigerated. The remaining 36 loaves were fabricated and cooked immediately prior to evaluation of the samples of all four types of loaves. This fresh loaf served as a reference product in the evaluation process.

The two temperatures at which cooked loaves were stored in an environmental chamber were 32°F. and 42°F. ± 1°F. The length of a storage cycle was nine days. On Day 0 after four hours of storage, Day 1, Day 2, Day 4, Day 7 and Day 9, a refrigerated loaf, a pasteurized loaf and a frozen, thawed loaf were removed from storage. These loaves were reheated.

After reheating the stored loaves and fabricating and cooking of the reference loaf, samples were taken from each loaf to evaluate selected quality related characteristics. The purpose of the evaluation was to ascertain if the conditions and length of storage, as well as the pre-storage handling procedures produced observable differences among the four types of products.

I. SOURCE OF THE MEAT

Two hundred seven pounds of ground beef were obtained from East Tennessee Packing Company, Knoxville, Tennessee. Specifications for purchase of the meat were furnished to the company. The ground beef acquired was from skeletal muscles of a U. S. Good grade animal. At the plant of the processor, the meat was chopped in a vertical cutter-mixer, ground and mixed thoroughly. After preparation of the ground product, the meat was packaged in oxygen impermeable plastic bags, securely sealed and quick-frozen at -20°F. The bags of meat were in the following weight-units: five pound packages, two pound packages, and one and one-half pound packages. The units were in appropriate numbers for preparation of 144 loaves. According to a laboratory report furnished by East Tennessee Packing Company, the fat content of the ground beef was 22 percent. Laboratory analysis confirmed the content at 22.9 percent (Armitage, 1974).

Upon receipt of the frozen ground beef at the Department of Food Science and Food Systems Administration one week prior to initiation of the research, the packages of meat were immediately placed in a Victory 2-Door Upright Freezer (Model FA 206). The thermostat of the freezer was set at 0°F. which gave an actual temperature range of -4°F. to 6°F. The frozen ground beef was stored in the freezer until packages of meat were removed for transfer to a controlled temperature-humidity chamber for thawing.

II. PREPARATION OF THE MEAT LOAF

Defrosting the Raw Ground Beef

For meat loaves which were to be frozen, refrigerated or pasteurized, 17 pounds of ground beef were removed from the freezer 12 hours prior to fabrication of the loaves. The raw ground beef was placed in the Environmental Chamber (Associated Testing Laboratories, Model HH 5127) with the thermostat set at 32°F. After 12 hours in the chamber, the internal temperature of the raw meat measured 30° to 32°F. The meat was then removed from the chamber to be used immediately in the fabrication of the loaves.

One and one-half pounds of raw ground beef were used to fabricate a single loaf prior to each sampling period. The 1.5 pound package of frozen meat was placed in the Environmental Chamber for 10-12 hours prior to its use in making the loaf. In this case, the temperature of the chamber was at either 32°F. or 42°F. depending upon the holding temperature at which the cooked loaves were being stored.

Fabrication of the Loaves

Meat loaves were fabricated in either 12 loaf or single loaf batches. The 12 loaves were prepared from the following formula and procedures:

Ground Beef	17 pounds
Bread Crumbs	32 ounces
Eggs, whole fresh	24 ounces
Salt	2.75 ounces
Water	3.5 pounds

A Hobart Mixer, Model D, was used for mixing the ingredients. The

eggs were placed in a 30-quart, stainless steel bowl with a flat beater and mixed at Speed 2 for one minute. After addition of the bread crumbs, salt and water to the eggs, the mixture was combined at Speed 1 for one minute. The ground beef was placed in the bowl with the other ingredients and mixed for one minute at Speed 1. Finally, to insure thorough mixing, the ingredients were combined at Speed 2 for 30 seconds. To form loaves, 900 grams of the mixture were weighed into preweighed and labeled disposable aluminum pans. The pans were 8-1/2 inches long, 4-1/2 inches wide and 2-1/2 inches deep. The back of a stainless steel mixing spoon was used to press the meat mixture into the pan and to level the surface of the loaf.

For preparation of a single loaf, the following modifications of the above formula and procedure was used:

Ground Beef	1.5 pounds
Bread Crumbs	2.5 ounces
Eggs, whole fresh	2.0 ounces
Salt	0.25 ounces
Water	4.5 ounces

A Hobart Mixer, Model 50D, with a five-quart, stainless steel bowl and a flat beater was used. The eggs, bread crumbs, salt and water were combined for one minute at Speed 2. After addition of the ground beef, the ingredients were mixed for one minute at Speed 1 and for 15 seconds at Speed 2.

Twenty-four pounds of white, loaf bread was purchased immediately prior to the start of the experimental portion of the study. The bread was made into bread crumbs by blending it in a blender. The crumbs were weighed and placed in plastic bags. The bags were securely

sealed and placed in the Victory 2-Door Freezer until immediately prior to use in the fabrication of the loaves.

The salt in the loaves was purchased at same time as the bread. Grade A, large size eggs were obtained on the day the 12 loaf batch was fabricated. An adequate number were procured to use for 12 loaves to be stored and six loaves to be made fresh on the day of sampling. Eggs for the frozen, thawed loaves were obtained on the day the loaves were fabricated and placed in the freezer. The water used was cool tap water.

Cooking of the Loaves

After fabrication of the loaves, they were placed in a preheated General Electric natural convection deck oven (Model CN50). The thermostat was set at 325°F. (Dennler, 1971) and the upper and lower heating elements were set on medium. Actual range of the temperatures achieved in the deck was 325° ± 25°F. Copper-constantan thermocouples attached to a Honeywell Electronic 16 Multipoint Temperature Recorder (Model 16) measured ambient temperature of the oven and internal temperatures of the meat loaves. The thermocouples were centered into the loaves vertically through a clay, 3/4 inch wide block resting on the rim of the pan. The thermocouple was fixed so that its point was located one inch from the bottom and the top of the loaf, halfway the length of the pan. The point had previously been determined as the cold point of the loaf. The loaves were heated until an internal end point temperature of between 165°F. and 170°F. (Draudt, 1972) was reached at the central loaf location occupied by the sensing portion

of the thermocouple. When 12 loaves were cooked, they were randomly placed in two rows within the deck, each row containing six loaves. Five thermocouples were used for 12 loaves, four inserted in the loaves at the end of each row and one inserted in a centrally placed loaf.

Frozen, Thawed Loaves

For each replication, 12 loaves which had been heated to an internal temperature of 165°-170°F. were removed from the oven, held at room temperature for 10 minutes, weighed, drained and reweighed. The loaves remained in the pans in which they were cooked and were covered with a double thickness of heavy weight aluminum foil. The foil pan cover extended one inch from the rim of the pan on every side. This one inch overlap was turned down the side of the pan and closely pressed against the rim of the pan. The edge of the overlap was sealed to the side of the pan with freezer tape. The packaged loaves were transported immediately after sealing to the Central Food Service of The University of Tennessee which was located one city block from the laboratory. There the loaves were placed in a -20°F. still air freezer and remained for 24 hours. After this quick freezing process, the frozen loaves were returned to the laboratory and placed in the same freezer containing the frozen raw ground beef. The frozen loaves remained in the laboratory freezer until six hours prior to the Day 0 reheating time. For this six hour interval they were placed in the Environmental Chamber for thawing. The temperature

of the chamber was set at 32°F. or 42°F. depending on the chosen temperature for storage of all cooked refrigerated loaves.

Refrigerated and Pasteurized Loaves

In addition to the six frozen, thawed loaves, 12 loaves were required for each holding period of nine days. Six of the 12 loaves were refrigerated after being cooked to an internal temperature of 165°-170°F., weighed, drained and reweighed before being sealed in the same procedure as the loaves which were to be frozen. These six loaves placed in the environmental chamber constituted the samples referred to as refrigerated.

The remaining six loaves of 12 cooked as a batch were treated in the same process as refrigerated loaves until just prior to sealing the pans. At this point, the internal temperature of the loaves was checked by insertion of a thermocouple. After the temperature was determined, the foil covers were placed on the pans. The six loaves to be "pasteurized" were returned to the deck oven. The thermostat was again set at 325°F. Based on preliminary tests, the sealed loaves remained in the oven a specified length of time which insured that the internal temperature of loaves reached at least 165°F. The following temperature-time relationships for "pasteurization" of the loaves to an internal temperature of 165°F. were determined.

If the Internal Temperature Was:	Heat for:
120°-130°F.	25 minutes
131°-140°F.	18 minutes
141°-150°F.	14 minutes
151°-160°F.	7 minutes

After the pasteurization process, these six loaves were also placed in the Environmental Chamber for holding at refrigerated temperatures.

Reference Loaves

At each sampling period, a freshly prepared loaf was cooked to an internal end point temperature of 165°-170°F. The loaf was fabricated and cooked so that it was removed from the oven in time prior to sampling to be held for 10 minutes at room temperature, weighed, drained and reweighed in the same procedure as the loaves with different handling treatment which had been refrigerated and reheated.

III. HOLDING CONDITIONS

At the initiation of a holding cycle which consisted of nine days of refrigerated storage, six loaves from each of the three handling treatments were placed in the Environmental Chamber (Associated Testing Laboratories, Model HH 5127). The humidity of the chamber at the temperatures used remained constant at 3 percent ± 1 percent. Higher humidity for the chamber could not be achieved. The alternate temperatures at which meat loaves were held in the chamber were 32°F. and 42°F. The chamber was able to maintain the selected temperature to ± 1°F. during the holding time frame of nine days. The two temperatures for storage were chosen as representative of the limits of refrigerated storage. Since the freezing point of meat is 28-29°F. (Hardenburg and Lutz, 1968), 32°F. was chosen as a temperature just above the freezing point. The United States Public Health Service

(USPHS, 1962) recommends 40°F. as the upper limit of refrigeration storage, and 45°F. as the permitted safe internal temperature of food. A temperature of 5.6°C. (42°F.) or below has been recommended by Frazier (1967) for refrigeration to deter growth of psychrophiles and to prevent growth of pathogenic organisms.

Within the specified storage period of nine days, one loaf from each handling procedure was removed from the environmental chamber on Day 0, Day 1, Day 2, Day 4, Day 7, and Day 9. The loaves removed were reheated and tested subjectively and objectively for possible changes occurring in quality characteristics of the food product. A day was considered a 24 hour period, so that between each sampling point equal time intervals occurred.

IV. REHEATING LOAVES HELD IN REFRIGERATED STORAGE

One loaf from each of the three handling procedures was removed from the environmental chamber approximately 75 minutes prior to sampling by the taste panel. The three loaves were unwrapped, weighed and placed in the Genreal Electric deck oven which had been preheated with a thermostat set at 325°F. under the same conditions as for the initial cooking of the loaves. As previously, when an internal temperature within the range of 165° to 170°F. was achieved, the loaves were removed from the oven, held at room temperature for 10 minutes, weighed, drained and reweighed. Samples from each reheated loaf and from the freshly cooked reference loaf were removed for the taste panel to judge and for the objective measurements.

A freshly prepared loaf was being cooked at the same time, and under the same conditions as the refrigerated loaves were being re-heated. The fresh loaf was placed in the oven approximately 15 minutes prior to the refrigerated loaves. A thermocouple was inserted in each of the four loaves using the same procedure as for initial cooking and the internal temperature of all loaves was monitored.

V. MEASUREMENT OF QUALITY CHARACTERISTICS

The most relevant quality characteristics of the meat loaves held in refrigerated storage were those of product safety as influenced by microbial population and sensory attributes which would affect the acceptability and consumption of the food. Objective and subjective measurements were chosen for use in the study which would indicate whether changes related to safety and sensory characteristics occurred under the influence of the chosen storage time and conditions. Since there are few reports in the literature which indicate the quantitative measurement of quality characteristics and changes in food produced in volume, cooked and stored under refrigeration, answers to two questions were sought from the data collected. These questions were:

1. Do quality changes occur in cooked meat loaves over a period of refrigerated storage?

2. If changes are indicated, what effects do such have upon the usefulness of the product for human consumption as food?

Cooking Losses

All loaves cooked were evaluated for cooking losses, both upon initial heating and reheating. Upon removal from the oven, loaves were held at room temperature for 10 minutes to allow surface moisture to evaporate and to provide time for the internal temperature of the loaves to reach a maximum point and begin to decline. The loaves in the preweighed pans in which they were cooked were weighed to the nearest 0.5 gram on the Mettler P3 balance to determine evaporation loss represented by the difference in raw and cooked weight. The pans containing the loaves were inverted upon wire racks suspended over a pan and allowed to drain for five minutes after which they were reweighed on the Mettler P3 balance to the nearest 0.5 gram. The difference in the cooked weight and the cooked, drained weight represented the drip loss.

When cooked loaves were removed from refrigerated storage, the pan covers were removed and the loaves weighed prior to reheating to determine evaporation losses during the holding period. After the second heating process, the same procedures as initially were carried out to calculate the losses from evaporation and drip occurring during the reheating period.

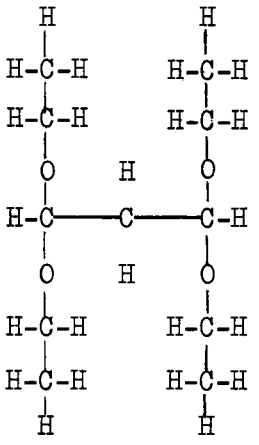
Moisture Content

Duplicate samples of five grams ± one gram in weight were taken from each loaf. The samples of meat were placed in numbered, preweighed aluminum weighing dishes and weighed to the nearest 0.005 gram on the

Mettler P120 balance. The thermostat of the General Electric Convection Oven (Model CN 90A) was set at 225°F. and the oven was preheated for 15 minutes prior to placement of the samples in the oven. The meat was dried uncovered in the convection oven for three hours. Upon removal from the oven it was reweighed. The meat samples were placed in the dessicator for 30 minutes and then weighed again. To insure that a constant weight was obtained, the samples were replaced in the convection oven for a repeat three hours of drying, after which they were reweighed. This procedure represents a modification of Air Drying Moisture Determination of AOAC (1970). AOAC recommends the use of 125°C. (289°F.) for air drying in a convection oven. In preliminary study, a drying temperature of 125°C. was found to heat the meat loaf samples excessively resulting in decomposition and loss of fat as well as moisture.

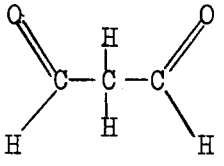
Oxidative Rancidity Determination

The distillation procedure for the 2-Thiobarbituric Acid Test, as developed by Tarladgis et al. (1960) was defined and used to evaluate oxidative rancidity development in each loaf at each sampling period. Sinnhuber and Yu (1958) recommended establishment of an absorbance curve using 1,1,3,3-Tetraethoxypropane (TEP) as a standard. The formula of TEP is as follows:



M. W. 220.313

Upon acid hydrolysis, TEP yields malonic dialdehyde. The formula for malonaldehyde is:



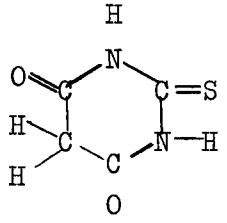
M. W. 72.035

Tarladgis et al. (1960) reported they used 10^{-8} dilutions of TEP to formulate a standard curve. Repeated efforts to obtain readings on either the Bausch and Lomb Spectronic 20 or the Beckman Model B spectrophotometers were unsuccessful. TEP dilutions of 1×10^{-3}, 1×10^{-4}, 1×10^{-5}, 1×10^{-6}, 1×10^{-7}, and 1×10^{-8} moles were prepared and distilled. Only the solutions of 1×10^{-5} M and 1×10^{-6} M gave readable absorbance values. Although Witte et al. (1970) have reported an absorbance of 0.147 nanometers for a 1×10^{-8} M TEP solution, Kwon and Watts (1964) used 10^{-6} M solutions to determine the recovery of malonaldehyde. In Table 22, Appendix A, it can be seen that a mean absorbance of 0.135 nanometers was obtained for a 1×10^{-6} M solution of TEP in the current study. There may exist a difference in the reporting of the molarity of the solutions used, since Tarladgis

et al. (1960) and Witte et al. (1970) reported a concentration of 1 x 10^{-8} M per five ml. of solution while Kwon and Watts (1964) defined the dilution as 1 x 10^{-6} M of TEP per 100 ml. of solution. The solutions prepared and reported in the current study were 10^{-6} M dilutions in 100 ml. volumes and thus these known concentrations appeared the most appropriate to report.

To establish a standard absorbance curve and to calculate the recovery rate of malonaldehyde, a 1 x 10^{-3} M solution of TEP in distilled water was prepared. Using the 1 x 10^{-3} M solution as the stock solution, dilutions to give a series of concentrations of TEP ranging from 1 x 10^{-4} to 10 x 10^{-4} moles were made. A set of triplicate 10 ml. aliquots of each concentration of TEP from 1 x 10^{-4} to 10 x 10^{-4} moles were taken by pipettes. To each TEP concentration, 97.5 ml. of distilled water and 2.5 ml. of 4 N hydrochloric acid were added. This yielded a series of 10^{-6} molar solutions. This series of TEP dilutions were placed in 500 ml. Kjeldahl flasks which were attached to the macro-Kjeldahl distillation rack. At the highest gas flame, they were heated approximately 10 minutes to collect 50 ml. of distillate. When cool, the distillate from each dilution was stirred and 5 ml. of each were pipetted into 50 ml. screw-top tubes. To the distillate was added 5 ml. of TBA reagent. The TBA reagent consisted of a 0.02 molar solution of 2-Thiobarbituric Acid in 90 percent glacial acetic acid. To make 100 ml. of 0.02 molar 2-Thiobarbituric Acid, 0.2883 grams of 2-TBA was diluted to 100 ml. in a volumetric flask with acetic acid and warmed slightly in a boiling water bath to bring into solution. The formula

for 2-Thiobarbituric Acid is as follows:



M. W. 144.15

A second set of TEP dilutions was prepared and was not distilled. Five ml. of each dilution from 100 ml. of 1 x 10^{-6} to 10 x 10^{-6} molar solutions were placed in 50 ml. screw-top tubes and 5 ml. of TBA reagent were added to each of the 10 tubes. A blank consisting of 5 ml. of distilled water and 5 ml. of TBA reagent was made. All the tubes were placed in a boiling water bath for 35 minutes after which they were cooled in tap water for 10 minutes. A portion of each dilution was transferred to a spectrophotometric tube and the absorbance of each sample was read against the TBA-distilled water blank. Readings were taken on a Bausch and Lomb Spectronic 20 and a Beckman Model B spectrophotometer at wavelengths of 520, 524, 530, 532, 535, 537 and 540 nanometers. The purpose of reading absorbance over this range was to determine the wavelength of maximum absorption. Readings taken on the Beckman Model B spectrophotometer were found to be more consistent as to the wavelength of maximum absorption and gave a more definitive standard curve when plotted. Thus, further readings reported in this study are from the Beckman Model B spectrophotometer. The absorption values and standard curve are reported in Table 22, Appendix A. Figure 1 is the TEP Standard Curve.

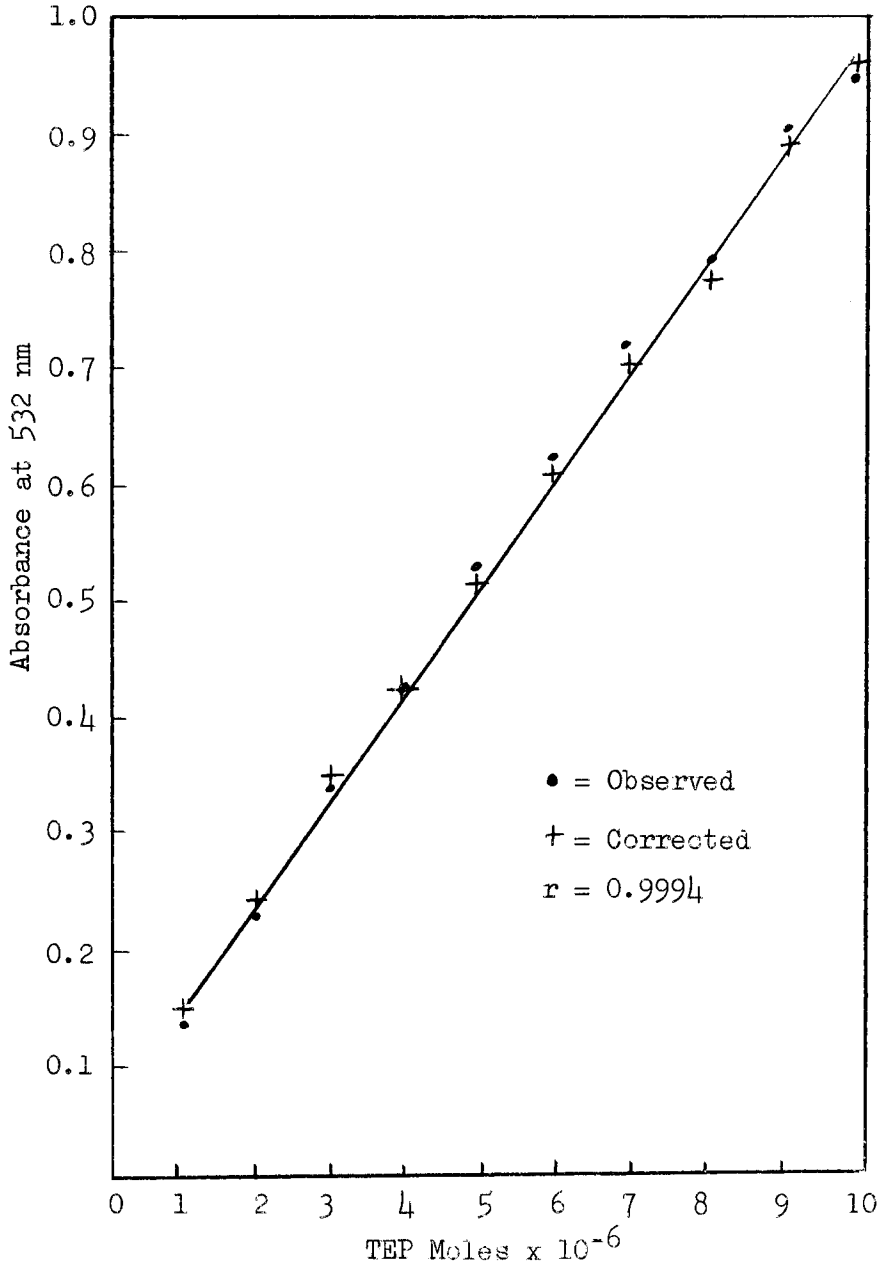


Figure 1. TEP Absorbance Standard Curve

Comparisons were made between absorbance readings from undistilled TEP and distilled TEP over the 1×10^{-6} to 10×10^{-6} M dilution range. The comparison was carried out at the wavelength of maximum absorption which was found to be 532 nanometers (see Table 23, Appendix A). The relationship which was ascertained through this comparison determined the percent of malonaldehyde which was recovered during the distillation process. One essential step in determination of recovery rate of malonaldehyde was not reported in Tarladgis et al. (1960). Five ml. of undistilled TEP were taken as a sample from 100 ml. of 1×10^{-6} M dilutions, while five ml. of distilled TEP were taken from 50 ml. of distillate. To correct this variation, the values for absorbance of the undistilled TEP were multiplied by a factor of two. The formula for the recovery rate of malonaldehyde is as follows:

$$\text{Percent Recovery} = \frac{\text{Absorbance}_{532} \text{ Distilled TEP}}{\text{Absorbance}_{532} \text{ Undistilled TEP} \times 2} \times 100$$

Table 23, Appendix A, contains the determinations from which recovery rate was calculated. A recovery rate of 68 percent was obtained, confirming the rate used by Tarladgis et al. (1960).

When the standard curve had been constructed and the percent recovery rate of TEP in distillation was known, it was possible to verify the formula used by Tarladgis et al. (1960) and to confirm the constant (K) which represents milligrams of monaldehyde per 1000 grams of meat. The formula as used by Tarladgis et al. was:

$$K \text{ (distillation)} = \frac{\text{Concentration of TEP in moles/5 ml. of distillate}}{\text{Optical density (absorbance)}} \times \text{Molecular weight of malonaldehyde} \times \frac{10^7}{\text{Weight of sample}} \times \frac{100}{\text{Percent recovery}} .$$

To obtain a value of 7.4×10^{-8} for the first term of the constant, Tarladgis et al. extrapolated the standard curve line reading the intersection point between an absorbance value of 1.0 and a concentration of 7.4×10^{-8} M although they did not actually take a reading at that dilution. In the present study, it was decided to use the absorbance reading from the lowest dilution which was 1×10^{-6} M per 100 ml. of solution. The value of 10^{7} in the third term of the constant was used by Tarladgis et al. as a correction factor to obtain a number larger than one for the K value. In this study it was changed to 10^{5} to account for use of 10^{-6} dilutions rather than 10^{-8} dilutions. The calculation of the constant K (distillation) was as follows:

$$K = \frac{1 \times 10^{-6}}{.135} \times 72.035 \times \frac{10^{5}}{10} \times \frac{100}{68}$$

$$K = 7.4 \times 10^{-6} \times 72.035 \times 10^{4} \times 1.47$$

K = 7.8 mg. of malonaldehyde per 100 grams of meat .

To determine Thiobarbituric Acid (TBA) values of the meat loaves, duplicate 10 g. samples of meat from each loaf was placed in a Virtis Homogenizer Flask (No. 16-117) containing 50 ml. of distilled water. The meat and water were mixed into a slurry by homogenizing for one minute at low speed and one minute at medium speed on the Virtis Homogenizer (Model S 45). The slurry was transferred quantitatively to a 125 ml. Erlenmeyer flask using 47.5 ml. of distilled water. To each flask was added 2.5 ml. of 4 N hydrochloric acid. The pH of this mixture was routinely verified with pHydrion paper to insure that it was between a pH of 1.3 and 1.8. At this pH range, Tarladgis et al. (1960)

found the maximum amount of malonaldehyde was distilled. Kwon and Watts (1964) confirmed that recovery of malonaldehyde was maximum below a pH of 3. The mixture was swirled and transferred to 500 ml. Kjeldahl flask. One measured spray of Dow Antifoam A was placed in the neck of each flask. The flasks were placed on the macro-Kjeldahl distillation rack and heated at the highest heat attainable from the gas flame. The flasks were heated from 9 to 12 minutes to obtain 50 ± 3 ml. of distillate.

The distillate was swirled to mix and 5 ml. were pipetted into a 50 ml. screw-top tube. Five ml. of freshly prepared TBA reagent were delivered by burette into the distillate. A blank consisting of 5 ml. of distilled water and 5 ml. of TBA reagent was prepared. All the tubes containing the distillate-TBA mixture and the blank mixture were capped, shaken and immersed in a boiling water bath for 35 minutes. After removal from the water bath, the tubes were cooled in tap water for 10 minutes. A portion of the contents of each tube was transferred to a spectrophotometric tube. The blank was examined for any indication of TBA decomposition due to the heat-acid treatment. The decomposition was indicated by a pink color in the blank solution. The absorbance of the blank was read daily against an unheated blank mixture. The maximum absorbance of the blank during the study was 0.020 nanometers. The absorbance of each sample was read against the blank at a wavelength of 532 nanometers on the Beckman Model B spectrophotometer. The absorbance values obtained were multiplied by the constant, K = 7.8 to give a TBA number equaling the

milligrams of malonaldehyde per 1000 grams of meat.

On Day 1 of each holding period, TBA numbers of raw, thawed ground beef and raw meat loaf mixtures were determined. This was performed to determine if oxidative changes were occurring in the raw frozen meat over the storage period from the beginning of the experimental portion of the study in January 1974 until its completion in April 1974. TBA values of raw meat samples also were studied to see if variations in thawing temperatures had any effect upon the raw meat entering the mixture. Further, the purpose of obtaining the TBA number of the meat loaf mixture was to ascertain if addition of the other ingredients to the ground beef effected any change in the TBA numbers of the raw meat.

pH Determination

A 10 g. sample from each loaf at each sampling period was taken for pH determinations. The meat was mixed with 50 ml. of distilled water and blended on the Virtis Homogenizer for 30 seconds at low speed. The meat and water slurry was allowed to stand for approximately one hour until equilibrium was reached. The supernatant liquid was poured from the flask and the pH value of the remaining meat mixture was determined using a Corning Model L Expanded Scale pH Meter. Prior to each use, the instrument was standardized using a standard buffer at pH 7.00. This procedure generally conformed with the method of AOAC (1970).

The purpose of determining the pH value of cooked meat loaves was twofold. First, it was necessary to ascertain the pH to see if

it was sufficiently low (below 6.0) to influence the growth of psychrophilic bacteria. Second, Keskinel et al. (1964) indicated that the pH of the product itself could influence the results of the TBA test. They found changes in the TBA numbers were minimal in meat with a pH above 6.22.

Standard Plate Count for Aerobic Bacteria

To indicate the microbial condition of the meat loaves following the various handling procedures, the time in storage and the conditions of storage, a Standard Plate Count was obtained. The Standard Plate Count determined the total count of aerobic bacteria present in the sample of meat tested on Day 0, Day 4, Day 7 and Day 9 of each storage period. The purpose of the Standard Plate Count has been described (Inter. Comm. Micro. Specs. for Food, 1968) as:

> To evaluate the adequacy of sanitation and temperature control during the processing, transport, and storage; for opinion of incipient spoilage; probable shelf life.

During the first replication at holding temperatures of 32°F. and 42°F., samples of meat were taken from the freshly prepared loaf immediately after it was cooked and from stored loaves after they were reheated. After the first cycle of storage at 32°F. and 42°F., samples were taken from stored loaves prior to reheating as well as after reheating.

The sample from each loaf in the first replication consisted of a 0.5 cm. slice from both end portions of the loaf and a 0.5 cm. slice from the entire bottom of the loaf. When the loaf was sampled

both before and after reheating, one sample was composed of the slice from one end and half the bottom. The second sample was taken from the remaining end portion and the second half of the bottom of the loaf. The researcher wore disposable plastic gloves and used a sterilized knife to take the samples. Samples were placed in weighed, labeled, sterile glass jars covered with aluminum foil. After meat was placed in the jar, the knife was used to cut and break the slices into small pieces and to mix the sample portions. The weight of the meat removed from the loaf prior to reheating was recorded with calculated adjustment for heating to complete the data for cooking loss determination. Samples were placed in a refrigerator for approximately one hour until the taste panel was completed and samples for other tests taken from the loaves. The sample jars were placed in a covered plastic container and transported to the Department of Microbiology for completion of the Standard Plate Count procedure.

Blender jars and lids for each sample were wrapped and sterilized in the autoclave for 15 minutes at 121°C. prior to each day's procedure. Flasks of 450 ml. of distilled water were also sterilized for 15 minutes at 121°C. Standard Plate Count Agar (Difco) was prepared and sterilized at 121°C. for 15 minutes. After the sterilization process, the agar was held in a water bath at 45°C. until it was used for pouring the plates.

A 50 g. ± 1 g. sample of meat loaf was weighed into a sterile blender jar containing 450 ml. of sterile water to provide a dilution of 1×10^{-1}. The meat-water mixture was combined for two minutes on

the blender. Immediately after blending, serial dilutions of 1 x 10^{-2}, 1 x 10^{-3}, and 1 x 10^{-4} concentrations were made. Accepted microbiological techniques and equipment were used to prepare duplicate series of dilutions for each meat sample. Just prior to pouring the 45°C. agar solution into the Petri dishes which contained the dilutions, one ml. of 1 percent solution of 2,3,3-triphenyltetrazoliumchloride (TTC) was added per 100 ml. of agar. The plates were incubated at 32°C. ± 1°C. for 48 hours ± 3 hours. All colonies on each plate were counted and the duplicate plate counts for each dilution were averaged.

The procedure which was used followed that recommended by the AOAC (1970), except for the use of a 32°C. incubator. AOAC recommends 35°C. The lower temperature was used since the food was stored under refrigeration and interest was in growth of psychrophilic bacteria as well as mesophiles.

Taste Panel Evaluation

A taste panel composed of seven graduate student volunteers from the Department of Food Science and Food Systems Administration evaluated the samples of meat loaf. The purpose of the sensory evaluation was to ascertain if a difference existed among the four samples resulting from handling treatments, storage conditions and length of storage (Amerine et al., 1965). The judges were informed as to the general conditions of the study, but were not provided specific temperatures, holding conditions and treatments until after the experimental portion of the study was completed.

The panel scored the meat using a nine-point scale. The quality characteristics evaluated were odor, appearance, flavor and juiciness. See Appendix B for a sample of the score card used in this study. In addition to giving numerical scores, the taste panel members were asked to judge each sample as an acceptable or unacceptable product (Mahoney et al., 1957). An arbitrary decision was reached by the researcher that if any sample at a testing session was judged as unacceptable by four of the seven judges, no further sensory evaluations would be made during that storage cycle on the remaining loaves which received the same handling treatment prior to refrigeration. For purposes of data calculation, values of one would be assigned if the product was not judged due to unacceptability.

The judges were trained prior to the initiation of the study using stored and fresh loaves. Triangle tests were used to identify both fresh and stored loaves. Discussion was held as to the descriptive terms which might be relevant to the development of off-odors and off-flavors. This discussion was held as the judges were presented stale and rancid meat loaves held for various lengths of time in refrigerated storage. Lastly, the judges were given the opportunity to evaluate samples under the same conditions and with the same score card which was to be used in actual testing.

After samples for microbial study were removed from the loaves, each loaf was cut in two equal portions across the center. Two 3/4 inch slices were obtained from each portion nearest the center of the loaf. The slices were cut in half to yield eight portions, seven of

which were randomly assigned and presented to the judges for tasting. The panel members received four samples at one time, one from the freshly prepared loaf cooked immediately prior to evaluation; one from a loaf which had been refrigerated; one from a loaf which had been frozen, thawed and refrigerated and one from a pasteurized and refrigerated loaf. The fresh sample was not identified to the judges. On three days at different intervals, judges were given a fifth sample identified as a fresh product to serve as a memory refresher.

Meat samples were placed on white plates and individually covered with an inverted custard cup to retain odor constituents. The number code for each sample was marked on the custard cup. The temperature of the meat was between 70°F. and 90°F. when sampled by the panel. The Day 0 panel met in mid-afternoon after samples had been in the environmental chamber for four hours. The other five sessions which met over a nine day storage period were held in mid-morning each day. This represented a 24 hour storage period from the initial time the loaves were placed in storage on Day 0 until Day 1 and 24 hour intervals for the days following Day 1.

Experimental Design and Statistical Analysis

A split plot design was utilized (Cochran and Cox, 1957). The main plot consisted of the holding temperatures and the subplot was the times of sampling within a nine day storage cycle. The time sequence for sampling at specified intervals comprised a stratified subplot. The loaves from the three handling treatments prior to refrigeration and the reference loaf were presented simultaneously over

all temperatures and times of holding.

The order in which the temperature of the environmental chamber was established for storage of the loaves was randomly chosen. The sequence was: 42°F., 32°F., 32°F., 42°F., 42°F. and 32°F. for three replications. Presentation of samples from four handling treatments to the taste panel was in random order. Samples were coded with three-digit numbers taken from a table of random numbers.

Statistical analyses included the analysis of variance for all quality variables which were observed and orthogonal comparisons among handling procedures. The selected contrasts among handling procedures were to compare: the freshly prepared loaf cooked immediately prior to preparation (F) versus all stored loaves, refrigerated (R) loaves to pasteurized (P) loaves, and frozen, thawed (FT) loaves to refrigerated (R) and pasteurized (P) loaves (see Table 4). Regression lines were calculated in regard to variable changes over the nine day storage period. The hypothesis that changes were linear over storage time was not rejected. Coefficients of correlation were calculated between TBA numbers and flavor scores, TBA numbers and odor scores and flavor and odor scores.

Table 4. Orthogonal Comparisons for Objective and Subjective Measurements

Comparisons Among Handling Procedures	Handling Procedures			
	Fresh	Refrigerated	Pasteurized	Frozen, Thawed
1. F. vs. R., P., and F., T.	+3	-1	-1	-1
2. R. vs. P.	0	+1	-1	0
3. F. T. vs. R. and P.	0	-1	-1	+2

CHAPTER IV

RESULTS AND DISCUSSION

The major variables evaluated in regard to refrigerated storage of cooked ground beef loaves were temperatures of storage, length of time loaves were in storage and handling procedures for cooked loaves prior to storage. Analyses of variance were calculated to determine if statistically significant differences existed in meat loaves influenced by these listed variables. Orthogonal comparisons selected prior to initiation of data collection were used to identify pertinent differences which might be statistically significant among the handling procedures.

In the course of the study the following objective measurements were made on the meat loaves: time in minutes of initial heating, pasteurizing and reheating; initial evaporation and drip cooking losses in grams; reheating evaporation and drip cooking losses in grams; moisture content in percent; TBA values as measured in absorbance at 532 nanometers and TBA numbers as calculated; pH values; and standard plate counts for aerobic bacteria. Sensory evaluation of the quality characteristics of odor, appearance, flavor and juiciness was performed by a trained taste panel consisting of seven judges.

Although data collected have been tabulated according to storage temperatures and days in storage to achieve a uniformity of presentation, not all measurements relate to these two factors. Measurements

such as heating time and initial cooking losses were not directly influenced by storage factors. The procedure of cooking raw loaves, of course, occurred prior to the holding point and point of evaluation. A freshly prepared meat loaf cooked immediately prior to evaluation served as a reference for all other loaves observed, so that in tabular compilations of data, the fresh loaf is listed by storage day as a point of reference for stored loaves, rather than to imply the fresh product was actually held in storage.

I. COOKING AND REHEATING TIME

Complete data related to heating time for all loaves are found in Tables 25-32, Appendix C. A summary of heating information is provided in Table 5.

Table 5. Summary of Initial, Pasteurization, Reheating and Total Heating Time in Minutes for 900 Gram Ground Beef Loaves: Freshly Prepared, Freshly Cooked Loaves Compared to Refrigerated, Pasteurized, and Frozen, Thawed Loaves Held in Refrigerated Storage

Heating Procedure	Fresh min.	Handling Procedures: Refrigerated min.	Pasteurized min.	Frozen, Thawed min.
Initial	54.6	59.6	59.6	58.9
Pasteurization	0.0	0.0	18.0	0.0
Reheat	0.0	41.7	42.3	43.9
Total	54.6	101.9	119.6	102.8

It may be observed in Table 5 that the total time which stored and reheated loaves were subjected to heat averaged within one minute among the three handling procedures when the pasteurization time of 18 minutes was removed. Orthogonal comparisons (Table 6) revealed that the 54.6 minute mean for total heating of reference loaves to be less than stored loaves at a highly significant difference level ($P < 0.01$). Reference loaves were not reheated which accounts for this difference. A comparison among handling procedures revealed a highly significant difference ($P < 0.01$) in frozen, thawed heating time when comparisons were made to refrigerated and pasteurized loaves. This difference is not of practical significance due to the inclusion of the added time of pasteurization in this orthogonal comparison. Total heating time for pasteurized loaves were significantly longer ($P < 0.01$) than for refrigerated products.

In the analysis of variance (Table 6), a significant difference ($P < 0.05$) was noted between the storage temperatures of 32°F. and 42°F. The reason for this statistically significant difference may perhaps be ascertained from data observed as to the internal temperature of raw meat loaves as placed in the oven for initial cooking, and cooked meat loaves as ready to be reheated. As reported in Table 33, Appendix C, the overall mean for cooked loaves stored at 32°F. was 49°F. and the mean for cooked loaves stored at 42°F. was 60°F. This represents an 11°F. differential. Since raw ground beef for preparation of single loaves to be freshly prepared and cooked prior to evaluation was defrosted at the storage temperature set for cooked loaves

Table 6. Analysis of Variance: Total Heating Time in Minutes for 900 Gram Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	2047.56	2047.56	9.96	P < 0.05
Replication/Temperature	4	821.56	205.39		
Handling Procedure	3	84011.24	28003.75	508.73	P < 0.01
F vs R, P and FT[a]	1	76613.02	76613.02	1392.96	P < 0.01
R vs P	1	5958.68	5958.68	108.33	P < 0.01
FT vs R and P	1	1420.91	1420.91	25.81	P < 0.01
(Temperature x Handling)	3	391.74	130.58	2.37	N. S.
(Replication x Handling)/Temp.	12	660.56	55.05		
Storage Day	5	50.95	10.19	0.18	N. S.
Temperature x Storage Day	5	329.56	65.91	1.19	N. S.
(Replication x Storage Day)/ Temperature	20	1108.44	55.42		
Handling x Storage Day	15	250.13	16.68	1.07	N. S.
(Temperature x Handling x Storage Day)	15	314.30	20.95	1.34	N. S.
(Replication x Handling x Storage Day)/Temperature	60	936.78	15.61		
Total	143	90922.83	635.82		

[a]F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

in the environmental chamber, a differential of 16°F. may be seen in Table 33, Appendix C, for meat thawed at 32°F. and 42°F.

The only internal temperature means which varied appreciably from overall values were those of loaves stored for four hours and removed for heating on Day 0. In these loaves, the average internal temperature of refrigerated and pasteurized loaves stored at 32°F. was 53°F. and at 42°F. was 60°F. The mean for frozen, thawed loaves stored at 32°F. for four hours was 44°F. and at 42°F., it was 49°F. The meaning of this comparison was that the internal temperatures of warm loaves did not, over a four hour storage period, equilibrate with the refrigerated ambient temperature while frozen, thawed loaves reached internal temperatures only a few degrees above the storage ambient after they were removed from the chamber and prepared for reheating. Thus, on Day 0, all loaves which were reheated did not start the reheating process with similar internal temperatures.

Other than tabulation of cooking and reheating times, this study did not evaluate energy use by various storage systems. In a time of energy awareness, it is pertinent to note that refrigerated and frozen, thawed meat loaves used a mean additional 47.3 and 48.2 minutes respectively for heating and pasteurized loaves required a mean additional 65.2 minutes over the energy need for freshly cooked loaves.

II. COOKING LOSSES

Data related to cooking losses are reported in Tables 35-42, Appendix D. The analysis of variance for total cooking losses is

found in Table 7. While initial and reheat cooking losses are highly variable within loaves, cooking losses at all steps of measurement were remarkedly consistent over the treatment means as can be seen in Table 8.

The only variable for which a statistically significant difference was found was handling procedure. Losses for freshly cooked loaves which were heated only once were highly significantly less ($P < 0.01$) than stored and reheated products. This may be noted in Table 8 where the degrees of freedom for handling procedure are partitioned into orthogonal contrasts. There was a highly significant difference ($P < 0.01$) in cooking losses sustained by pasteurized loaves as compared with refrigerated products. Total cooking losses for frozen, thawed loaves were not significantly different from the losses of the other two stored loaves.

Table 43, Appendix D, provides data regarding weight loss between original weighing of loaves after initial cooking and a second weighing immediately after removal from the environmental chamber. The overall mean for weight loss in this interval was 3.4 grams and the range was from 0.0 grams to 16.0 grams. These values represent minimal losses, especially since loaves were held for only 10 minutes after cooking and before weighing, draining for five minutes, reweighing, sealing and placing in refrigerated storage. The internal temperature of loaves to be refrigerated or frozen was between 130°F. and 140°F. as they were placed in storage and temperatures of pasteurized loaves were 165°F. when they were put into the environmental chamber.

Table 7. Analysis of Variance: Total Cooking Losses in Grams for 900 Gram Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	720.03	720.03	0.41	N. S.
Replication/Temperature	4	7038.86	1759.72		
Handling Procedure	3	20613.37	6871.12	6.29	P < 0.01
F vs R, P and FT[a]	1	19481.00	19481.00	17.84	P < 0.01
R vs P	1	85.59	85.59	0.078	N. S.
FT vs R and P	1	1046.77	1046.77	0.96	N. S.
(Temperature x Handling)	3	1723.85	574.62	0.53	N. S.
(Replication x Handling)/Temp.	12	13104.07	1092.07		
Storage Day	5	2838.12	567.62	1.39	N. S.
Temperature x Storage Day	5	1971.22	394.24	0.96	N. S.
(Replication x Storage Day)/ Temperature	20	8168.30	408.41		
Handling x Storage Day	15	2576.34	171.76	1.18	N. S.
(Temperature x Handling x Storage Day)	15	1877.57	125.17	0.86	N. S.
(Replication x Handling x Storage Day)/Temperature	60	8736.11	145.60		
Total	143	69368.66	485.09		

[a] F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

Table 8. Summary of Initial, Reheat and Total Cooking Losses in Grams[a] for 900 Gram Ground Beef Loaves: Fresh Loaves Compared to Loaves Subjected to Prestorage Handling Procedures

Cooking Losses	Handling Procedure			
	Fresh g.	Refrigerated g.	Pasteurized g.	Frozen, Thawed g.
Initial:				
Evaporation	53.2	41.2	40.9	55.5
Drip	95.2	90.3	92.4	82.2
Total	148.4	131.5	133.3	137.7
Reheat:				
Evaporation	0.0	24.3	24.9	23.0
Drip	0.0	15.2	15.9	19.3
Total	0.0	40.5	40.8	42.3
Total (g.)	148.4	172.0	174.2	180.0
Total (%)	16.5	19.1	19.4	20.0

[a]Totals in grams and values comprising totals may not equal due to rounding.

This short time frame after cooking and the high internal temperatures were in contrast to the procedures of the Nacka system (Bjorkman and Delphin, 1966) and the AGS system (McGuckian, 1969). In these two systems, food was cooled prior to placing in storage for the stated purpose of minimizing losses during storage. It would appear that rapid action in sealing packages and placing loaves in storage does not produce weight losses during the holding period when the products are securely sealed. If evaporation did occur, the moisture might have been reabsorbed by the loaves over the storage cycle.

III. MOISTURE CONTENT

Tables 44 and 45, Appendix D, provide data relating to the moisture content of the meat loaves. Table 9 is a summary of moisture content percentages. Table 10 contains the analysis of variance for moisture content. The only statistically significant variable was handling procedure ($P < 0.01$). Orthogonal comparisons revealed that moisture content of reference loaves was highly significantly larger ($P < 0.01$) than that of stored loaves. Actual percentage mean for fresh loaves was 62.2 and there was a pooled value of 60.6 percent for all stored loaves. Moisture content of refrigerated and pasteurized loaves were not found to be significantly different from one another. Frozen, thawed loaves' moisture content was not significantly different from the other stored loaves.

A minimum of information was obtained from observations on moisture content. The heating processes, handling procedures and

Table 9. Summary of Moisture Content (%) of Cooked Ground Beef Loaves: Freshly Prepared, Freshly Cooked Loaves Compared to Loaves Subjected to Pre-storage Handling Procedures Prior to Storage at 32°F. and 42°F.

Days in Storage	Temperature °F.		Handling Procedure			
			Fresh[a]	Refrigerated[a]	Pasteurized[a]	Frozen, Thawed[a]
0	32		62.7	62.4	58.9	61.0
	42		63.8	60.0	62.0	61.4
1	32		62.1	60.6	60.9	59.4
	42		63.2	62.3	63.3	60.1
2	32		64.3	60.0	60.9	59.9
	42		62.3	62.3	60.5	61.2
4	32		60.6	61.2	60.4	60.9
	42		62.4	59.0	59.9	61.3
7	32		61.5	60.9	60.5	59.3
	42		62.0	58.6	60.3	61.5
9	32		61.3	60.2	60.6	60.0
	42		60.8	60.6	60.3	57.6
Handling Procedure Mean			62.3	60.7	60.7	60.3
Temperature Mean	32	60.8				
	42	61.1				
Overall Mean		61.0				

[a]At each temperature, value represents mean of three replications.

Table 10. Analysis of Variance: Moisture Content (%) for Cooked Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	2.67	2.67	0.45	N. S.
Replication/Temperature	4	23.77	5.94		
Handling Procedure	3	80.01	26.67	11.98	P < 0.01
F vs R, P and FT[a]	1	75.84	75.84	34.16	P < 0.01
R vs P	1	0.009	0.009	0.004	N. S.
FT vs R and P	1	4.01	4.01	1.81	N. S.
(Temperature x Handling)	3	6.14	2.05	0.92	N. S.
(Replication x Handling)/Temp.	12	26.70	2.22		
Storage Day	5	39.94	7.99	1.25	N. S.
Temperature x Storage Day	5	15.82	3.16	0.50	N. S.
(Replication x Storage Day)/ Temperature	20	127.25	6.36		
Handling x Storage Day	15	41.52	2.77	0.61	N. S.
(Temperature x Handling x Storage Day)	15	70.75	4.72	0.43	N S.
(Replication x Handling x Storage Day)/Temperature	60	271.67	4.53		
Total	143	706.24	4.94		

[a]F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

storage conditions evidently were not of a variation sufficient to influence moisture content. Although air flow in the environmental chamber was continuous and rapid to maintain a constant temperature, loaves were well sealed against exposure to air movement. Thus, the rapid air flow did not appear to effect the removal of moisture from the surfaces of the loaves.

IV. RANCIDITY DETERMINATION BY TBA NUMBERS

Thiobarbituric Acid (TBA) values for all loaves are reported in Tables 46-49, Appendix D. In these tables, both spectrophotometric absorbance at 532 nanometers and TBA numbers (Tarladgis et al., 1960) have been listed. TBA numbers represent absorbance at 532 nanometers times a constant of 7.8 to yield milligrams of malonaldehyde per 1000 grams of sample. The constant of 7.8 was confirmed after experimentation and modification of the method of Tarladgis et al. Modifications were previously noted in the procedures chapter of the current study. It is concluded that future reporting of TBA data in absorbance readings would be a sound procedure since the Tarladgis et al. method contains steps which are difficult to reproduce as well as to defend on a scientific basis. Perhaps use of a constant of this nature could be justified in 1960, but there have been 14 intervening years in which reporting of spectrophotometric data has become extensive and common. Today, a statement as to the spectrophotometer used, the absorbance setting in nanometers and the weight of the meat sample which was distilled would provide a suitable basis for comparison of various results.

As could be noted in Table 2, page 23, which summarized research using TBA values, it was difficult to make comparisons as to rate of development of oxidative rancidity because various reporting schemes were utilized.

A summary of TBA values are in Tables 11 and 12. The analysis of variance for TBA numbers is found in Table 13. Highly significant differences ($P < 0.01$) were found both for handling procedures and days in storage, as well as for interaction of handling procedure by days in storage. The interaction of handling procedure and days in storage might primarily be due to the effect of the reference loaf. Orthogonal comparisons determined for handling procedures (Table 13) revealed highly significant ($P < 0.01$) between TBA numbers of reference loaves and all stored loaves. A significant difference was not found between TBA numbers of refrigerated loaves and pasteurized loaves. Frozen, thawed loaves had TBA numbers with highly significantly different ($P < 0.01$) from refrigerated and pasteurized loaves.

Figures 2 and 3 picture data points and regression lines for TBA numbers over the nine day storage period. In these figures, it can be noted that values for fresh, refrigerated and pasteurized products are quite similar after four hours of storage whereas the TBA numbers of frozen, thawed loaves are already observably higher. At the Day 1 measurement period, TBA numbers for all stored loaves are generally above 1.00 which is the value cited by Watts (1962) as the threshold level for identification of off-odor by a taste panel.

Table 11. TBA Values: Absorbance at 432 nm of Cooked Ground Beef Loaves; Freshly Prepared, Freshly Cooked Loaves Compared to Loaves Subjected to Pre-storage Handling Procedures Prior to Storage at 32°F. and 42°F.

Days in Storage	Temperature °F.	Handling Procedure			
		Fresh[a]	Refrigerated[a]	Pasteurized[a]	Frozen, Thawed[a]
0	32	0.107	0.115	0.125	0.148
	42	0.109	0.127	0.121	0.168
1	32	0.106	0.137	0.160	0.177
	42	0.156	0.149	0.156	0.207
2	32	0.116	0.168	0.179	0.217
	42	0.177	0.215	0.253	0.282
4	32	0.128	0.186	0.236	0.248
	42	0.156	0.312	0.297	0.402
7	32	0.106	0.317	0.318	0.399
	42	0.136	0.370	0.414	0.474
9	32	0.132	0.395	0.334	0.453
	42	0.143	0.483	0.479	0.509

[a]At each temperature, value represents mean of three replications.

Table 12. TBA Values: TBA Numbers[a] of Cooked Ground Beef Loaves; Freshly Prepared, Freshly Cooked Loaves Compared to Loaves Subjected to Pre-storage Handling Procedures Prior to Storage at 32°F. and 42°F.

Days in Storage	Temperature °F.	Handling Procedure			
		Fresh[b]	Refrigerated[b]	Pasteurized[b]	Frozen, Thawed[b]
0	32	0.8372	0.0996	0.9750	1.1570
	42	0.8528	0.9958	0.9464	1.3140
1	32	0.8242	1.0686	1.2532	1.3858
	42	1.2220	1.1622	1.2194	1.6094
2	32	0.9022	1.3130	1.3988	1.6978
	42	1.3832	1.6822	1.9760	2.1996
4	32	0.9984	1.4508	1.8408	1.9370
	42	1.2220	2.4336	2.3218	3.1408
7	32	0.8242	2.4752	2.4830	3.1148
	42	1.0660	2.8860	3.2318	3.6972
9	32	1.0452	3.0810	2.6078	3.5360
	42	1.1180	3.7700	3.7392	3.9754

[a]TBA number equals absorbance$_{532}$ x 7.8 and is equivalent to milligrams of malonaldehyde per 1000 grams of sample.

[b]At each temperature, value represents mean of three replications.

Table 13. Analysis of Variance: TBA Numbers of Cooked Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	6.33	6.33	0.0003	N. S.
Replication/Temperature	4	4.23	1.06		
Handling Procedure	3	36.34	12.11	12.78	P < 0.01
F vs R, P and FT[a]	1	31.85	31.85	244.97	P < 0.01
R vs P	1	0.08	0.08	0.59	N. S.
FT vs R and P	1	4.42	4.42	34.02	P < 0.01
(Temperature x Handling)	3	0.42	0.14	0.43	N. S.
(Replication x Handling)/Temp.	12	1.53	0.13		
Storage Day	5	62.83	12.57	10.64	P < 0.01
Temperature x Storage Day	5	1.93	0.38	0.23	N. S.
(Replication x Storage Day)/ Temperature	20	4.68	0.23		
Handling x Storage Day	15	20.07	1.34	3.83	P < 0.01
(Temperature x Handling x Storage Day)	15	1.83	0.12	0.76	N. S.
(Replication x Handling x Storage Day)/Temperature	60	6.53	0.09		
Total	143	145.73	1.02		

[a]F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

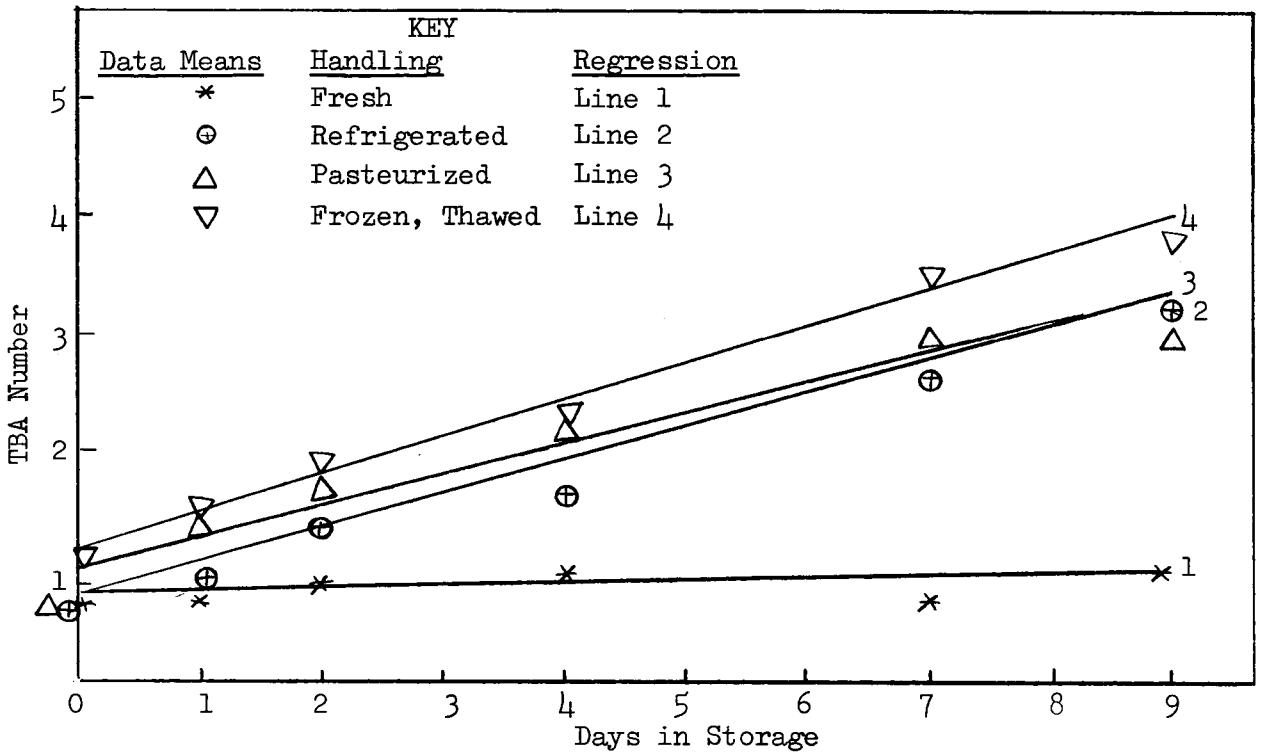


Figure 2. Effect of Storage Time in Days Upon the TBA Numbers of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 32°F. and Compared to a Freshly Cooked Loaf

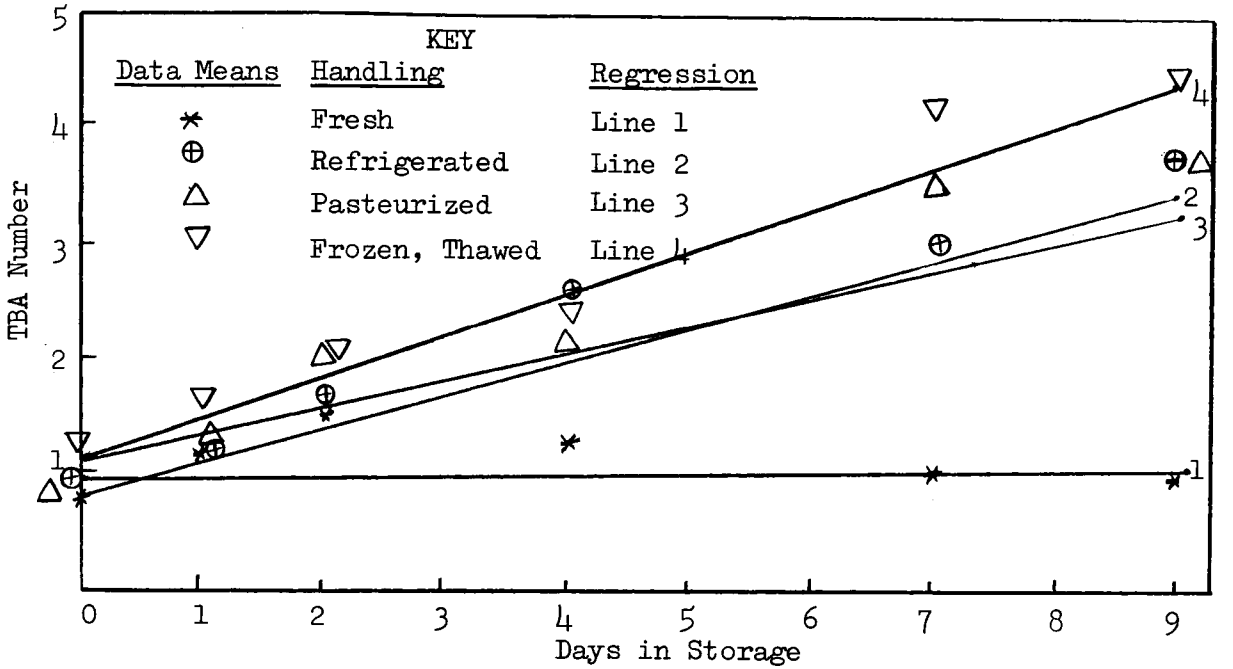


Figure 3. Effect of Storage Time in Days Upon the TBA Numbers of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 42°F. and Compared to a Freshly Cooked Loaf

The linear regression lines around the data points in Figures 2 and 3 do not resemble the curves for increasing TBA numbers over a storage period as shown by Timms and Watts (1958), Watts (1962) and Keskinel et al. (1964). As reported in the earlier studies, there was an extremely rapid rise in TBA values (see Table 2, page 23) and a leveling off of values by storage Day 4 to Day 7. The currently reported regression lines more nearly resemble values reported by Sato and Hegarty (1971) over a four day period. Earlier reports do not appear to have determined regression lines to ascertain the shape of the curve by numerical analysis.

Keskinel et al. (1964) roasted beef in foil and then ground it following the cooking process. Disruption of the muscle system, first by heating and then immediately followed by grinding just prior to storage might account for the extremely rapid rise in TBA numbers. Sato and Hegarty (1971), in contrast, used beef round which was ground prior to the cooking process. The pattern of increases in TBA values for stored meat loaves in the current study coincided with the description of the process of autoxidation by Sato and Herring (1973). By their explanation, oxidative rancidity which develops by autoxidation does so through the following steps:

1. Initiation-Induction

Fat molecules convert to unstable free radicals and oxidation begins to occur at a slow rate. The food remains organoleptically acceptable in this phase. The chemical reaction is $RH \longrightarrow R\cdot + H\cdot$.

2. Propagation

The free radicals act as catalysts for further free radical formation. These increasing free radicals interact with molecular oxygen yielding peroxides and hydroperoxides. Both peroxides and hydroperoxides are very unstable compounds. The peroxides yield free radicals and hydroperoxides. Hydroperoxides break down into aldehydes and acids which are responsible for noxious odors and flavors. Under certain conditions, the food may become unacceptable for consumption.

3. Termination

Termination of the reactive process occurs when free radicals serving as autocatalysts are deactivated or destroyed.

When raw meat is ground, membranes of the muscle are disrupted, starting the process of free radical formation. If the meat is frozen, the autoxidation process may remain in the initiation stage, but in refrigeration, the propagation stage may be achieved. Under refrigeration, the microbial load of the raw meat may be an extenuating circumstance in spoilage. When raw ground meat is formed into a food product such as meat loaf and is cooked prior to refrigeration, the existing free radicals are deactivated, but more are formed in membrane disruption due to the heating process. It is postulated that autoxidation of cooked meat will occur during refrigerated storage. Termination of the process will occur at time of reheating. Thus, in the current study, there was a continuing increase in TBA values over the nine day storage period. This tended to indicate the existence of

autoxidized lipid deterioration continually catalyzed by the presence of free radicals.

TBA values for raw ground beef which was held frozen and raw meat loaf mixture are found in Table 50, Appendix E. Values observed varied from 0.9204 to 1.6770 for ground beef, but there was no progressive trend over 11 weeks of frozen storage. Variations in TBA numbers of raw ground beef possibly could be influenced by conditions and lengths of thawing time. Addition of other products to the ground beef generally had the effect of slightly reducing TBA numbers in raw meat loaf mixture from corresponding raw meat. There is little to be concluded from the raw meat values except to note that in the frozen storage period, there was not a progressive increase in TBA numbers over 11 weeks. Additionally, results of rancidity determinations of cooked products did not appear to be directly related to TBA numbers of raw meat. This lack of relationship might be explained by the Sato and Herring (1973) model of autoxidation with termination of the oxidative process in raw meat being produced by the cooking process and a second cycle of oxidation starting in cooked meat.

V. pH VALUES

Values observed for pH were not statistically analyzed. The pH values of the loaves are recorded in Table 51, Appendix E. The pH of the raw ground beef was found to range between 5.86 and 6.00. Keskinel et al. (1964) found that with a pH of 6.22 or above for raw beef, changes in TBA values were minimized over a storage period. None of

the raw meat tested had a pH above 6.00.

Cooked loaves had pH values ranging from 5.80 to 6.40. Only two samples tested had pH values of 6.00 or below which is the reported lower limit for growth of the bacteria, Pseudomonas (Nickerson and Sinskey, 1972). It would appear that if Pseudomonas were present in the cooked loaves that the pH values of the products generally would not be a deterrent to their growth.

VI. STANDARD PLATE COUNTS

Standard Plate Counts for meat loaves stored at 32°F. and 42°F. are found in Tables 14 and 15. Data in these tables have not been statistically analyzed, since the important aspects of microbial condition of the meat loaves were determined by actual levels of bacterial counts over the storage period and under the handling procedures of the study. Results reported in both tables appear similar with no observable effect of storage at a 10°F. interval within refrigerated storage. Neither does there appear to be any progressive growth over a nine day storage period. The different treatments do not seem to influence the microbial growth pattern. The process of pasteurization does not reduce the counts in the samples to 0, since nine of the 23 tested loaves which had been pasteurized had observable plate counts.

Only one fresh sample had a plate count of above 100 colonies per gram of meat and that was 670 colonies per gram. Of the other 22 fresh loaves which were sampled, 18 had counts of less than 100 per gram while four samples had counts of 0. Of the 135 samples from

Table 14. Standard Plate Counts for Fresh, Refrigerated, Pasteurized and Frozen, Thawed Cooked Ground Beef Loaves Stored at 32°F.

Days in Storage	Replication	Handling Procedure: Fresh Cold	Fresh Heated	Refrigerated Cold	Refrigerated Reheated	Pasteurized Cold	Pasteurized Reheated	Frozen, Thawed Cold	Frozen, Thawed Reheated
		Ct./g.		Ct./g.		Ct./g.		Ct./g.	
0	1	--	<100	--	<100	--	<100	--	<100
	2	--	<100	0	0	0	0	0	0
	3	--	<100	127,000	0	<100	0	<100	<100
4	1	--	<100	--	0	--	<100	--	0
	2	--	<100	<100	0	<100	0	<100	0
	3	--	<100	<100	0	<100	<100	<100	<100
7	1	--	0	--	0	--	<100	--	<100
	2	--	<100	0	0	<100	0	<100	0
	3	--	<100	<100	0	<100	0	<100	0
9	1	--	<100	--	0	--	0	--	0
	2	--	<100	<100	<100	<100	0	<100	<100
	3	--	<100	<100	0	<100	0	<100	0

--no data collected.

Table 15. Standard Plate Counts for Fresh, Refrigerated, Pasteurized and Frozen, Thawed Cooked Ground Beef Loaves Stored at 42°F.

Days in Storage	Replication	Handling Procedure							
		Fresh		Refrigerated		Pasteurized		Frozen, Thawed	
		Cold	Heated	Cold	Reheated	Cold	Reheated	Cold	Reheated
		Ct./g.		Ct./g.		Ct./g.		Ct./g.	
0	1	--	--	--	--	--	--	--	--
	2	--	<100	<100	0	<100	0	0	0
	3	--	<100	<100	0	<100	0	<100	<100
4	1	--	<100	--	<100	--	780	--	<100
	2	--	<100	0	0	0	0	0	0
	3	--	<100	<100	0	0	<100	0	<100
7	1	--	670	--	<100	--	0	--	0
	2	--	0	<100	0	<100	0	0	<100
	3	--	0	0	0	<100	0	0	0
9	1	--	<100	--	0	--	<100	--	0
	2	--	<100	<100	0	0	<100	<100	0
	3	--	0	<100	<100	0	<100	30	<100

--no data collected.

stored loaves, only two had counts above 100 colonies, whereas 60 loaves had counts of 0. One of the counts above 100 was 780 colonies per gram. The species involved here was identified as Bacillus cereus. The other high count was one of 127,000 colonies per gram and it was identified as Staphlococcus aureus. The presence of Staphlococcus aureus was due to procedural contamination during sample collection or preparation. This species was found to be present in a product sampled before reheating and the same loaf was found to have a 0 count after reheating.

Standard plate counts were obtained on 48 meat loaves after storage, both before and after the reheating process. Of the 48 loaves sampled cold, 15 had counts of 0, one had a count of 127,000 colonies per gram and 32 had counts of less than 100 colonies per gram. After reheating, 35 loaves had counts of 0 and 13 had counts of less than 100 per gram. Reheating did not produce a product with count of 0 in all cases. Some products which had 0 counts per gram as sampled cold were found to have counts of less than 100 colonies per gram after reheating.

Gram stains were prepared of several colonies. The resultant slides were examined under the microscope and bacteria present were identified by a microbiologist. Of 10 colonies examined, the following species of bacteria were identified: Bacillus cereus (2), Staphlococcus aureus, Pseudomonas (4), Pediococcus (2) and a strain of Streptococcus.

Standard plate counts were carried out on raw ground beef which had a count of 75,000 colonies per gram and on raw meat loaf mixture

which had 128,000 colonies per gram. The process of adding ingredients and mixing the meat loaf had the effect of almost doubling the plate count of the raw meat. The cooking process came near to achieving a product with a 0 count. If found to contain microbial growth in storage, the loaf was probably contaminated in handling or had present a heat resistant strain of bacteria.

The overall effect of the extremely low numbers of bacteria which did not increase over the storage period was to remove microbial population of the meat loaves as a variable. Counts of less than 100 colonies per gram, even if all were of the Pseudomonas species, would not be large enough to produce off-odors and off-flavors in the stored meat. Low counts were apparently achieved by a combination of heating to 165°F. internal temperature during cooking and reheating followed by handling procedures in which minimum post-cooking contamination occurred. The one count of over 100,000 illustrates that contamination is possible, but that in this study, it only rarely occurred. That one count also emphasizes the importance of thorough reheating of stored cooked meat loaves to minimize the microbial population of the product as consumed.

The traditional view of meat spoilage has been that the deterioration is accompanied by increases in microbial population (Elliott, 1963). The growth of psychrophilic bacteria is accompanied by activity of bacterial enzymes. The growth of bacteria and enzymatic activity was considered the initiator of the spoilage phenomena. If changes did take place in the cooked, stored meat loaves observed in this study, microbial population was not a factor in rendering the loaves

spoiled or unacceptable for consumption.

VII. TASTE PANEL EVALUATIONS

Taste panel scores for the quality characteristics of odor, appearance, flavor and juiciness are reported in Tables 52-59, Appendix F. Analyses of variance for each of these characteristics are in tables which follow.

For the quality characteristic of odor, there were highly significant ($P < 0.01$) differences in handling procedures and across days in storage. The two storage temperatures were not rated significantly different by a taste panel. The handling procedure-storage day interaction was highly significant ($P < 0.01$), probably due to inclusion of the reference loaf as a handling procedure. Orthogonal comparisons (Table 16) indicated that odor scores of reference loaves were significantly higher ($P < 0.01$) than scores for the three stored products. Odor scores for refrigerated and pasteurized loaves were not significantly different. Odor scores for frozen, thawed loaves were highly significantly different ($P < 0.01$) from the other two stored products, and odor scores for the frozen, thawed loaves consistently had the lowest numerical ratings which implied development of off-odors. Figures 4 and 5 picture odor scores. When a coefficient of correlation was calculated between the TBA numbers and odor scores, it was determined to be -0.638, a highly significant correlation.

Table 16. Analysis of Variance: Odor Scores of Cooked Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	0.01	0.001	0.001	N. S.
Replication/Temperature	4	14.300	3.580		
Handling Procedure	3	33.570	11.190	12.780	P < 0.01
F vs R, P and FT[a]	1	22.55	22.55	25.62	P < 0.01
R vs P	1	0.11	0.11	0.12	N. S.
FT vs R and P	1	10.91	10.91	11.02	P < 0.01
(Temperature x Handling)	3	1.14	0.38	0.43	N. S.
(Replication x Handling)/Temp.	12	10.51	0.88		
Storage Day	5	30.61	6.12	10.64	P < 0.01
Temperature x Storage Day	5	0.65	0.13	0.23	N. S.
(Replication x Storage Day)/ Temperature	20	11.50	0.58		
Handling x Storage Day	15	18.12	1.21	3.83	P < 0.01
(Temperature x Handling x Storage Day)	15	3.59	0.24	0.76	N. S.
(Replication x Handling x Storage Day)/Temperature	60	18.93	0.32		
Total	143	142.92	0.99		

[a] F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

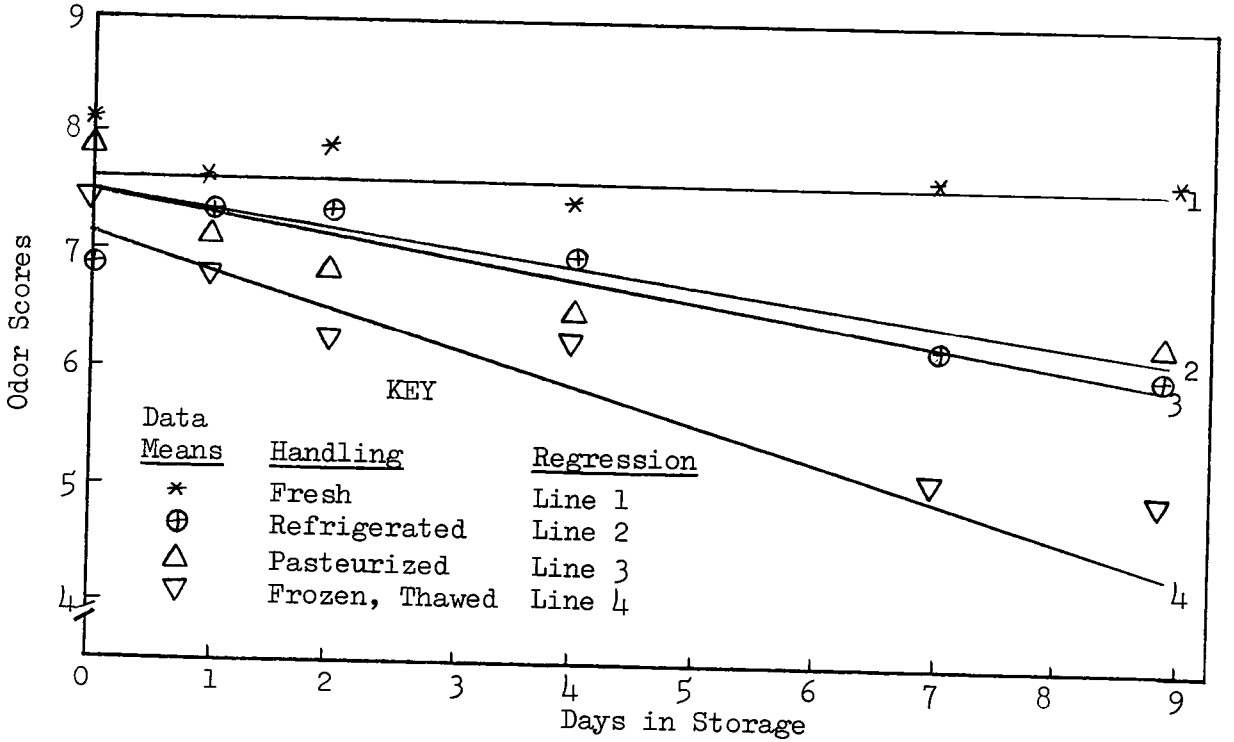


Figure 4. Effect of Storage Time in Days Upon Odor Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 32°F. and Compared to a Freshly Cooked Loaf

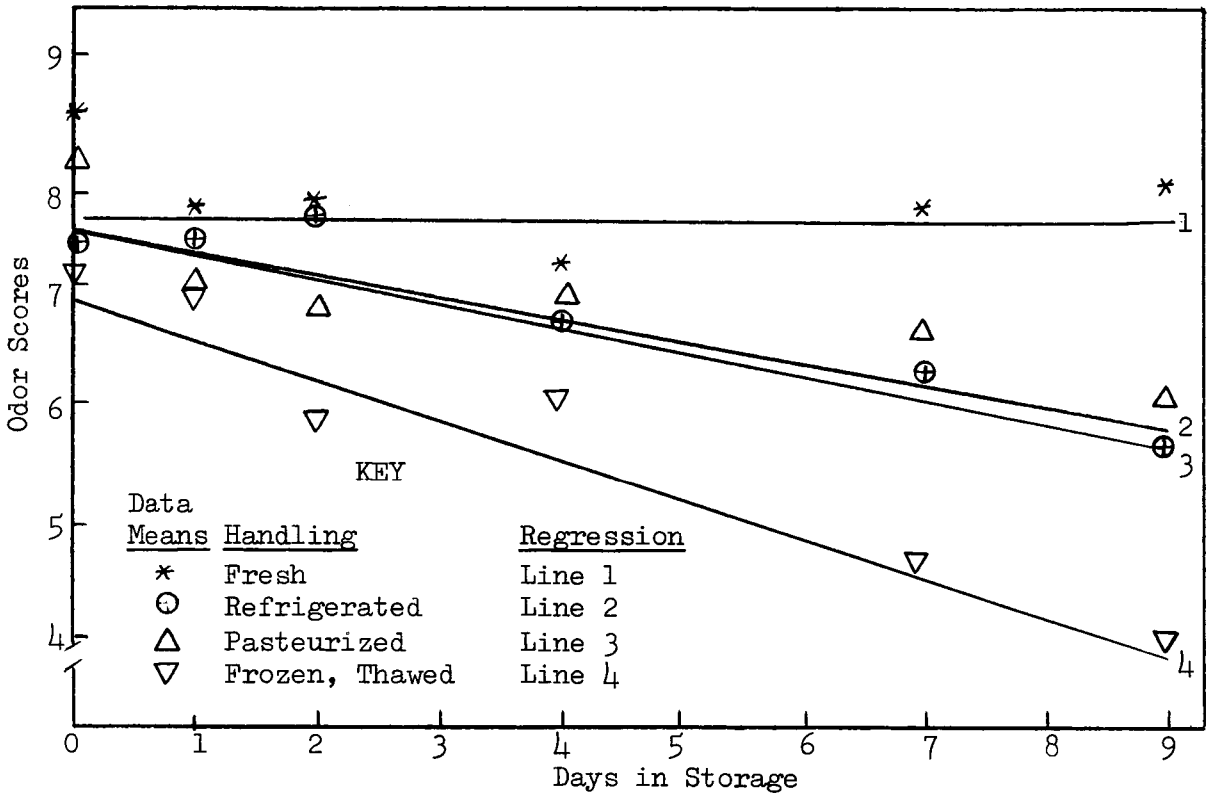


Figure 5. Effect of Storage Time in Days Upon Odor Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 42°F. and Compared to a Freshly Cooked Loaf

Descriptive terms which were given as comments by judges as to the developing off-odors included: sour, rancid, leftover, stale and strong for frozen, thawed loaves; old, rancid, sharp and stinging for refrigerated and pasteurized loaves. Odor of refrigerated and pasteurized loaves was mentioned infrequently by the judges, while odor of frozen, thawed products received numerous comments. Judges' comments as to off-odors increased in frequency from storage Day 4 through Day 9.

Appearance scores of loaves gave a similar statistical picture as for odor. Figures 6 and 7 illustrate the scores for appearance giving the mean data points from Tables 54 and 55, Appendix F, and the regression lines. In the analysis of variance in Table 17, there were highly significant differences ($P < 0.01$) among handling procedures. Highly significant differences ($P < 0.01$) were noted across days in storage as well as for handling procedure-storage day interaction. Appearance scores were similar for 32°F. and 42°F. and significant differences were not found. In the orthogonal comparisons (Table 17), appearance of reference loaves were scored significantly higher ($P < 0.01$) than stored loaves. Significant differences ($P < 0.01$) were revealed between frozen, thawed loaves' appearance and the appearance of other stored products.

Judges comments as to reasons for lowering appearance scores of stored loaves were frequently color related. By Day 7 of the storage period, loss of a strong brown color was noted by judges. Change in color was first toward gray and ultimately to yellow-green. The meat most frequently noted as being yellow-green by judges was frozen, thawed loaf.

Table 17. Analysis of Variance: Appearance Scores of Cooked Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	0.28	0.28	0.36	N. S.
Replication/Temperature	4	3.15	0.79		
Handling Procedure	3	20.49	6.83	18.76	P < 0.01
F vs R, P and FT[a]	1	13.01	13.01	36.13	P < 0.01
R vs P	1	0.04	0.04	0.10	N. S.
FT vs R and P	1	7.45	7.45	20.70	P < 0.01
(Temperature x Handling)	3	0.19	0.06	0.18	N. S.
(Replication x Handling)/Temp.	12	4.37	0.36		
Storage Day	5	15.58	3.12	12.80	P < 0.01
Temperature x Storage Day	5	0.46	0.09	0.38	N. S.
(Replication x Storage Day)/ Temperature	20	4.87	0.24		
Handling x Storage Day	15	8.64	0.58	2.41	P < 0.01
(Temperature x Handling x Storage Day)	15	1.10	0.07	0.31	N. S.
(Replication x Handling x Storage Day)/Temperature	60	14.30	0.24		
Total	143	73.44	0.51		

[a]F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

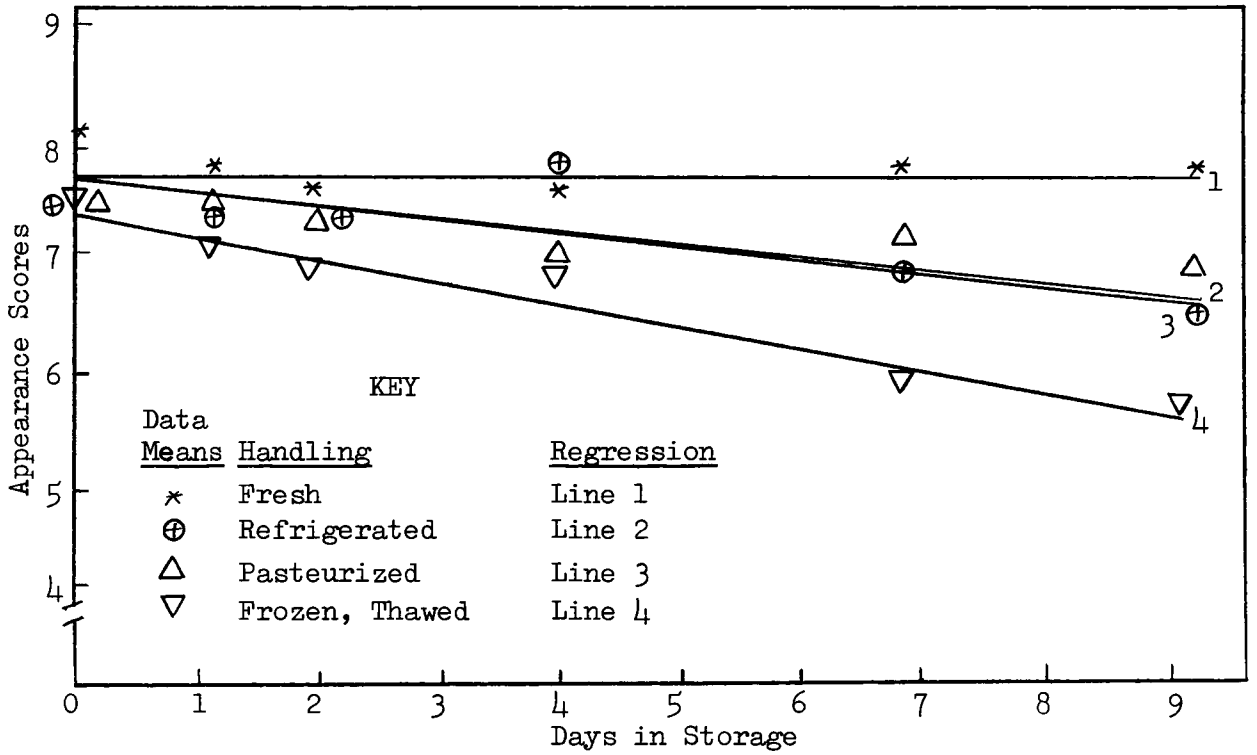


Figure 6. Effect of Storage Time in Days Upon Appearance Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 32°F. and Compared to a Freshly Cooked Loaf

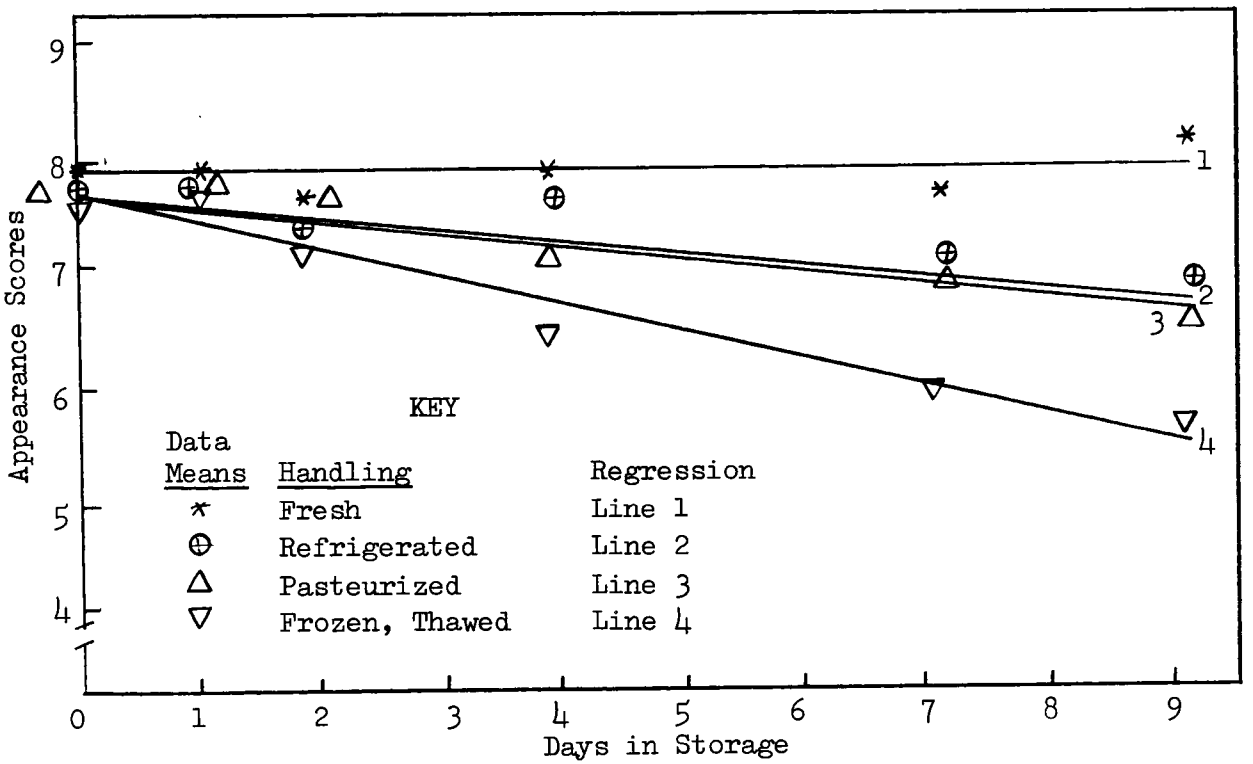


Figure 7. Effect of Storage Time in Days Upon Appearance Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 42°F. and Compared to a Freshly Cooked Loaf

For flavor scores, differences in both handling procedures and days in storage variables were highly significant ($P < 0.01$) as seen in Table 18. Handling procedure-storage day interaction was significantly different ($P < 0.01$). Statistical differences were not revealed between storage temperatures.

Figures 8 and 9 illustrate flavor scores received by the four handling procedures over the storage period. In orthogonal comparisons (Table 18), reference loaves were significantly different ($P < 0.01$) from stored loaves. Flavor of refrigerated and pasteurized loaves were not statistically different, whereas flavor of frozen, thawed loaves was significantly lower ($P < 0.01$) than the other two stored products. The flavor of the frozen, thawed loaves can be observed to be one numerical value lower than the other products by the first judging after only four hours in storage.

Judges' comments regarding development of off-flavors started appearing by Day 1 and increased over the length of storage time. Flavor comments related to frozen, thawed were the most common. The judges' remarks as to the characteristics of the off-flavors developed in storage are included in Table 19.

To evaluate the relationship between objective measures of flavor change as determined by TBA numbers and subjective taste panel scores for flavor, a coefficient of correlation was calculated between the two scores. The coefficient of correlation between TBA numbers and flavor scores was calculated to be -0.715. Further a correlation coefficient between odor and flavor scores was found to be 0.888.

Table 18. Analysis of Variance: Flavor Scores of Cooked Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	0.37	0.37	0.18	N. S.
Replication/Temperature	4	8.27	2.07		
Handling Procedure	3	62.12	20.71	20.93	P < 0.01
F vs R, P, and FT[a]	1	37.40	37.40	38.38	P < 0.01
R vs P	1	0.002	0.002	0.002	N. S.
FT vs R and P	1	24.13	24.13	24.37	P < 0.01
(Temp. x Handling)	3	2.22	0.74	0.75	N. S.
(Replication x Handling)/Temp.	12	11.87	0.99		
Storage Day	5	45.54	9.51	20.91	P < 0.01
Temperature x Storage Day	5	0.23	0.05	0.10	N. S.
(Replication x Storage Day)/ Temperature	20	9.10	0.45		
Handling x Storage Day	15	20.40	1.36	3.11	P < 0.05
(Temperature x Handling x Storage Day)	15	7.30	0.49	1.11	N. S.
(Replication x Handling x Storage Day)/Temperature	60	26.25	0.44		
Total	143	195.69	1.37		

[a]F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

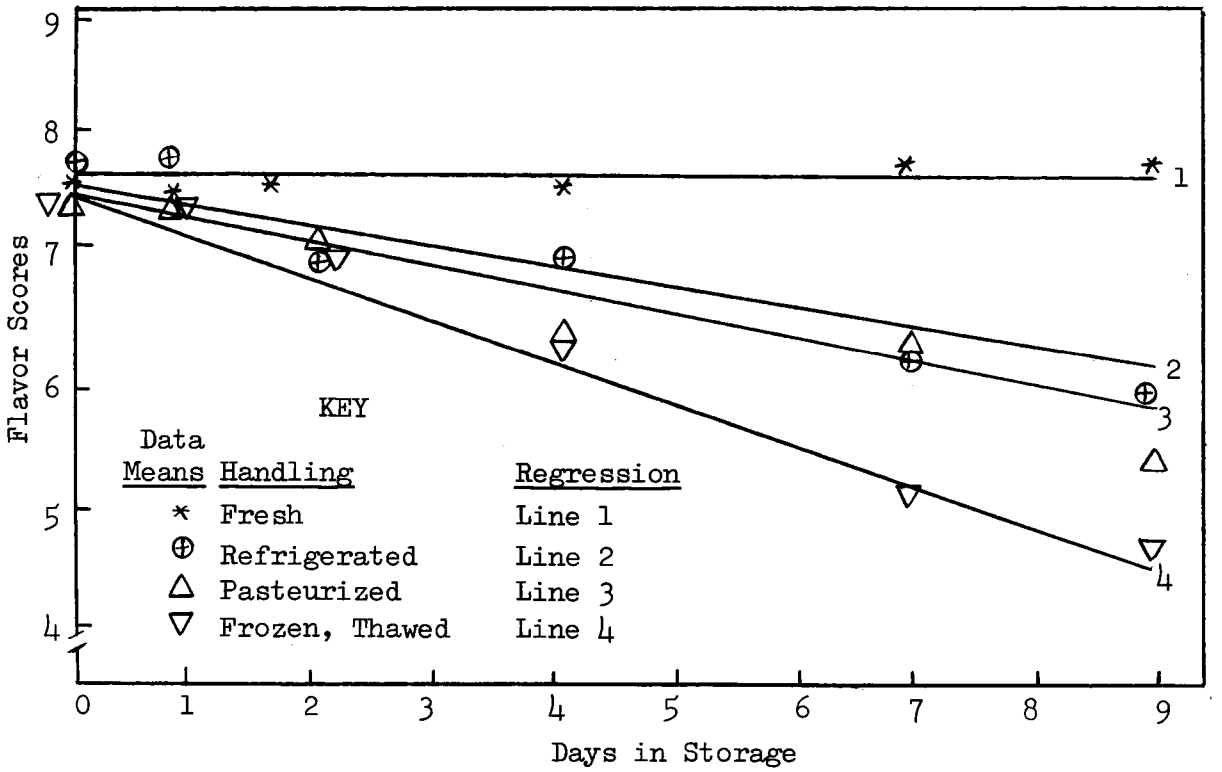


Figure 8. Effect of Storage Time in Days Upon Flavor Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 32°F. and Compared to a Freshly Cooked Loaf

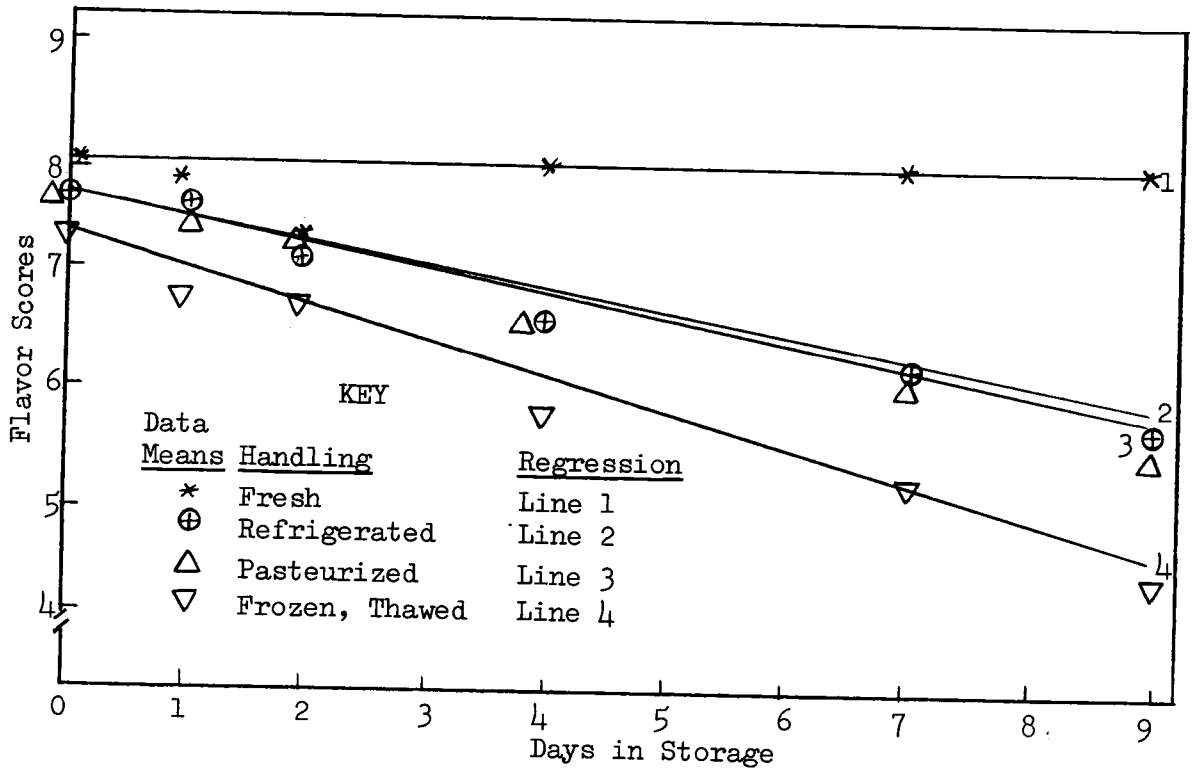


Figure 9. Effect of Storage Time in Days Upon Flavor Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 42°F. and Compared to a Freshly Cooked Loaf

Table 19. Descriptive Terms Used by Judges to Characterize Off-Flavors of Cooked Ground Beef Loaves Stored at 32°F. and 42°F. for a Maximum of Nine Days

Handling Procedure	Descriptive Terms
Refrigerated	Cardboard, storage, gamey, sharp, canned, bad, WOF, nauseous
Pasteurized	Astringent, objectionable, stored, old, WOF, rancid, gamey
Frozen, thawed	Cardboard, tangy, leftover, bad aftertaste, storage, astringent, old, sharp, old fat, repulsive, WOF, bitter, strong

Both coefficients of correlation were highly significant ($P < 0.01$). This would indicate that aroma of the ground beef loaves would give an indication of eating quality.

In the analysis of variance for the quality characteristic of juiciness (Table 20), highly significant differences ($P < 0.01$) were noted for handling procedures and days in storage. Figures 10 and 11 illustrate the differences over storage time and between handling procedures. When orthogonal comparisons were made, the reference loaves were significantly different ($P < 0.01$) from stored loaves. There was not a significant difference in the juiciness of refrigerated and pasteurized loaves. A highly significant difference ($P < 0.01$) in juiciness of frozen, thawed loaves was noted when they were contrasted to refrigerated and pasteurized loaves.

Table 20. Analysis of Variance: Juiciness Scores of Cooked Ground Beef Loaves

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P > F Value
Temperature	1	0.15	0.15	0.10	N. S.
Replication/Temperature	4	5.95	1.49		
Handling Procedure	3	38.74	12.74	15.13	P < 0.01
F vs R, P and FT[a]	1	27.37	27.37	32.59	P < 0.01
R vs P	1	0.13	0.13	0.15	N. S.
FT vs R and P	1	10.74	10.74	12.78	P < 0.01
(Temperature x Handling)	3	0.79	0.26	0.31	N. S.
(Replication x Handling)/Temp.	12	10.11	0.84		
Storage Day	5	16.65	3.33	7.01	P < 0.01
Temperature x Storage Day	5	1.50	0.30	0.63	N. S.
(Replication x Storage Day)/ Temperature	20	9.49	0.47		
Handling x Storage Day	15	6.83	0.46	1.54	N. S.
(Temperature x Handling x Storage Day)	15	4.92	0.33	1.10	N. S.
(Replication x Handling x Storage Day)/Temperature	60	17.78	0.30		
Total	143	112.43	0.79		

[a]F = fresh; R = refrigerated; P = pasteurized; FT = frozen, thawed.

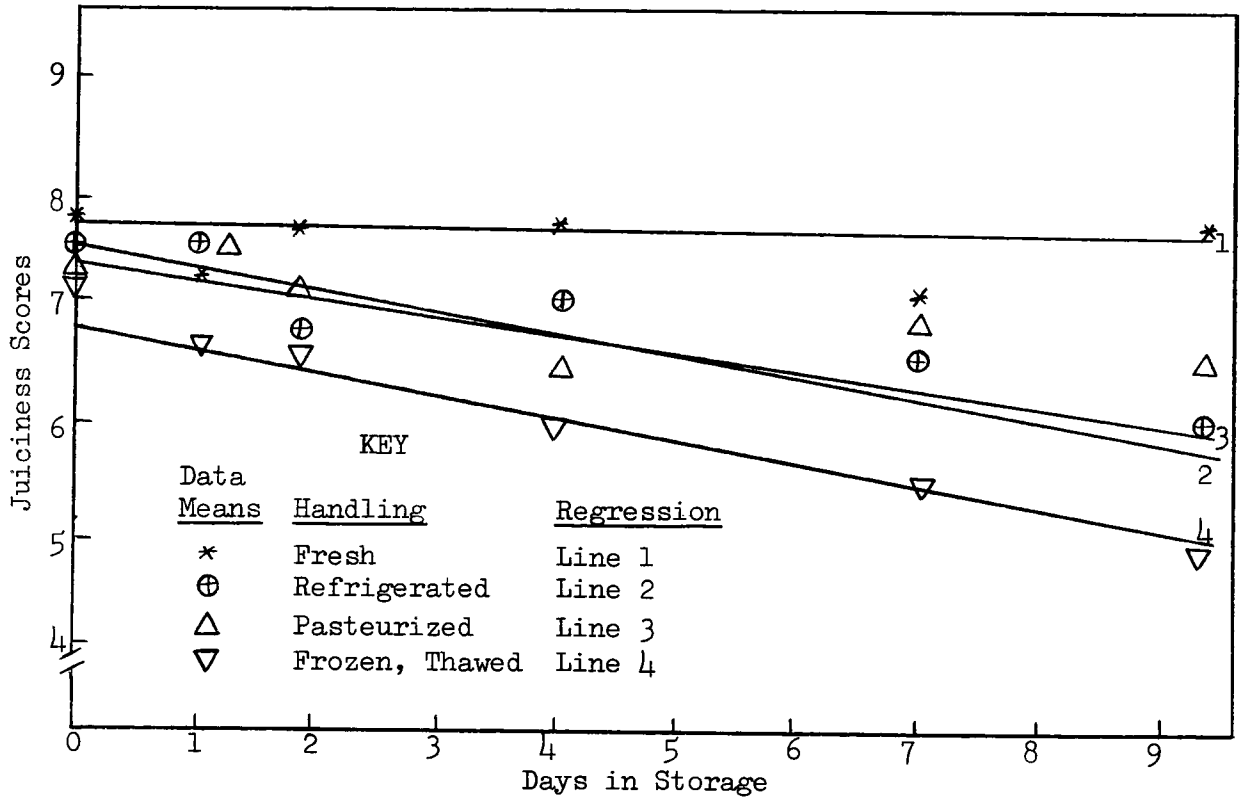


Figure 10. Effect of Storage Time in Days Upon Juiciness Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 32°F. and Compared to a Freshly Cooked Loaf.

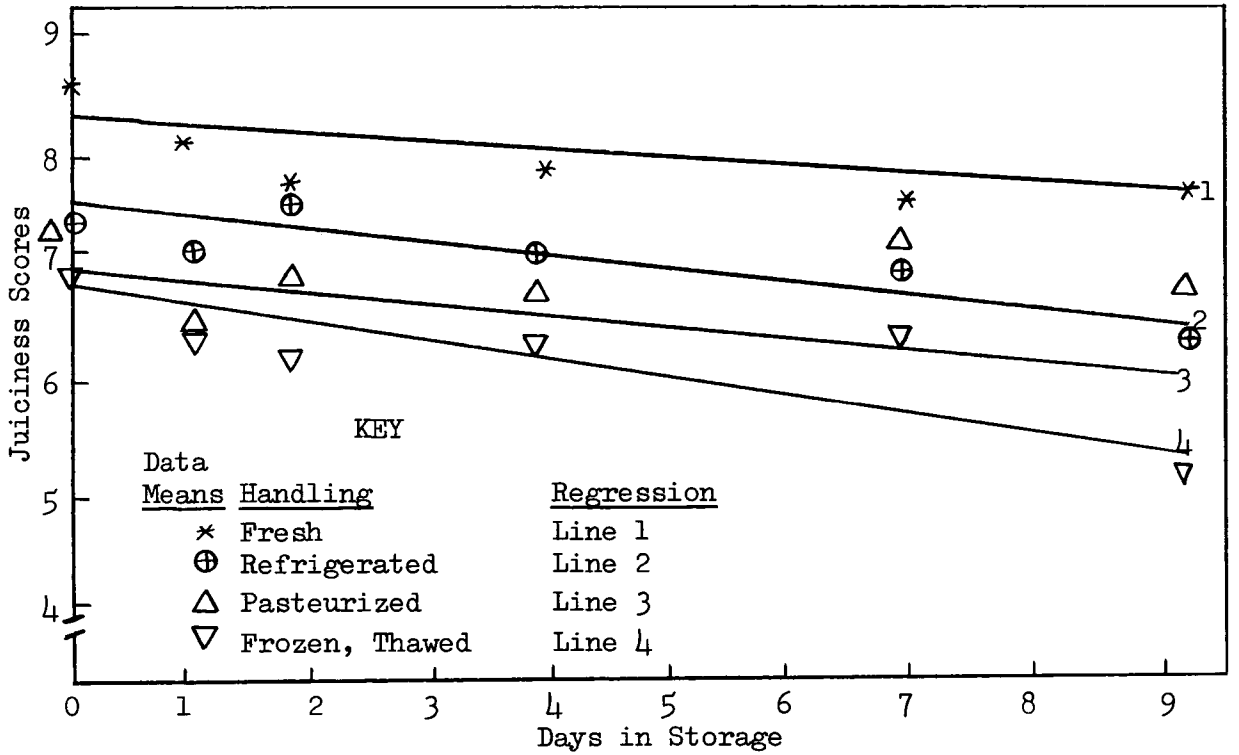


Figure 11. Effect of Storage Time in Days Upon Juiciness Scores of Cooked Ground Beef Loaves Handled by Three Procedures Prior to Refrigeration at 42°F. and Compared to a Freshly Cooked Loaf

As evaluated by a taste panel, freshly prepared loaves cooked immediately prior to evaluation were scored significantly higher than refrigerated, pasteurized, and frozen, thawed loaves in regard to the quality characteristics of odor, appearance, flavor and juiciness. In the view of the panel, off-odors and off-flavors were increasingly apparent in stored loaves across the nine day storage period, these differences being significantly different. Appearance of the stored loaves and juiciness of stored loaves decreased over time in the ratings received, but significant differences were not observed among the pre-storage handling treatments. Flavor, odor, appearance and juiciness of frozen, thawed loaves were scored as significantly lower than scores for all these characteristics of refrigerated and pasteurized products.

In evaluation of all characteristics, temperature of storage did not reveal a significant difference. The failure of a notable difference due to storage temperature variation could be twofold in reason. First, the design of the experiment meant that less information could be obtained from the temperature variable. Second, use of the environmental chamber in which there was only a $\pm$ 1°F. differential over the storage period provided a stable holding environment. This is in contrast to an ordinary refrigerator in which cyclic changes of temperature occur over a four to six hour period. Additionally, the door of the environmental chamber was opened only six times per storage cycle to remove the day's samples and recovery time to return to the set temperature was approximately 15 minutes. Food spoilage caused by microbial action is highly temperature related. If the rancidity which developed

had been microbially initiated, the 10°F. temperature differential could have been significant. Further research is needed to ascertain effects of variable refrigerated storage temperature upon the development of rancidity produced by autoxidation.

Judges also were asked to score each loaf sampled as to whether it was acceptable or unacceptable. The most frequent judgments of unacceptability came on storage Days 7 and 9, as may be seen in Table 21. One frozen, thawed loaf was judged as unacceptable by four of seven judges on Day 7 in the third 32°F. replication and was not included in the judging on Day 9 of the cycle. This was the only loaf to be judged as unacceptable by four judges prior to Day 9. Cognizance should be taken of the possible effect of use of the environmental chamber as the storage vehicle upon the slope of the rating lines as to the day after which products received judgments as unacceptable. Stability of the temperature of storage within the chamber might serve to elongate the time in which a meat loaf remained acceptable. Further research is needed to relate storage in an environmental chamber with storage in an institutional refrigerator.

VIII. CONCLUSIONS

For all measurements made in the current research study, freshly prepared ground beef loaves cooked immediately prior to evaluation were significantly different from loaves which were refrigerated, pasteurized or frozen, then thawed under refrigeration. Loaves handled by these three procedures were placed in 32° and 42° ± 1°F. storage for

Table 21. Number of Judges Scoring Cooked, Stored Ground Beef Loaves as Unacceptable

Days in Storage	Replication	Handling Procedure: 32°F. Refrigerated	32°F. Pasteurized	32°F. Frozen, Thawed	42°F. Refrigerated	42°F. Pasteurized	42°F. Frozen, Thawed
2	1	0	0	0	0	0	2
	2	0	0	1	0	0	0
	3	1	0	1	0	0	0
4	1	0	0	3	0	0	1
	2	0	0	1	2	1	2
	3	0	2	2	0	0	0
7	1	1	1	2	0	0	3
	2	1	1	2	1	1	3
	3	2	0	4	1	0	1
9	1	4	2	2	2	4	3
	2	0	0	4	4	3	2
	3	3	0	Not Tasted[a]	2	2	1

[a]Four of the seven judges rated frozen, thawed loaf unacceptable on Day 7.

nine days. Reference loaves had statistically shorter heating time, less cooking losses, higher moisture content, lower TBA numbers and higher taste panel scores for odor, appearance, flavor and juiciness.

The value of subjecting loaves to a "pasteurizing" treatment may be questioned. The process of pasteurization required more energy use whereas failing to achieve a product with 0 counts. Significant differences for other variables between loaves which were pasteurized and loaves which were refrigerated were not found. Pasteurization did not have the effect of retarding flavor deterioration as measured by either TBA numbers or taste panel scores. Neither did it serve to improve flavor in contrast to refrigerated products. Under conditions of minimum handling of a product following initial cooking and assurance of thorough reheating prior to consumption, pasteurization appears to be an unnecessary step.

Significant decreases in quality characteristics occurred over the nine day refrigerated storage period for cooked meat loaves. These decreases appeared linear in nature. The slope of the line was likely influenced by the storage conditions created by the environmental chamber. Within the stable 32°F. and 42°F. ± 1°F. temperatures of storage, the maximum time frame for holding cooked meat loaf in refrigeration would appear to be four days in relation to general acceptability of the product. If storage conditions were not "ideal" and the procedures of handling did not insure minimum contamination, the period of acceptability might be shortened. While refrigerated storage systems for cooked food may offer economic and personnel

advantages to the food service system, for meat loaves, the method does not achieve a product in which quality characteristics are maintained at an acceptable level.

Quality changes occurring in frozen, thawed loaves indicated that this handling procedure produced results which were significantly different from the other two handling procedures. Flavor, odor, appearance and juiciness scores of frozen, thawed loaves were significantly lower than refrigerated and pasteurized. TBA scores were significantly higher for frozen, thawed loaves. It would appear that if refrigerated storage were used for cooked ground beef loaf that frozen, thawed loaves would be least acceptable and the added procedures, time and heating of pasteurized loaves would produce a loaf no different from one which was simply refrigerated.

CHAPTER V

SUMMARY

In response to the recognition that knowledge is needed concerning quality of food produced from innovative food holding systems which are already being utilized by the food service industry, this research study was initiated. The present study was undertaken specifically to examine the effects of refrigerated storage or holding upon precooked ground beef loaf. Meat loaf was prepared and processed under conditions generally recommended for quantity food production. After the loaves were initially cooked, they were handled by one of three procedures currently in use in quantity food production systems which incorporate refrigerated storage. These handling treatments were: immediate refrigeration of the cooked loaf, pasteurization of the loaf followed by refrigeration, and freezing, then thawing of a cooked loaf as a part of refrigeration. The loaves were stored at one of two refrigerated temperatures representing the lower and upper limits of effective refrigeration--32°F. and 42°F. Over a nine day holding period, meat loaves were removed from storage on Day 0, after four hours of storage, Day 1, Day 2, Day 4, Day 7 and Day 9. Upon removal from storage, they were reheated. Following the second heat treatment, quality related properties were measured to ascertain effects of refrigerated storage. Stored loaves were compared to a meat loaf which had been freshly fabricated and cooked immediately prior to evaluation.

Data were collected pertinent to cooking and reheating times, losses during initial cooking and reheating, moisture content, oxidative rancidity as measured by TBA values, pH, standard plate counts, and taste panel evaluation of odor, appearance, flavor and juiciness of the cooked loaves. Statistical analyses of the data included analysis of variance, orthogonal comparisons among handling treatments and coefficients of correlation for flavor, odor and TBA numbers.

While freshly prepared loaves required significantly less ($P < 0.01$) cooking time since they were not reheated, pasteurized loaves needed significantly more ($P < 0.01$) time for heating than refrigerated loaves. Cooking losses for the reference loaves were significantly less ($P < 0.01$) than losses of stored and reheated products. The pasteurized loaves had significantly higher ($P < 0.01$) losses than refrigerated loaves. As a corollary to the cooking losses, fresh loaves had a significantly higher ($P < 0.01$) moisture content than the stored loaves, but no other differences were found in regard to moisture.

The TBA numbers provided an objective measure of oxidative rancidity development whereas odor and flavor scores from the taste panel gave an objective evaluation of the loaves. Objective and subjective measurements revealed similar results. Highly significant differences ($P < 0.01$) were found over the storage time for TBA numbers, which increased over the nine day period, and odor and flavor scores, which decreased. The hypothesis that changes over storage time noted in TBA numbers, odor and flavor were linear was not rejected.

Among handling procedures, highly significant differences ($P < 0.01$) between reference loaves and stored loaves were found in relation to TBA numbers and odor and flavor scores. Significant differences were not found between refrigerated and pasteurized loaves whereas frozen, thawed loaves were highly significantly different ($P < 0.01$) from other stored loaves by all three measurements.

The taste panel found similar differences in appearance and juiciness of fresh loaves, thus indicating that overall scores for quality characteristics were superior to all stored products. Frozen, thawed loaves received values indicating lower quality for all characteristics and differences were not indicated between refrigerated and pasteurized loaves.

As determined by the standard plate count, the effect of the handling, cooking, storage and reheating process was to achieve a product with an exceptionally low colony count. Only two loaves tested had counts above 100 colonies per gram. Pasteurized loaves showed a microbial picture which was no different from any loaves from other handling treatments. Essentially, the presence and growth of bacteria in the loaves in this study were removed as a variable. This would give rise to the idea that the flavor and odor changes which occurred were produced by autoxidation.

The only significant difference noted for the two storage temperatures was for total heating times. This difference was influenced by internal loaf temperatures upon their removal from storage for reheating. The fact that other differences were not found could

be due both to the split plot experimental design and the use of the environmental chamber for holding which served to provide a stable holding environment.

When compared to freshly prepared products cooked immediately prior to evaluation, ground beef loaves treated by three handling procedures prior to refrigerated storage did not maintain the level of quality found in the reference loaves. According to taste panel judgments, acceptability of loaves held at the temperatures and under the conditions of this study appears to be limited to a maximum storage period of four days. Further research involving other food products and utilizing institutional refrigeration equipment would be useful to extend the meaning of results found in the present study. The role of thawing in quality deterioration needs further examination.

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APPENDIXES

APPENDIX A

TEP TABLES

Table 22. Standard Curve for Absorbance of Distilled TEP Solutions

Concentration of TEP	Replications, Absorbance Measured at 532 nm. 1	2	3	4	5	Observed Mean	Regression Point Means
1×10^{-6}	0.155	0.165	0.120	0.850	0.150	0.135	0.150
2×10^{-6}	0.235	0.285	0.220	0.285	0.200	0.245	0.242
3×10^{-6}	0.325	0.385	0.325	0.380	0.275	0.338	0.334
4×10^{-6}	0.370	0.475	0.455	0.480	0.360	0.428	0.427
5×10^{-6}	0.480	0.560	0.520	0.570	0.480	0.522	0.519
6×10^{-6}	0.570	0.690	0.650	0.640	0.540	0.618	0.611
7×10^{-6}	0.650	0.780	0.760	0.730	0.630	0.714	0.703
8×10^{-6}	0.720	0.850	0.820	0.800	0.700	0.778	0.795
9×10^{-6}	0.860	0.910	0.850	0.900	0.940	0.902	0.887
10×10^{-6}	0.920	0.960	0.910	1.000	1.000	0.958	0.979

Table 23. TEP Absorbance Values Observed Over Range from 520 to 540 Nanometers, Measured on Model B Beckman Spectrophotometer

Molar Concentration of TEP	Wavelengths in Nanometers						
	520	525	530	532	535	538	540
1×10^{-6}	0.120	0.140	0.150	0.180	0.175	0.135	0.120
2×10^{-6}	0.140	0.170	0.240	0.230	0.210	0.150	0.145
3×10^{-6}	0.170	0.195	0.270	0.275	0.255	0.190	0.175
4×10^{-6}	0.185	0.220	0.300	0.300	0.280	0.195	0.190
5×10^{-6}	0.245	0.285	0.380	0.385	0.350	0.255	0.240
6×10^{-6}	0.250	0.295	0.390	0.390	0.365	0.260	0.245
7×10^{-6}	0.200	0.245	0.315	0.320	0.310	0.200	0.220
8×10^{-6}	0.630	0.750	1.000	1.000	0.950	0.630	0.580
9×10^{-6}	0.900	1.000	1.600	1.700	1.600	0.840	0.760
10×10^{-6}	1.000	1.600	1.800	1.800	1.750	1.000	0.920

Wavelength of maximum absorption is 532 nanometers.

Table 24. Recovery Percentage of TEP Measured at Absorbance$_{532}$

Molar Concentration of TEP	Replication	Undistilled TEP (5 ml. from 100 ml.)	Factor (2)	Distilled TEP (5 ml. from 50 ml.)	Percent Recovery
1×10^{-6}	1	0.165	0.130	0.085	
	2	0.120	0.240	0.150	
	3	0.085	0.170	0.120	
	Mean		0.180	0.118	65.6
2×10^{-6}	1	0.130	0.260	0.195	
	2	0.145	0.290	0.200	
	3	0.190	0.380	0.220	
	Mean		0.310	0.205	66.2
3×10^{-6}	1	0.200	0.400	0.295	
	2	0.210	0.420	0.275	
	3	0.240	0.480	0.325	
	Mean		0.433	0.298	68.6
4×10^{-6}	1	0.265	0.530	0.380	
	2	0.280	0.560	0.360	
	3	0.295	0.590	0.455	
	Mean		0.560	0.490	71.1
5×10^{-6}	1	0.345	0.690	0.470	
	2	0.350	0.700	0.480	
	3	0.385	0.770	0.520	
	Mean		0.720	0.490	68.1
6×10^{-6}	1	0.380	0.760	0.540	
	2	0.415	0.830	0.540	
	3	0.450	0.900	0.650	
	Mean		0.830	0.577	69.5
7×10^{-6}	1	0.460	0.920	0.630	
	2	0.455	0.910	0.650	
	3	0.540	1.080	0.760	
	Mean		0.970	0.680	70.1
8×10^{-6}	1	0.540	1.080	0.700	
	2	0.500	1.000	0.700	
	3	0.630	1.260	0.820	
	Mean		1.110	0.740	66.6
9×10^{-6}	1	0.630	1.260	0.850	
	2	0.630	1.260	0.940	
	3	0.700	1.400	0.850	
	Mean		1.307	0.880	67.3
10×10^{-6}	1	0.800	1.600	0.900	
	2	0.655	1.330	1.000	
	3	0.780	1.560	0.910	
	Mean		1.6997	0.937	62.6
	Mean Over All Concentrations				67.6

APPENDIX B

TASTE PANEL SCORE CARD

Date_____ Judge_____

Directions: Give full value for excellent quality.
Use only the whole numbers listed on the scale.
Judge the characteristics in the following order:
1. Odor, 2. Appearance, 3. Flavor, 4. Juiciness.

Scale for scoring odor, appearance and flavor.

9--Excellent
8--Very good
7--Good
6--Fair plus
5--Fair
4--Fair minus
3--Poor
2--Very poor
1--Extremely poor

Scale for scoring juiciness:

9--Very juicy
8--Juicy
7--Moderately juicy
6--Slightly juicy
5--Neutral
4--Slightly dry
3--Moderately dry
2--Dry
1--Extremely dry

Sample No.				
Odor				
Appearance				
Flavor				
Juiciness				

Comments:

On the basis of your collective ratings for each sample, would you consider each: (Write Yes or No in each blank).

Sample No.				
Acceptable				
Unacceptable				

APPENDIX C

HEATING TIME TABLES

Table 25. Initial Heating and Reheating Time in Minutes: Freshly Prepared, Freshly Cooked Ground Beef Loaves Which Were Reference for 32°F.

Reference: Days in Storage	Replication	Heating Time		
		Initial Min.	Reheat Min.	Total Min.
0	1	58	0	58
	2	61	0	61
	3	58	0	58
	Mean	59	0	59
1	1	60	0	60
	2	55	0	55
	3	56	0	56
	Mean	57	0	57
2	1	58	0	58
	2	61	0	61
	3	55	0	55
	Mean	58	0	58
4	1	54	0	54
	2	52	0	52
	3	58	0	58
	Mean	55	0	55
7	1	63	0	63
	2	57	0	57
	3	63	0	63
	Mean	61	0	61
9	1	55	0	55
	2	62	0	62
	3	53	0	53
	Mean	57	0	57

Table 26. Initial Heating and Reheating Time in Minutes: Freshly Prepared, Freshly Cooked Ground Beef Loaves Which Were Reference for 42°F.

Reference: Days in Storage	Replication	Heating Time		
		Initial Min.	Reheat Min.	Total Min.
0	1	51	0	51
	2	57	0	57
	3	61	0	61
	Mean	56	0	56
1	1	48	0	48
	2	52	0	52
	3	53	0	53
	Mean	51	0	51
2	1	45	0	45
	2	50	0	50
	3	54	0	54
	Mean	49	0	49
4	1	47	0	47
	2	50	0	50
	3	51	0	51
	Mean	49	0	49
7	1	49	0	49
	2	53	0	53
	3	50	0	50
	Mean	50	0	50
9	1	50	0	50
	2	54	0	54
	3	53	0	53
	Mean	52	0	52

Table 27. Initial Heating and Reheating Time in Minutes: Refrigerated Loaves Cooked Prior to Storage at 32°F.

Days in Storage	Replication	Heating Time			
		Initial Min.	Pasteurized Min.	Reheat Min.	Total Min.
0	1	60	0	44	104
	2	61	0	46	107
	3	65	0	42	107
	Mean	62		44	106
1	1	60	0	54	114
	2	61	0	50	111
	3	65	0	41	106
	Mean	62		48	110
2	1	60	0	40	100
	2	61	0	46	105
	3	65	0	49	114
	Mean	62		45	107
4	1	60	0	39	99
	2	61	0	39	100
	3	65	0	51	116
	Mean	62		43	105
7	1	60	0	48	108
	2	61	0	42	103
	3	65	0	48	113
	Mean	62		46	108
9	1	60	0	40	100
	2	61	0	42	103
	3	65	0	41	106
	Mean	62		41	103

Table 28. Initial Heating and Reheating Time in Minutes: Refrigerated Loaves Cooked Prior to Storage at 42°F.

Days in Storage	Replication	Heating Time			
		Initial Min.	Pasteurized Min.	Reheat Min.	Total Min.
0	1	55	0	43	98
	2	58	0	34	92
	3	59	0	33	91
	Mean	57		37	94
1	1	55	0	28	83
	2	58	0	42	100
	3	59	0	41	100
	Mean	57		37	94
2	1	55	0	30	85
	2	58	0	40	98
	3	59	0	41	100
	Mean	57		37	94
4	1	55	0	40	95
	2	58	0	46	104
	3	59	0	36	95
	Mean	57		41	98
7	1	55	0	47	102
	2	58	0	36	94
	3	59	0	36	95
	Mean	57		40	97
9	1	55	0	40	95
	2	58	0	46	104
	3	59	0	40	99
	Mean	57		42	99

Table 29. Initial Heating, Pasteurizing, and Reheating Time in Minutes: Pasteurized Loaves Cooked Prior to Storage at 32°F.

Days in Storage	Replication	Heating Time			
		Initial Min.	Pasteurized Min.	Reheat Min.	Total Min.
0	1	60	18	44	122
	2	61	18	46	125
	3	65	18	42	125
	Mean	62	18	44	124
1	1	60	18	41	119
	2	61	18	50	129
	3	65	18	41	124
	Mean	62	18	47	124
2	1	60	18	40	118
	2	61	18	46	125
	3	65	18	49	132
	Mean	62	18	45	124
4	1	60	18	51	129
	2	61	18	39	118
	3	65	18	51	124
	Mean	62	18	47	127
7	1	60	18	45	123
	2	61	18	42	121
	3	65	18	48	131
	Mean	62	18	45	125
9	1	60	18	47	125
	2	61	18	42	121
	3	65	18	46	129
	Mean	62	18	45	125

Table 30. Initial Heating, Pasteurizing, and Reheating Time in Minutes: Pasteurized Loaves Cooked Prior to Storage at 42°F.

Days in Storage	Replication	Heating Time			
		Initial Min.	Pasteurized Min.	Reheat Min.	Total Min.
0	1	55	18	43	116
	2	58	18	34	110
	3	59	18	33	110
	Mean	57	18	36	112
1	1	55	18	28	101
	2	58	18	42	118
	3	59	18	41	118
	Mean	57	18	37	112
2	1	55	18	30	103
	2	58	18	40	116
	3	59	18	41	118
	Mean	57	18	37	112
4	1	55	18	40	113
	2	58	18	46	122
	3	59	18	36	113
	Mean	57	18	40	116
7	1	55	18	47	120
	2	58	18	36	112
	3	59	18	36	113
	Mean	57	18	39	115
9	1	55	18	40	113
	2	58	18	46	122
	3	59	18	40	117
	Mean	57	18	42	117

Table 31. Initial Heating and Reheating Time in Minutes: Cooked Frozen Ground Beef Loaves Which Were Thawed Prior to Storage at 32°F.

Days in Storage	Replication	Heating Time			
		Initial Min.	Pasteurized Min.	Reheat Min.	Total Min.
0	1	55	0	57	112
	2	63	0	46	109
	3	55	0	42	97
	Mean	58		48	106
1	1	55	0	54	109
	2	63	0	50	113
	3	55	0	41	96
	Mean	58	0	48	106
2	1	55	0	65	120
	2	63	0	46	109
	3	55	0	49	104
	Mean	58	0	53	111
4	1	55	0	39	94
	2	63	0	39	102
	3	55	0	51	106
	Mean	58		43	101
7	1	55	0	45	100
	2	63	0	42	105
	3	55	0	48	103
	Mean	58		45	103
9	1	55	0	40	95
	2	63	0	42	105
	3	55	0	41	96
	Mean	58		41	99

Table 32. Initial Heating and Reheating Time in Minutes: Cooked Frozen Ground Beef Loaves Which Were Thawed Prior to Storage at 42°F.

Days in Storage	Replication	Heating Time			
		Initial Min.	Pasteurized Min.	Reheat Min.	Total Min.
0	1	55	0	43	98
	2	63	0	51	114
	3	62	0	33	95
	Mean	60		42	102
1	1	55	0	28	83
	2	63	0	42	105
	3	62	0	41	103
	Mean	60		37	97
2	1	55	0	30	85
	2	63	0	40	103
	3	62	0	41	103
	Mean	60		37	97
4	1	55	0	40	95
	2	63	0	46	109
	3	62	0	44	106
	Mean	60		43	103
7	1	55	0	47	102
	2	63	0	49	112
	3	62	0	44	106
	Mean	60		47	107
9	1	55	0	40	95
	2	63	0	46	109
	3	62	0	40	102
	Mean	60		42	102

Table 33. Internal Temperatures of Loaves to be Cooked and Reheated: Temperature Just Before Loaves Were Placed in Oven

Days in Storage	Replication	Handling Procedure: Fresh	Refrigerated	Pasteurized	Frozen, Thawed	Fresh	Refrigerated	Pasteurized	Frozen, Thawed
		32°F. Storage				42°F. Storage			
0	1	48	43	54	34	58	64	66	46
	2	40	55	55	52	56	60	62	45
	3	42	54	56	47	47	56	54	56
	Mean	43	51	55	44	54	60	61	49
1	1	40	46	49	46	64	60	66	64
	2	48	48	50	50	61	57	57	55
	3	42	50	51	50	58	53	55	54
	Mean	43	48	49	49	61	57	59	58
2	1	43	49	48	50	59	60	60	55
	2	43	50	47	48	60	56	58	57
	3	44	48	50	50	60	53	56	55
	Mean	43	49	48	49	60	56	58	56
4	1	34	50	47	49	62	56	56	55
	2	44	52	52	48	60	54	57	56
	3	46	50	46	50	60	58	57	56
	Mean	41	51	45	49	61	56	56	56
7	1	38	46	48	48	58	55	59	54
	2	44	47	48	48	58	56	57	54
	3	40	48	50	50	58	56	55	57
	Mean	41	47	49	49	58	56	57	55
9	1	46	50	58	50	61	57	57	54
	2	40	48	48	48	54	52	51	52
	3	42	48	43	46	55	56	53	55
	Mean	43	49	46	48	57	55	54	54
Overall Means		42	Stored		48.6	58	Stored		59.6
Grand Mean		32°F.--47°F. 42°F.--59°F.							

Table 34. Internal Temperature of Raw Loaves: Temperature Measured Just Before Loaves Were Placed in Oven to Cook

12 Loaf Batches	Loaves With Thermocouples 1 °F.	2 °F.	3 °F.	4 °F.	5 °F.	Mean °F.
1	47	46	44	46	47	46
2	50	51	54	52	52	52
3	52	50	52	52	51	51
4	45	44	45	42	42	44
5	44	43	44	40	40	42
6	58	60	60	59	58	59
7	45	45	45	45	45	45
8	54	50	48	52	50	51
9	45	45	45	46	46	45
Mean						48

APPENDIX D

COOKING LOSSES TABLES AND MOISTURE CONTENT TABLES

Table 35. Cooking Losses in Grams: Freshly Prepared, Freshly Cooked Ground Beef Loaves[a] Which Were References for Loaves in 32°F. Storage

Reference: Days in Storage	Replication	Initial Losses Evap. g.	Drip g.	Total g.	Reheat Losses Evap. g.	Drip g.	Total g.	Total g.
0	1	42.5	123.0	165.6	0	0	0	165.5
	2	46.0	109.0	155.0	0	0	0	155.0
	3	67.0	54.0	121.0	0	0	0	121.0
	Mean							147.2
1	1	55.0	106.0	161.0	0	0	0	161.0
	2	54.5	106.0	160.5	0	0	0	160.5
	3	60.0	64.0	114.0	0	0	0	114.0
	Mean							145.2
2	1	56.0	95.5	151.5	0	0	0	151.5
	2	60.0	99.5	159.5	0	0	0	159.5
	3	40.0	82.0	122.0	0	0	0	122.0
	Mean							144.3
4	1	58.5	72.5	130.5	0	0	0	130.5
	2	79.0	86.0	165.0	0	0	0	165.0
	3	51.0	60.0	111.0	0	0	0	111.0
	Mean							135.5
7	1	66.0	98.5	164.5	0	0	0	164.5
	2	57.0	81.0	138.0	0	0	0	138.0
	3	67.0	70.0	137.0	0	0	0	137.0
	Mean							146.5
9	1	57.5	70.5	128.0	0	0	0	128.0
	2	59.0	79.0	138.0	0	0	0	138.9
	3	51.0	54.0	105.0	0	0	0	105.0
	Mean							123.5

[a] Raw, net weight of loaves equaled 900 grams.

Table 36. Cooking Losses in Grams: Freshly Prepared, Freshly Cooked Ground Beef Loaves[a] Which Were References for Loaves in 42°F. Storage

Reference: Days in Storage	Replication	Initial Losses Evap. g.	Drip g.	Total g.	Reheat Losses Evap. g.	Drip g.	Total g.	Total g.
0	1	66.0	102.0	168.0	0	0	0	168.0
	2	55.0	112.0	167.0	0	0	0	167.0
	3	54.0	77.0	131.0	0	0	0	131.0
	Mean							155.3
1	1	43.0	112.5	155.5	0	0	0	155.5
	2	47.0	127.5	174.5	0	0	0	174.5
	3	53.0	100.0	153.0	0	0	0	153.0
	Mean							161.0
2	1	38.5	98.0	136.5	0	0	0	136.5
	2	48.0	116.0	164.0	0	0	0	164.0
	3	64.0	88.0	152.0	0	0	0	152.0
	Mean							150.8
4	1	29.5	90.5	120.0	0	0	0	120.0
	2	47.0	150.0	197.0	0	0	0	197.0
	3	49.5	100.0	149.5	0	0	0	149.5
	Mean							155.5
7	1	51.0	128.0	179.0	0	0	0	179.0
	2	55.5	138.5	194.0	0	0	0	194.0
	3	51.0	94.0	145.0	0	0	0	145.0
	Mean							172.7
9	1	39.0	133.5	172.5	0	0	0	172.5
	2	57.0	97.0	154.0	0	0	0	154.0
	3	49.0	54.0	103.0	0	0	0	103.0
	Mean							143.2

[a]Raw, net weight of loaves equaled 900 grams.

Table 37. Cooking Losses in Grams: Refrigerated Ground Beef Loaves[a] Cooked Prior to Storage at 32°F.

Days in Storage	Replication	Initial Losses			Reheat Losses			Total
		Evap. g.	Drip g.	Total g.	Evap. g.	Drip g.	Total g.	g.
0	1	72.0	90.0	162.0	5.0	21.0	26.0	188.0
	2	36.0	65.0	101.0	22.5	29.5	52.0	153.0
	3	56.0	94.0	150.0	23.0	9.0	32.0	182.0
	Mean							174.3
1	1	23.0	101.0	124.0	45.0	49.0	94.0	218.0
	2	56.0	50.0	106.0	31.0	23.0	54.0	160.0
	3	52.0	93.0	145.0	14.0	6.0	20.0	165.0
	Mean							181.0
2	1	35.5	110.0	145.5	21.0	41.0	62.0	207.5
	2	58.0	47.0	105.0	21.0	26.0	47.0	152.0
	3	60.5	72.0	132.5	19.0	9.0	28.0	160.5
	Mean							173.3
4	1	44.0	94.0	138.0	19.0	9.5	28.5	166.5
	2	45.0	81.5	126.5	27.5	4.0	31.5	158.0
	3	31.0	99.0	130.0	33.0	28.0	61.0	191.0
	Mean							171.8
7	1	44.0	92.0	136.0	19.0	12.5	31.5	167.5
	2	45.0	71.0	116.0	22.0	4.0	26.0	142.0
	3	49.0	101.0	150.0	33.0	14.0	47.0	197.0
	Mean							168.8
9	1	41.0	89.0	130.0	33.0	4.0	37.0	167.0
	2	46.0	89.0	135.0	26.0	10.0	36.0	171.0
	3	30.0	83.0	113.0	23.5	12.5	36.0	148.0
	Mean							167.3

[a]Raw, net weight of loaves equaled 900 grams.

Table 38. Cooking Losses in Grams: Refrigerated Ground Beef Loaves[a] Cooked Prior to Storage at 42°F.

Days in Storage	Replication	Initial Losses Evap. g.	Drip g.	Total g.	Reheat Losses Evap. g.	Drip g.	Total g.	Total g.
0	1	26.5	87.5	114.0	28.0	26.0	54.0	168.0
	2	46.0	94.0	140.0	22.0	33.0	55.0	195.0
	3	41.0	120.0	161.0	36.0	6.0	42.0	203.0
	Mean							188.7
1	1	24.5	91.0	115.0	18.5	12.5	31.0	146.5
	2	29.0	121.0	150.0	23.0	10.0	33.0	183.0
	3	73.0	66.0	139.0	19.0	6.0	25.0	164.0
	Mean							164.5
2	1	28.0	76.0	104.0	18.0	15.5	33.5	137.5
	2	41.0	96.0	137.0	25.0	7.5	32.5	169.5
	3	45.5	106.0	151.5	20.0	9.0	29.0	180.5
	Mean							162.5
4	1	25.0	108.0	133.0	27.0	20.0	47.0	180.0
	2	47.0	91.0	138.0	31.0	4.0	35.0	173.0
	3	37.0	71.0	108.0	20.0	21.0	41.0	149.0
	Mean							168.0
7	1	22.0	91.0	113.0	32.0	34.0	66.0	179.0
	2	32.5	129.0	161.5	13.5	3.5	17.0	178.5
	3	30.5	103.0	133.5	27.0	5.0	32.0	165.5
	Mean							174.3
9	1	21.0	77.0	98.0	38.5	23.5	62.0	160.0
	2	55.0	100.0	155.0	30.0	4.0	34.0	189.0
	3	37.5	105.0	142.5	12.5	3.0	15.5	158.0
	Mean							169.0

[a]Raw, net weight of loaves equaled 900 grams.

Table 39. Cooking Losses in Grams: Pasteurized Ground Beef Loaves[a] Cooked Prior to Storage at 32°F.

Days in Storage	Replication	Initial Losses			Reheat Losses			Total
		Evap. g.	Drip g.	Total g.	Evap. g.	Drip g.	Total g.	g.
0	1	43.5	114.0	157.5	16.0	17.0	33.0	190.5
	2	42.5	50.5	93.0	41.5	10.0	51.5	144.5
	3	47.0	99.0	146.0	30.0	12.0	42.0	188.0
	Mean							174.3
1	1	31.0	94.0	125.0	16.5	32.0	48.5	173.5
	2	51.5	82.5	134.0	33.5	15.0	48.5	182.5
	3	39.0	108.0	147.0	15.0	13.0	28.0	175.5
	Mean							177.0
2	1	27.0	103.0	130.0	14.0	22.0	36.0	166.0
	2	57.0	74.0	131.0	24.0	25.0	49.0	180.0
	3	44.0	80.0	124.0	30.0	24.0	54.0	178.0
	Mean							174.7
4	1	29.0	97.0	126.0	27.0	28.0	55.0	181.0
	2	44.5	103.0	147.5	22.0	7.5	29.5	177.0
	3	29.0	121.0	150.0	33.0	7.0	40.0	190.0
	Mean							182.7
7	1	31.5	84.5	116.0	35.5	16.5	52.0	168.0
	2	46.5	69.5	116.0	31.0	9.0	40.0	156.0
	3	44.0	88.0	132.0	38.0	10.0	48.0	180.0
	Mean							168.0
9	1	30.0	83.0	113.0	23.5	12.5	36.0	149.0
	2	54.0	32.0	106.0	32.5	11.0	43.5	149.5
	3	39.0	99.0	138.0	23.0	14.0	37.0	175.0
	Mean							157.8

[a]Raw, net weight of loaves equaled 900 grams.

Table 40. Cooking Losses in Grams: Pasteurized Ground Beef Loaves[a] Cooked Prior to Storage at 42°F.

Days in Storage	Replication	Initial Losses			Reheat Losses			Total
		Evap. g.	Drip g.	Total g.	Evap. g.	Drip g.	Total g.	g.
0	1	30.0	83.5	113.5	19.0	37.0	56.0	169.5
	2	46.5	112.0	158.5	19.0	3.0	22.0	180.5
	3	40.5	106.0	146.5	28.0	24.0	52.0	198.5
	Mean							182.8
1	1	37.5	97.5	135.0	12.0	13.0	25.0	160.0
	2	45.0	93.0	138.0	20.0	19.0	39.0	177.0
	3	60.0	87.0	147.0	20.0	13.0	33.0	180.0
	Mean							172.3
2	1	41.0	58.0	99.0	12.0	27.0	39.0	138.0
	2	27.0	126.0	153.0	12.0	32.5	44.5	197.5
	3	41.0	128.0	169.0	30.0	3.0	33.0	202.0
	Mean							179.2
4	1	37.0	71.0	108.0	20.0	21.0	41.0	149.0
	2	47.5	111.0	158.5	22.5	6.5	29.0	187.5
	3	40.0	80.0	120.0	29.0	13.0	42.0	162.0
	Mean							166.2
7	1	41.0	82.0	123.0	31.0	20.0	51.0	174.0
	2	30.5	119.0	149.5	40.5	4.0	44.5	194.0
	3	52.0	69.0	121.0	22.0	14.0	36.0	157.0
	Mean							175.0
9	1	31.0	87.0	118.0	16.0	22.0	38.0	156.0
	2	48.5	105.0	153.0	30.0	6.0	36.0	189.5
	3	42.0	125.0	167.0	23.0	4.0	27.0	194.0
	Mean							179.8

[a]Raw, net weight of loaves equaled 900 grams.

Table 41. Cooking Losses in Grams: Cooked, Frozen Ground Beef Loaves[a] Thawed Prior to Storage at 32°F.

Days in Storage	Replication	Initial Losses			Reheat Losses			Total
		Evap. g.	Drip g.	Total g.	Evap. g.	Drip g.	Total g.	g.
0	1	45.0	117.0	162.0	39.0	17.0	56.0	218.0
	2	71.0	77.5	148.5	27.0	11.0	38.0	186.5
	3	45.0	89.0	134.0	33.0	15.0	48.0	182.0
	Mean							195.5
1	1	51.0	103.0	154.0	29.0	26.5	55.5	209.5
	2	59.0	80.5	139.5	26.5	18.0	44.5	184.0
	3	69.0	57.0	126.5	20.0	22.0	42.0	168.5
	Mean							187.3
2	1	55.5	118.0	173.5	22.0	9.5	31.5	205.0
	2	51.5	74.5	126.0	21.0	29.0	50.0	176.0
	3	38.5	100.0	138.5	28.0	24.0	52.0	190.5
	Mean							190.5
4	1	42.0	104.0	146.0	20.0	24.0	44.0	190.0
	2	55.0	50.0	105.0	26.0	20.0	46.0	151.0
	3	58.0	63.0	121.0	17.0	23.0	40.0	161.0
	Mean							167.3
7	1	66.0	77.0	143.0	30.5	5.5	36.0	179.0
	2	57.0	48.5	105.5	22.0	24.0	46.0	151.5
	3	63.0	67.0	130.0	20.0	20.0	40.0	170.0
	Mean							166.8
9	1	50.5	65.0	115.5	18.0	44.5	62.5	178.0
	2	39.0	86.5	165.5	22.0	18.0	40.0	165.5
	3	48.5	92.0	140.5	23.5	4.0	27.5	168.0
	Mean							170.5

[a]Raw, net weight of loaves equaled 900 grams.

Table 42. Cooking Losses in Grams: Cooked, Frozen Ground Beef Loaves[a] Thawed Prior to Storage at 42°F.

Days in Storage	Replication	Initial Losses Evap. g.	Initial Losses Drip g.	Initial Losses Total g.	Reheat Losses Evap. g.	Reheat Losses Drip g.	Reheat Losses Total g.	Total g.
0	1	66.0	93.0	159.0	33.0	10.5	43.5	202.5
	2	51.5	83.0	134.5	34.0	17.0	51.0	185.5
	3	29.0	108.0	137.0	21.0	22.0	43.0	180.0
	Mean							189.3
1	1	74.5	71.0	145.5	10.0	11.5	21.5	167.0
	2	47.0	76.0	123.0	29.0	22.0	51.0	174.0
	3	35.0	85.0	120.0	21.0	34.0	55.0	175.0
	Mean							172.0
2	1	92.5	52.0	144.5	18.0	12.0	30.0	174.5
	2	57.5	90.5	148.0	16.0	16.0	32.0	180.0
	3	28.0	104.0	132.0	22.0	30.0	52.0	184.0
	Mean							179.5
4	1	53.0	81.0	134.0	14.0	18.5	32.5	166.5
	2	58.0	80.0	138.0	20.0	15.5	35.0	173.0
	3	45.0	98.0	143.0	19.0	15.0	34.0	177.0
	Mean							172.2
7	1	59.0	104.0	163.0	39.0	5.0	44.0	207.0
	2	54.0	69.0	123.0	16.0	30.0	46.0	169.0
	3	45.0	91.0	136.0	17.0	19.0	36.0	172.0
	Mean							182.7
9	1	96.5	67.0	163.5	19.0	6.0	25.0	188.5
	2	65.0	51.0	116.0	20.0	42.0	62.0	178.0
	3	73.0	84.0	157.0	11.5	12.0	23.5	180.5
	Mean							182.3

[a]Raw, net weight of loaves equaled 900 grams.

Table 43. Weight Losses in Grams Occurring in Loaves from the Time of Weighing After Initial Heating Until Weighing Upon Removal from Refrigerated Storage at 32°F. and 42°F.

		Handling Procedure					
		32°F. Storage			42°F. Storage		
Days in Storage	Replication	Refrigerated g.	Pasteurized g.	Frozen, Thawed g.	Refrigerated g.	Pasteurized g.	Frozen, Thawed g.
0	1	2.0	3.0	5.0	1.0	2.0	1.0
	2	3.0	2.0	1.5	2.0	5.0	3.5
	3	3.0	3.0	2.0	3.0	2.0	4.0
	Mean	2.7	2.7	2.8	2.0	3.0	2.8
1	1	2.0	4.0	3.0	2.0	2.0	1.0
	2	4.0	1.0	4.0	4.0	5.0	2.0
	3	3.0	3.0	0.5	3.0	3.0	1.0
	Mean	3.0	2.7	2.5	3.0	3.3	1.3
2	1	1.0	6.0	1.0	3.0	1.0	1.0
	2	5.0	2.0	2.0	6.0	3.5	4.0
	3	3.0	4.0	1.0	3.0	4.0	1.0
	Mean	3.0	4.0	1.3	4.0	2.8	2.0
4	1	0.0	4.0	2.0	1.0	2.0	4.0
	2	3.5	1.5	4.0	3.0	9.0	2.0
	3	4.0	2.0	1.0	4.0	8.0	3.0
	Mean	2.5	2.5	2.3	2.7	6.3	3.0
7	1	10.0	4.0	5.0	3.0	3.0	3.0
	2	6.0	9.0	3.0	5.0	5.5	4.0
	3	7.0	5.0	2.0	7.0	7.0	3.0
	Mean	7.7	6.0	3.3	5.0	5.2	3.3
9	1	5.0	4.0	4.5	3.0	4.0	3.0
	2	8.0	5.0	3.5	3.0	9.0	4.0
	3	.6.0	9.0	1.5	16.0	10.0	5.5
	Mean	6.3	6.0	3.2	7.3	7.7	4.2
Overall Means Across Handling				3.6			3.1
Grand Mean							3.4

Table 44. Moisture Content (%) of Cooked Ground Beef Loaves Stored at 32°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh %	Refrigerated %	Pasteurized %	Frozen, Thawed %
0	1	62.2	60.6	59.6	62.0
	2	64.2	62.8	61.6	60.1
	3	61.7	62.8	55.6	60.8
	Mean	62.7	62.4	58.9	61.0
1	1	63.3	62.8	63.6	61.2
	2	61.7	59.2	59.8	59.5
	3	61.4	59.8	59.2	57.4
	Mean	62.1	60.6	60.9	59.4
2	1	63.8	63.3	60.6	63.2
	2	63.6	56.6	63.1	55.0
	3	65.4	60.0	59.1	61.4
	Mean	64.3	60.0	60.9	59.9
4	1	61.2	63.4	58.4	59.4
	2	60.7	60.4	59.6	61.8
	3	59.8	59.8	63.1	61.6
	Mean	60.6	61.2	60.4	60.9
7	1	60.5	60.2	59.3	55.0
	2	62.4	62.9	60.8	61.6
	3	61.5	59.7	61.5	61.2
	Mean	61.5	60.9	60.5	59.3
9	1	64.2	59.9	59.2	58.8
	2	56.3	61.0	61.0	59.7
	3	63.3	59.8	61.5	61.4
	Mean	61.3	60.2	60.6	60.0

Table 45. Moisture Content (%) of Cooked Ground Beef Loaves Stored at 42°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure: Fresh %	Refrigerated %	Pasteurized %	Frozen, Thawed %
0	1	63.2	55.8	62.5	61.1
	2	64.5	59.9	62.6	62.2
	3	63.7	64.4	61.0	61.0
	Mean	63.8	60.0	62.0	61.4
1	1	63.1	60.6	63.7	60.4
	2	63.6	61.4	60.3	58.9
	3	62.8	64.9	65.8	61.0
	Mean	63.2	62.3	63.3	60.1
2	1	61.3	62.5	59.6	61.7
	2	62.0	63.9	62.2	60.4
	3	63.7	60.6	59.8	61.6
	Mean	62.3	62.3	60.5	61.2
4	1	62.4	58.8	59.8	62.6
	2	60.9	59.7	59.0	61.8
	3	63.8	58.5	60.8	59.5
	Mean	62.4	59.0	59.9	61.3
7	1	62.1	59.6	59.6	59.3
	2	61.2	61.3	59.4	63.0
	3	62.8	55.0	61.9	62.1
	Mean	62.0	58.6	60.3	61.5
9	1	56.6	58.4	61.1	52.9
	2	61.6	59.6	61.5	61.2
	3	64.2	63.8	58.4	58.6
	Mean	60.8	60.6	60.3	57.6

APPENDIX E

TBA NUMBERS AND pH VALUES

Table 46. TBA Values: Absorbance at 532 nm and TBA Numbers, Ground Beef Loaves Cooked Prior to Refrigeration at 32°F. and Freshly Prepared, Freshly Cooked Loaves Which Were References

Days in Storage	Replication	Handling Treatment: Fresh Absorbance$_{532}$	Fresh TBA No.[a]	Refrigerated Absorbance$_{532}$	Refrigerated TBA No.[a]
0	1	0.132	1.0296	0.148	1.1544
	2	0.095	0.7410	0.108	0.8424
	3	0.095	0.7410	0.090	0.7020
	Mean	0.107	0.8372	0.115	0.8996
1	1	0.120	0.9360	0.154	1.2012
	2	0.082	0.6396	0.102	0.7956
	3	0.115	0.8970	0.155	1.2090
	Mean	0.106	0.8242	0.137	1.0686
2	1	0.120	0.9360	0.175	1.3650
	2	0.112	0.8736	0.138	1.0764
	3	0.115	0.8970	0.192	1.4976
	Mean	0.116	0.9022	0.168	1.3130
4	1	0.132	1.0296	0.160	1.2480
	2	0.110	0.8580	0.188	1.4664
	3	0.142	1.1076	0.210	1.6380
	Mean	0.128	0.9984	0.186	1.4508
7	1	0.155	1.2090	0.372	2.9016
	2	0.060	0.4680	0.240	1.8720
	3	0.102	0.7956	0.340	2.6520
	Mean	0.106	0.8242	0.317	2.4752
9	1	0.168	1.3104	0.540	4.2120
	2	0.122	0.9516	0.335	2.6130
	3	0.112	0.8736	0.310	2.4180
	Mean	0.132	1.0452	0.395	3.0810

[a]TBA No. equals absorbance$_{532}$ x 7.8 and is equivalent to milligrams of malonaldehyde per 1000 grams.

Table 47. TBA Values: Absorbance at 532 nm and TBA Numbers, Ground Beef Loaves Cooked and Pasteurized Prior to Refrigeration at 32°F. and Cooked, Frozen Loaves Thawed Prior to Refrigeration at 32°F.

Days in Storage	Replication	Handling Treatment: Pasteurized Absorbance$_{532}$	Pasteurized TBA No.[a]	Frozen, Thawed Absorbance$_{532}$	Frozen, Thawed TBA No.[a]
0	1	0.138	1.0764	0.165	1.2870
	2	0.102	0.7956	0.140	1.0920
	3	0.135	1.0530	0.140	1.0920
	Mean	0.125	0.9750	0.148	1.1570
1	1	0.166	1.2948	0.230	1.7940
	2	0.138	1.0764	0.145	1.1310
	3	0.178	1.3884	0.158	1.2324
	Mean	0.160	1.2532	0.177	1.3858
2	1	0.215	1.6770	0.225	1.7550
	2	0.165	1.2870	0.170	1.3260
	3	0.158	1.2324	0.258	2.0124
	Mean	0.179	1.3988	0.217	1.6978
4	1	0.300	2.3400	0.238	1.8564
	2	0.178	1.3884	0.172	1.3416
	3	0.230	1.7940	0.335	2.6130
	Mean	0.236	1.8408	0.248	1.9370
7	1	0.390	3.0420	0.475	3.7050
	2	0.275	2.1450	0.328	2.5584
	3	0.290	2.2620	0.395	3.0810
	Mean	0.318	2.4830	0.399	3.1148
9	1	0.390	3.0420	0.600	4.6800
	2	0.338	2.6364	0.375	2.9250
	3	0.275	2.1450	0.385	3.0030
	Mean	0.334	2.6078	0.453	3.5360

[a]TBA No. equals absorbance$_{532}$ x 7.8 and is equivalent to milligrams of malonaldehyde per 1000 grams.

Table 48. TBA Values: Absorbance at 532 nm and TBA Numbers, Ground Beef Loaves Cooked Prior to Refrigeration at 42°F. and Freshly Prepared, Freshly Cooked Loaves Which Were References

Days in Storage	Replication	Handling Treatment: Fresh Absorbance$_{532}$	Fresh TBA No.[a]	Refrigerated Absorbance$_{532}$	Refrigerated TBA No.[a]
0	1	0.080	0.6240	0.118	0.9204
	2	0.150	1.1700	0.150	1.1700
	3	0.098	0.7644	0.115	0.8970
	Mean	0.109	0.8528	0.127	0.9958
1	1	0.130	1.0140	0.100	0.7800
	2	0.180	1.4040	0.185	1.4430
	3	0.160	1.2480	0.162	1.2636
	Mean	0.156	1.2220	0.149	1.1622
2	1	0.172	1.3416	0.232	1.8096
	2	0.180	1.4040	0.195	1.5210
	3	0.180	1.4040	0.220	1.7160
	Mean	0.177	1.3832	0.215	1.6822
4	1	0.158	1.2324	0.238	1.8564
	2	0.150	1.1700	0.328	2.5584
	3	0.162	1.2636	0.380	2.8860
	Mean	0.156	1.2220	0.312	2.4336
7	1	0.115	0.8970	0.340	2.6520
	2	0.145	1.1310	0.425	3.3150
	3	0.150	1.1700	0.345	2.6910
	Mean	0.136	1.0660	0.370	2.8860
9	1	0.200	1.5600	0.405	3.1590
	2	0.115	0.8970	0.585	4.5630
	3	0.115	0.8970	0.460	3.5580
	Mean	0.143	1.1180	0.483	3.7700

[a]TBA No. equals absorbance$_{532}$ x 7.8 and is equivalent to milligrams of malonaldehyde per 1000 grams.

Table 49. TBA Values: Absorbance at 532 nm and TBA Numbers, Ground Beef Loaves Cooked and Pasteurized Prior to Refrigeration at 42°F. and Cooked, Frozen Loaves Thawed Prior to Refrigeration at 42°F.

Days in Storage	Replication	Handling Treatment: Pasteurized Absorbance$_{532}$	Pasteurized TBA No.[a]	Frozen, Thawed Absorbance$_{532}$	Frozen, Thawed TBA No.[a]
0	1	0.102	0.7956	0.178	1.3884
	2	0.142	1.1076	0.178	1.3884
	3	0.120	0.9360	0.148	1.1544
	Mean	0.121	0.9464	0.168	1.3140
1	1	0.135	1.0530	0.202	1.5756
	2	0.192	1.4976	0.205	1.5990
	3	0.142	1.1076	0.212	1.6536
	Mean	0.156	1.2194	0.206	1.6094
2	1	0.330	2.5740	0.262	2.0436
	2	0.225	1.7550	0.292	2.2776
	3	0.205	1.5990	0.292	2.2776
	Mean	0.253	1.9760	0.282	2.1996
4	1	0.218	1.7004	0.440	3.4320
	2	0.355	2.7690	0.358	2.7924
	3	0.320	2.4960	0.410	3.1980
	Mean	0.297	2.3218	0.402	3.1408
7	1	0.318	2.4804	0.422	3.2916
	2	0.430	3.5490	0.430	3.3540
	3	0.470	3.6660	0.470	4.4460
	Mean	0.414	3.2318	0.474	3.6972
9	1	0.472	3.6816	0.595	4.6410
	2	0.530	4.1340	0.482	3.7596
	3	0.440	3.4320	0.452	3.5256
	Mean	0.479	3.7392	0.509	3.9754

[a]TBA No. equals absorbance$_{532}$ x 7.8 and is equivalent to milligrams of malonaldehyde per 1000 grams.

Table 50. TBA Values: Absorbance at 532 nm and TBA Numbers of Raw Ground Beef and Raw Meat Loaf Mixture

Storage Cycles[a]	Weeks Meat Held Frozen	Raw Ground Beef		Raw Meat Loaf	
		Absorbance$_{532}$	TBA No.[a]	Absorbance$_{532}$	TBA No.[a]
1	1	0.190	1.4820	0.135	1.0530
2	3	0.118	0.9204	0.170	1.3260
3	5	0.192	1.4976	0.198	1.5444
4	7	0.215	1.6770	0.148	1.1554
5	9	0.198	1.5440	0.158	1.2324
6	11	0.135	1.0530	0.128	0.9984

[a]TBA No. determined on Day 1 of each storage cycle. TBA No. equals absorbance$_{532}$ x 7.8 and is equivalent to milligrams of malonaldehyde per 1000 grams.

Table 51. pH Values: Cooked Ground Beef Loaves Stored at 32°F. and 42°F. and pH Values of Raw Ground Beef and Raw Meat Loaf Mixture

Days in Storage	Temp. of Storage °F.	Handling Procedure				Raw	
		Fresh	Refrig-erated	Pasteur-ized	Frozen, Thawed	Ground Beef	Meat Loaf
0	32	6.24	6.31	6.31	6.31		
	42	6.12	6.20	6.20	6.25		
						6.00	6.10
1	32	6.34	6.20	6.32	6.30		
	42	6.28	6.28	6.25	6.23		
						5.85	6.20
2	32	6.13	6.25	6.20	6.23		
	42	6.25	6.28	6.25	6.23		
						6.00	6.00
4	32	6.23	6.21	6.20	6.25		
	42	6.24	6.16	6.20	6.18		
						5.80	6.04
7	32	6.02	5.80	6.02	6.00		
	42	6.16	6.26	6.14	6.13		
						5.85	5.92
9	32	6.29	6.21	6.24	6.22		
	42	6.31	6.25	6.37	6.40		
						5.85	6.02

APPENDIX F

TASTE PANEL SCORES

Table 52. Taste Panel Scores[a]: Means[b] for Odor Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized or Frozen, Thawed Loaves Prior to Storage at 32°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	8.33	6.50	7.33	7.00
	2	7.83	7.17	8.16	7.83
	3	8.14	7.00	8.14	7.85
	Mean	8.10	6.89	7.88	7.56
1	1	7.14	6.28	7.00	6.85
	2	8.00	7.86	7.71	7.28
	3	7.85	8.00	7.00	6.28
	Mean	7.66	7.38	7.24	6.80
2	1	7.33	7.50	6.66	6.00
	2	8.00	7.00	7.42	6.57
	3	8.14	8.00	6.85	6.42
	Mean	7.82	7.50	6.98	6.33
4	1	8.00	7.00	7.14	6.57
	2	6.71	7.14	7.28	7.00
	3	7.60	7.40	5.60	5.00
	Mean	7.44	7.18	6.67	6.19
7	1	7.85	7.14	6.85	5.00
	2	6.83	7.33	6.83	6.16
	3	8.28	5.28	6.42	4.28
	Mean	7.65	6.58	6.70	5.14
9	1	8.00	5.00	6.28	6.28
	2	7.14	7.14	7.71	5.57
	3	8.14	6.57	5.71	3.00
	Mean	7.76	6.24	6.57	4.95

[a]1-9 scoring scale, 1 = extremely poor odor and 9 = excellent odor.

[b]Mean of 21 scores.

Table 53. Taste Panel Scores[a]: Means[b] for Odor Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized or Frozen, Thawed Loaves Prior to Storage at 42°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	6.85	7.28	6.42	7.14
	2	7.85	8.00	7.71	7.71
	3	8.14	7.86	8.14	7.57
	Mean	7.61	7.71	7.43	7.47
1	1	6.57	8.00	7.14	6.14
	2	7.14	7.28	7.71	7.86
	3	8.40	8.00	7.60	8.40
	Mean	7.37	7.76	7.48	7.48
2	1	7.14	6.42	6.42	5.71
	2	7.28	7.28	8.00	7.43
	3	8.00	7.14	7.14	7.71
	Mean	7.47	6.95	7.18	6.95
4	1	6.42	6.42	5.43	5.57
	2	8.14	7.57	7.00	7.00
	3	8.00	7.28	7.71	7.00
	Mean	7.52	7.09	6.71	6.43
7	1	6.85	7.57	5.71	4.42
	2	8.00	6.42	7.42	5.57
	3	8.42	7.00	6.57	5.85
	Mean	7.70	6.43	6.57	5.28
9	1	7.00	7.14	5.85	5.71
	2	7.67	6.67	6.33	4.67
	3	8.43	5.28	5.00	4.42
	Mean	7.71	6.36	5.72	4.93

[a]1-9 scoring scale, 1 = extremely poor odor and 9 = excellent odor.

[b]Mean of 21 scores.

Table 54. Taste Panel Scores[a]: Means[b] for Appearance Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized or Frozen, Thawed Loaves Prior to Storage at 32°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	8.00	7.33	7.33	7.00
	2	8.16	8.00	7.66	7.67
	3	8.28	7.00	7.57	7.85
	Mean	8.15	7.44	7.52	7.51
1	1	7.71	7.14	7.86	7.00
	2	8.00	7.14	7.14	7.28
	3	8.00	8.14	7.85	7.14
	Mean	7.90	7.47	7.62	7.14
2	1	7.33	7.66	7.50	6.33
	2	7.57	7.42	7.43	7.57
	3	8.00	7.28	7.28	7.14
	Mean	7.63	7.45	7.40	7.01
4	1	8.00	7.85	7.28	7.42
	2	6.71	7.42	7.00	7.00
	3	7.80	7.60	6.60	6.00
	Mean	7.50	7.62	6.96	6.81
7	1	7.71	7.71	7.57	6.42
	2	7.66	7.00	7.00	6.83
	3	8.00	6.14	7.00	5.71
	Mean	7.79	6.95	7.19	6.32
9	1	8.00	6.14	6.28	7.00
	2	6.85	7.14	7.57	6.57
	3	8.57	6.57	6.57	4.14
	Mean	7.81	6.62	6.81	5.90

[a] 1-9 scoring scale, 1 = extremely poor appearance and 9 = excellent appearance.

[b] Mean of 21 scores.

Table 55. Taste Panel Scores[a]: Means[b] for Appearance Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized or Frozen, Thawed Loaves Prior to Storage at 42°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	8.00	7.85	8.00	7.42
	2	8.14	8.00	8.00	7.71
	3	7.28	7.28	7.57	7.14
	Mean	7.99	7.71	7.76	7.57
1	1	7.14	8.28	8.28	7.00
	2	8.00	7.71	7.71	7.57
	3	8.60	7.60	7.80	8.40
	Mean	7.91	7.86	7.93	7.66
2	1	6.85	6.85	7.85	6.85
	2	8.14	7.42	7.57	7.14
	3	8.00	7.71	7.57	7.28
	Mean	7.66	7.33	7.66	7.09
4	1	7.57	7.28	6.14	5.71
	2	8.00	7.71	7.42	7.00
	3	8.14	8.14	7.71	7.00
	Mean	7.90	7.71	7.09	6.57
7	1	6.85	7.57	6.85	5.85
	2	8.00	6.42	7.85	6.14
	3	8.42	7.42	6.57	6.00
	Mean	7.76	7.14	7.09	6.00
9	1	8.14	7.00	6.57	5.71
	2	7.66	7.00	6.66	5.50
	3	8.28	6.85	6.71	5.85
	Mean	8.02	6.91	6.65	5.69

[a]1-9 scoring scale, 1 = extremely poor appearance and 9 = excellent appearance.

[b]Mean of 21 scores.

Table 56. Taste Panel Scores[a]: Means[b] for Flavor Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized, or Frozen, Thawed Loaves Prior to Storage at 32°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	9.00	7.66	8.50	6.66
	2	8.00	8.00	8.33	7.33
	3	8.28	6.85	8.28	7.28
	Mean	8.43	7.50	8.37	7.09
1	1	7.71	7.14	7.28	7.14
	2	8.14	7.71	7.42	7.00
	3	7.57	8.14	7.85	7.00
	Mean	7.81	7.66	7.52	7.05
2	1	7.66	7.66	7.16	4.83
	2	8.28	8.00	7.14	6.57
	3	8.00	7.57	6.28	6.14
	Mean	7.98	7.74	6.86	5.85
4	1	7.85	6.85	7.14	6.28
	2	6.00	7.85	6.57	6.85
	3	8.20	7.40	6.60	5.40
	Mean	7.35	7.37	6.77	6.18
7	1	7.42	7.00	7.00	4.85
	2	7.83	7.00	7.16	5.83
	3	8.42	5.85	6.42	3.85
	Mean	7.89	6.61	6.86	4.84
9	1	8.14	4.85	5.71	5.57
	2	7.57	7.57	7.71	5.00
	3	8.80	5.00	5.86	1.28
	Mean	8.17	5.81	6.43	3.95

[a]1-9 scoring scale, 1 = extremely poor flavor and 9 = excellent flavor.

[b]Mean of 21 scores.

Table 57. Taste Panel Scores[a]: Means[b] for Flavor Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized, or Frozen, Thawed Loaves Prior to Storage at 42°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	7.85	7.14	6.42	6.85
	2	7.85	8.00	7.85	7.71
	3	8.14	8.00	8.14	7.42
	Mean	7.95	7.71	7.47	7.33
1	1	7.00	7.85	7.71	5.00
	2	8.00	7.57	7.85	7.00
	3	8.40	7.40	7.80	8.20
	Mean	7.80	7.61	7.79	6.73
2	1	6.85	6.57	7.28	6.00
	2	7.14	7.00	7.71	7.14
	3	7.71	7.57	7.00	7.42
	Mean	7.23	7.05	7.33	6.85
4	1	7.14	6.57	6.42	4.71
	2	8.14	7.28	6.28	6.14
	3	8.28	6.42	7.14	6.57
	Mean	7.85	6.76	6.61	5.80
7	1	7.00	6.57	6.28	4.86
	2	8.28	5.42	7.00	5.85
	3	8.28	6.71	5.71	5.57
	Mean	7.85	6.23	6.33	5.43
9	1	7.28	7.14	5.85	4.42
	2	7.83	6.00	6.00	4.83
	3	8.28	4.42	4.71	5.00
	Mean	7.80	5.85	5.52	4.75

[a]1-9 scoring scale, 1 = extremely poor flavor and 9 = excellent flavor.

[b]Mean of 21 scores.

Table 58. Taste Panel Scores[a]: Means[b] for Juiciness Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized or Frozen, Thawed Loaves Prior to Storage at 32°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	8.66	8.00	6.33	6.33
	2	8.00	8.00	8.16	7.33
	3	8.59	6.00	7.14	7.28
	Mean	8.42	7.33	7.21	6.98
1	1	8.00	6.28	6.28	6.57
	2	8.42	7.14	6.42	6.28
	3	8.00	7.71	6.85	6.57
	Mean	8.14	7.04	6.52	6.47
2	1	7.83	7.83	7.00	5.66
	2	7.28	7.42	6.42	6.00
	3	8.00	7.14	6.85	7.00
	Mean	7.70	7.46	6.76	6.22
4	1	8.28	6.14	6.42	5.42
	2	6.85	7.85	6.85	6.71
	3	8.20	7.00	6.80	6.80
	Mean	7.78	7.00	6.69	6.31
7	1	7.42	7.14	7.42	6.14
	2	7.00	7.50	6.66	6.33
	3	8.00	6.00	7.00	6.71
	Mean	7.47	6.88	7.03	6.39
9	1	7.42	5.71	6.42	5.71
	2	6.85	7.57	7.85	5.85
	3	8.43	5.57	5.86	3.71
	Mean	7.57	6.28	6.71	5.09

[a] 1-9 scoring scale, 1 = extremely dry and 9 = very juicy.

[b] Mean of 21 scores.

Table 59. Taste Panel Scores[a]: Means[b] for Juiciness Scores of Cooked Ground Beef Loaves Which Were Designated Refrigerated, Pasteurized or Frozen, Thawed Loaves Prior to Storage at 42°F. and Compared to Freshly Prepared, Freshly Cooked Loaves

Days in Storage	Replication	Handling Procedure			
		Fresh	Refrigerated	Pasteurized	Frozen, Thawed
0	1	8.28	7.57	7.28	6.85
	2	7.57	7.71	7.14	6.57
	3	8.00	7.57	7.14	7.71
	Mean	7.95	7.62	7.19	7.04
1	1	6.42	8.14	7.57	5.71
	2	7.00	7.00	7.57	7.00
	3	8.20	7.80	7.80	7.40
	Mean	7.21	7.65	7.65	6.70
2	1	7.57	6.42	7.42	5.85
	2	7.42	6.57	6.85	7.00
	3	7.85	7.42	7.14	7.14
	Mean	7.61	6.80	7.14	6.66
4	1	8.00	6.28	5.85	4.57
	2	7.28	6.71	5.57	6.28
	3	8.00	8.00	7.57	7.28
	Mean	7.76	7.00	6.33	6.04
7	1	6.57	6.85	6.71	4.71
	2	6.71	6.14	7.14	6.14
	3	7.85	6.28	6.71	6.42
	Mean	7.04	6.42	6.85	5.76
9	1	7.42	5.85	6.28	4.57
	2	7.83	6.33	7.00	6.16
	3	8.00	5.85	6.00	5.14
	Mean	7.75	6.01	6.43	5.29

[a]1-9 scoring scale, 1 = extremely dry and 9 = very juicy.

[b]Mean of 21 scores.

VITA

Eugenia Malone Zallen was born in Camp Hill, Alabama on July 18, 1932. She received her education in the Camp Hill Public Schools, graduating in 1950. She was graduated from Auburn University in 1953 with a Bachelor of Science degree, majoring in Foods and Nutrition. She completed a dietetic internship at Duke University Medical Center. In 1960, she received a Master of Science degree from Purdue University with a major in Institution Management. She has done graduate study at Auburn University, Iowa State University and Oklahoma State University.

Included in her professional experiences are positions as a dietitian at Duke University Hospital and Emory University Hospital and as a faculty member at Auburn University and the University of Maryland. Professional societies in which she holds membership are the American Dietetic Association (Registered Dietitian), American Home Economics Association, Society for Nutrition Education, Institute of Food Technologists and Food Service Systems Management Education Council. Her honor societies are Alpha Lambda Delta, Omicron Nu, Mortar Board, Phi Kappa Phi and Sigma Delta Epsilon.

She is the wife of Harold Zallen of Oklahoma City, Oklahoma and the daughter of Pauline Kelly Malone and the late Benjamin Floyd Malone of Camp Hill, Alabama.