SOME FACTORS INFLUENCING THE PALATABILITY OF FROZEN BEEF

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INTRODUCTION

Pre-packaged frozen meats are being studied with growing interest as a means of marketing boneless meat cuts in a wasteless, convenient form. Although the success of frozen meats is dependent upon many factors, perhaps the most important is that of consumer acceptance. The average homemaker still harbors suspicion as to quality and wholesomeness of frozen cuts. This fact, together with the relatively high cost of the product has greatly stymied retail sales. Ziemba (1959) found that frozen meat volume is presently about three per cent of our total meat production. The expected gain is three to five per cent by 1960 and eight to fifteen per cent by 1965.

The restaurant and institutional trade was the first group to recognize the potentialities offered by preportioned frozen cuts. This group has found that frozen portion meat offers much in the way of simplifying menu planning, cutting meat preparation cost and reducing waste and shrinkage. Consumer education as to these advantages will help eliminate much of the sales resistance towards pre-packaged frozen meat.

When frozen fruits and vegetables were first introduced to the homemaker through the retail market they were met with "consumer reluctance", similar to that now being encountered by frozen meat. Inconsistent quality at the consumer level due to blanching, odors, and loss of flavor made the homemaker a sceptical buyer. Through a successful research

study, the problem of quality deterioration of frozen fruits and vegetables was largely solved. These frozen products have been accepted by the consumer and are often preferred to the fresh form because of their convenience. Unfortunately, no such research program has yet been conducted with frozen red meat. The successful marketing of frozen meats that are consistent in quality is dependent upon a research program similar to that of frozen fruits and vegetables. There is a definite need for a better understanding of the basic components of meat and the reasons for variation in quality characteristics of the fresh and frozen forms. An investigation involving the reasons for quality reversion of frozen beef would be beneficial to the meat industry as a guide in processing a high quality frozen product.

Because quality is essential to consumer acceptance of frozen meat, the term should be explained. Meat quality may be defined as the total sum of factors, such as color, texture, firmness and marbling, which make the meat acceptable or not acceptable to a given population. The factors usually considered in the evaluation of quality in uncooked beef are; color and amount of lean, youthfulness, firmness, texture and marbling. Cooked beef is evaluated on the basis of its appearance and palatability - including aroma, flavor, tenderness and juiciness. A study of freezing effects must take into consideration each one of these quality factors and how they may be altered by freezing.

The present study is an initial phase of an experiment being conducted at the Oklahoma State Experiment Station Meat Laboratory, designed to evaluate the factors responsible for or contributing to the deterioration in quality of frozen meats. Prior to studying quality reversion due to freezing, it was necessary to develop cooking and sampling techniques

for the critical evaluation of fresh and frozen pair-mate steaks. Preliminary investigations were also conducted on the influence of packaging materials on freezing rates of the experimental cuts. Since the freezing rates and storage life of meat are greatly dependent upon the kind of wrapping material used, a wrap was sought that would not alter the rate of freezing or produce adverse affects such as freezer burn. The final phase of the experiment was designed to investigate quality changes of steak frozen at decreasing temperature levels. Tenderness was evaluated from the taste panel ratings for tenderness, number of chews, and the objective measure of tenderness by the Warner-Bratzler shear. Moisture changes were analyzed from data obtained on cooking losses and taste panel ratings of juiciness. In addition, other measurements such as pH readings and press fluid determinations were recorded for the investigation on quality reversion.

REVIEW OF LITERATURE

A great many factors, both known and unknown, may influence the quality of frozen meats. The studies reported here are concerned with (1) effect of freezing temperatures, (2) wrapping materials and (3) subjective and objective evaluation of frozen meats.

a. Freezing Methods and Effects

1. Muscle Structure

Much of the research in the past 40 years has been with the histological effects of slow and rapid freezing on the structure of a normal muscle fiber. At this point it may be beneficial to consider the structure of a normal fiber of a voluntary muscle and how it is affected by freezing. Observations made by Hiner et al. (1945) concerning the histological characteristics of beef in relation to temperature of freezing, showed the normal fibers to be round or oval in cross section and to vary in length and in diameter. They stated that each fiber is made up of a contractile muscle substance called sarcoplasm which is enclosed by a tight sheath called the sarcolemma. A number of these fibers make up a bundle and a number of these bundles make up a muscle.

Beef muscle is composed of 60 to 75 per cent water, most of which is found in the muscle fiber. When freezing takes place this water tends to crystallize as pure water pushing aside the substances that are dissolved or suspended in it. The pushing or crowding effect of the

water freezing in the muscle is a result of expansion. According to Griffiths et al. (1927) an ice crystal occupies about one-eleventh more space than the water from which it comes. This creates high internal pressure that was measured at 200 pounds to the square inch in beef during freezing.

2. Effect of Temperature and Rate of Freezing

Information was obtained by Hiner et al. (1945) on muscle fiber alterations that took place during slow freezing. Samples from the longissimus dorsi muscle were frozen at 18°F., and compared histologically, with similar samples frozen at 0, -10, -40 and -114°F. The author found that when freezing took place slowly (at 18°F.), large ice crystals were formed between the muscle fibers and drew water to themselves from the meat juices within the fibers. This resulted in the formation of large interfibrillar crystals that pushed the semi-dehydrated muscle fibers into irregular groups. Histological examination showed that the size of the ice crystal between fibers decreased, as freezing temperatures were lowered from 18 to -114°F. They believed the higher drip loss with the slow freezing temperatures was due to moisture freezing largely outside the muscle fibers. Upon thawing, the moisture was not reabsorbed by the fibers and consequently it dripped from the meat.

Evidence of sarcolemma rupture with slow freezing was brought out by Moulton (1929). He stated that in slow freezing, the muscle membrane may suffer a molecular or chemical breakdown and is not capable of re-absorbing the water during thawing. Since slow frozen beef fibers cannot reabsorb the water that is lost through rupture of the sarcolemma, a relatively large portion will drip from the meat when thawed and cooked.

Gerrard (1951) stated that there is a zone of maximum ice formation between 25 and 31°F. In slow freezing when long periods are spent passing through this temperature range, large crystals will form between the muscle fibers, and should the meat be stored within this range, the crystals increase in size.

As the temperature decreases and freezing becomes more rapid, there appears to be less time or opportunity for the transfer of water into spaces between muscle fibers. Hiner et al. (1946) found that during rapid freezing the water is trapped by the fibrils and cannot migrate to localized centers. This results in ice crystals becoming smaller, more numerous, and evenly distributed in the fiber, contrasted to the large crystals formed between the fibers in slow freezing. Further work by Hiner et al. (1947) showed that fiber splitting begins at 0°F. When a temperature of -10°F. was used for freezing beef, more intrafiber ice crystals were seen along with some fiber splitting. There was a further decrease in crystal size with an increase in fiber splitting at -40°F. When a temperature of -114°F. was used, the freezing appeared to be so rapid that the fibers were split longitudinally. The ice crystals appeared almost entirely within the fibers. The fiber splitting effect of rapid freezing was a direct result of expansion of the intrafiber frozen water. This splitting of the fibrils left the meat more tender, which illustrated the direct relationship between rapid freezing and tenderness of beef.

Hankins et al. (1940) concluded that freezing steaks at 20, -10 and -40°F. materially increased their tenderness over that of unfrozen steaks. Also, -10 and -40°F. had a substantially more tenderizing effect than 20°F., but they reported no real difference between the two

lowest temperatures. However, when Hiner and Hankins (1947) ran a similar test using the temperatures of +18, 0, -10, -40 and -114°F., and examined samples of meat under a microscope, they found there was a difference in tenderness among the lower temperatures. Their samples frozen at +18°F. were 9.2 per cent more tender than those not frozen, and the beef frozen at -114°F. was 28.6 per cent more tender than the unfrozen check samples. At temperatures between +18°F. and -114°F., the tenderness increased with decreasing temperature.

Ramsbottom et al. (1949) found that the rate of freezing affected the color of beef. Steaks frozen slowly at 20°F. were much darker than the corresponding fresh steaks. Those frozen at -110°F. were much lighter, whereas those frozen at -21°F. were similar in color to the fresh steaks. The difference in color was attributed to differences in size of the ice crystal. The meat frozen rapidly and with the smallest ice crystal appeared lighter.

Most of the research on the effects of freezing has been done with one or two inch steaks. To determine the freezing effects on large samples, Hiner et al. (1947) experimented with beef rounds (shank and rump off) ranging in weight from 40 to 45 pounds. Three thermometers were used to determine the freezing rates in each round. Temperatures of freezing were +18, 0, -15, -40 and -114°F. in still air.

Results of the study indicated that it required approximately 126 hours to freeze a beef round to the center at +18°F., 48 hours at 0°F. and less than 19 hours at -114°F. Tissue within the first 25 mm. from the surface of the beef rounds, frozen at the above mentioned temperatures, showed the same general histological picture as that of the small thin samples. However, at succeeding 25 mm. intervals toward the

center of the round, the ice areas and intrafiber crystals became progressively smaller at all temperatures.

Beef rounds frozen at +18, 0 and -114°F. were more tender than their unfrozen pair-mates. The least tenderizing effect was at +18° and the greatest at -114°F. At none of the temperatures studied were any important differences in tenderness found between samples taken at different distances from the surface. This was true despite the differences in histological structure.

Ramsbottom et al. (1939) made a study to determine the effect of freezing temperature on the amount of drip that exudes from the frozen product upon defrosting. In addition, studies were made on the pH of the meat and on the micro-structure of the frozen and defrosted beef. The authors divided the research into two parts. The first involved paired wholesale beef ribs that were frozen in still air on wood shelves at temperatures of 10, -10, -30 and -50°F. One week after freezing they were thawed on trays in closed tin containers at a temperature of 50°F. The drip was collected during a three day period. The second experiment included the use of steaks one inch in thickness and weighing approximately one-half pound. The steaks were cut from boneless rib rolls. They were frozen on hardwood trays at temperatures of 20, -10 and -50°F. One week later the steaks were weighed, suspended in closed tin containers, and thawed at a temperature of 50°F. One and one-half days were allowed for drip collection.

It was observed that differences in drip between right and left ribs frozen at different temperatures were small and non-significant. The statistical analysis showed the percentage drip from steaks frozen at various temperatures to differ. The experiment

showed that irrespective of freezing temperature, there was little drip in the large rib cuts where the area of cut surface was small in relation to the volume of meat. In the small steaks, where the area of cut surface was large in relation to volume of meat, the amount of drip was dependent to a larger extent on the freezing temperature. In large cuts the muscle tissue had the opportunity to reabsorb the "frozen out" water, while in small cuts the fluids were readily lost by the tissue as drip. The author explained that when small steaks were rapidly frozen, intrafiber freezing occurred and when defrosted, the fluids were retained for the most part by the fiber and the drip was relatively small. If the steaks were slowly frozen, extrafiber freezing took place and upon being defrosted, more of the fluid was lost as drip before it could be reabsorbed by the partially dehydrated muscle fibers.

They found the differences in drip of the steaks and wholesale ribs were not attributed to pH, since the pH values for all samples were very similar. Photomicrographs showed that the temperature of freezing materially affected the structural appearance of the frozen muscle tissue.

Hankins et al. (1951) studied the effects of freezing samples of beef that varied widely in tenderness. Nine different muscles from cattle that varied in age from ten week-old veal calves to twelve year old cows, were used for the experiment. The samples were cut in pairs, one being tested fresh, with 14 days aging, and the pair mate frozen after aging. After the steaks were frozen at 0°F., they were removed and thawed for 24 hours at a temperature of 45°F. The steaks were then heated to 140°F. and evaluated for tenderness by the Warner-Bratzler shear. The tenderness values were tested for significance of difference between means, using the "t" test for each group.

It was found that freezing had less tenderizing effect in general, on the neck and foreshank, than on the more tender samples of the loin, rib and chuck. The test between different age groups showed that freezing had a much more tenderizing effect on the samples from 900 pound steers than those from veal calves. In most cases the muscles of the veal calves were not significantly tenderized by freezing. Their analysis of variance showed that tenderizing due to freezing was highly significant between age groups but not between samples from the same age group.

Ramsbottom (1947) made a study of the freezer storage effect on fresh meat. The experiment compared the relationship of meat quality with the time and temperature of freezer storage. Beef, pork and lamb were used with observations made on appearance and palatability after seven years storage of beef steaks, and ten years storage at 0°F. of lamb legs and shoulders. Appearance and palatability scores decreased with the increase in storage temperature and time. Meat stored at 26°F. had a storage life of 30 days while those stored at -10 and -20°F. were still rated good after 365 days. It was found the tenderness was not significantly changed from the storage of beef steaks at -10°F. for seven years. However, lamb stored for ten years at 0°F. was dehydrated and showed freezer burn and in addition the fat had developed a rancid flavor.

McCoy et al. (1949) studied the effects of aging before freezing on the palatability, using 24 matched sides of U.S. Good grade beef. The methods of aging and freezing were varied. The results showed no significant difference between method of freezing or method of aging. Aged beef, regardless of method of aging, deteriorated more rapidly than unaged beef in frozen storage. There was also some indication that frozen

beef became less tender during storage.

b. Wrapping Material

Research in freezing rates and storage life of meats brought out the importance of the correct selection of wrapping material. Gunadagni et al. (1957) while working on Time-Temperature Tolerance studies of frozen strawberries, found the type of packaging material to be the most important single factor affecting the storage life of frozen strawberries held at a temperature of 0°F.

Dunker et al. (1953) experimented with wrapping materials and methods of freezing to determine their effects on freezing rates of beef and pork. Freezing methods used were blast, plate and still air. Wrapping materials used were butcher paper, cellophane, aluminum foil, white parchment, cry-o-wrap and polyethylene. These wraps were used on 6 x 6 x 6 and 6 x 6 x 3 inch samples of pork and beef. Their freezing rates were compared with a sample that had no wrapper. The authors found freezing rates to vary proportionally with the insulating properties of the wrapping materials. Meat wrapped in butcher paper required a 34 per cent longer freezing period than samples without wrapping. Cellophane wrapped meat took 41 per cent more time while aluminum foil and parchment paper took 72 per cent, cry-o-wrap 76 per cent and polyethylene 103 per cent. Samples frozen at -68°F. had smaller moisture losses than those frozen at ⁄5°F. They assumed this to be due to the low moisture carrying capacity of the air at -68°F., and because of the outer layer of the meat forming an ice glaze around the sample within a few minutes, preventing further weight losses at very low temperatures. The work of Dunker and co-workers agreed with other studies showing that

freezing and thawing rates of meat are affected by the type of wrapping material; composition, size and shape of sample; ambient temperature; and methods of freezing.

An interesting study was made by Ramsbottom et al. (1949) on factors affecting the freezing rates of meats. Information was obtained on freezing rates as affected by air velocity, packaging materials and composition of the meat. The air velocities tested were less than 40 fpm., 500 fpm., and 1500 fpm. Ground beef, containing 25 per cent fat, was tested in (1) cellophane, (2) cellophane and packed in cartons, and (3) samples without wrapping. The freezing temperature used was -16°F. It was found that increasing the air velocity to 500 fpm. increased the freezing rate of bare and packaged items. They found the increased rate of freezing due to increased air velocity, was less pronounced on packaged items than on bare items. Freezing time, judged on time required for the temperature to pass through the zone of maximum ice formation (31 to 25°F.), was increased as much as 500 per cent due to the insulating value of the packaging.

The authors found that beef, lamb, pork and veal freeze at similar rates when allowances were made for differences in the fat and moisture content. This work agreed with that of Dunker and co-workers in that meats containing a high per cent of fatty tissue will freeze more rapidly than meats containing very little fat.

c. Cookery and Organoleptic Evaluation

1. Methods of Cookery

Paul et al. (1956) studied the effects of cold storage and method of cooking on the muscles from the rounds of six commercial grade cows.

Steaks from the rounds were cooked by the dry and moist heat methods. The carcasses were first held seven days at 32 to 34°F., and then cut into steaks and stored for additional periods of time up to two weeks. As a method of cooking commercial grade beef dry heat was superior to moist heat. They used a gas oven for the dry heat method and cooked all of the steaks to an internal temperature of 160°F. It was suggested that selection of different end points in cooking may also have an effect on palatability. The additional storage beyond seven days did not improve the palatability of the steaks.

The effects of slow and quick freezing on the quality of broiled steaks was the object of an experiment by Brady et al. (1942). The experimental steaks came from U.S. Commercial beef rounds, U.S. Good lamb legs and "U.S. Choice" pork hams. The quick freezing temperature was -15°F., and the slow freezing temperature was 0°F. The method of cooking was to broil the steaks to an internal temperature of 158°F. They found that cooking loss due to evaporation and drip ran considerably higher on the slow frozen steaks than on the quick frozen steaks. Differences in palatability scores were not significant between quick and slow frozen steaks.

Work by Cover (1943) brought out the importance of using low rates of heat penetration in the cooking of beef to make it more tender. Paired standing-rib and arm-bone chuck roasts were cooked well-done and bottom-round roasts were cooked both rare and well-done. An oven temperature of 176°F. was used for slow heat penetration and an oven temperature of 255°F. was used as a normal standard for comparison. The results of this test showed the roasts to be more tender when the rate of heat penetration was slow enough so that it required 30 hours or more for them to lose their pink color. With more rapid heat penetration, the

roasts were not always tender.

Cover listed two factors to affect the toughness of meat, muscle fiber and connective tissue, which her test showed could be made "very tender" by very slow heat penetration while cooking. She explained that chemical factors affecting the breakdown of connective tissue was the changing of collagen into gelatin by heat. The reason for muscle fiber tenderization was not explained.

Observations were made by Paul et al. (1955) as to the action of freezing on tenderness as compared to cold storage. Steaks tested were from the longissimus dorsi muscle of eight animals (U.S. Good, Prime, Commercial). Items studied were; cooking time, cooking losses, and shear force values of steak fried in deep fat. Storage conditions included holding the muscle for different periods of time at either cold storage (41 to 44°F.) or freezing them at -18°F.

Frozen steaks required slightly longer cooking times and had higher cooking losses than unfrozen ones. There was a high correlation (0.76, $P < .01$) between cooking losses and time of cooking, indicating cooking losses were closely related to the time required for cooking. Also, it was found that frozen steaks cooked without thawing were less tender than those thawed before cooking. They concluded that cold storage or freezing of the steaks after three days aging in the carcass, increased the tenderness.

2. Objective Evaluation of Tenderness

The Warner-Bratzler shear is probably the most widely used apparatus to objectively measure the the tenderness of meat. Comparison of shear values to judging panel scores have been correlated. Deatherage et al. (1952) made the comparison of sensory panel and Warner-Bratzler shear

force measurements on broiled steaks. An insignificant correlation coefficient of 0.173 was obtained in the relationship of increase in tenderness as determined by the organoleptic panel to the decrease in shear strength as determined by the machine. They summarized that although shear strengths appear to measure fairly satisfactorily a property of meat, these values are not closely related to tenderness of broiled steaks as determined by a competent sensory panel.

Ramsbottom et al., (1945) obtained significant results comparing sensory panel and shear readings on tenderness. Twenty-five representative muscles from three U.S. Good beef carcasses were used in their experiment. The shear values from the cooked muscle were compared with the shear value of the raw muscle, organoleptic rating, and histological rating. Significant correlation coefficients of 0.6 for raw muscle, 0.9 for organoleptic rating and 0.7 for histological ratings were obtained. They found that tenderness varied from muscle to muscle and in few instances there was variation in tenderness within the muscle. Results showed most of the 25 muscles used in their study decreased in tenderness on cooking.

EXPERIMENTAL PROCEDURES

This experiment was divided into three major phases. The procedures for the study are given in the following order: (1) cookery and organoleptic evaluation, (2) effect of wrapping materials on the rate of freezing and (3) the effect of decreasing freezer temperatures.

I. Materials

Experimental cuts used throughout this study were taken from the longissimus dorsi muscle of the beef short loin. The bone and excess fat were removed, leaving the steaks uniform in size and fat covering. The thickness and number of cuts used depended upon the objective of each phase of this experiment.

Six pair of U.S. Good beef short loins were used to develop procedures and techniques for organoleptic and objective evaluation of frozen steaks. These short loins were obtained from 16 month old Hereford steers of similar breeding and management. Each short loin was divided into five two inch thick steaks, giving a total of sixty steaks for cookery and organoleptic evaluation test.

Two inch thick boneless strip steaks were also utilized in studying the effect of wrapping materials on freezing rates. These particular steaks were taken from the short loin of a medium weight Hereford steer carcass that graded U.S. Good. Particular care was exercised in order to obtain experimental cuts of uniform size and weight.

Three pairs of short loins were used in the final phase of the experiment involving the effects of decreasing freezer temperatures on tenderness. Slightly larger U.S. Choice loins were obtained for the experiment. Because of the number of steaks required from each short loin, it was not possible to use two inch thick cuts. Therefore, each short loin was divided into 12 steaks of one-inch thickness. This gave a total of 72 steaks to be used in the evaluating quality changes as freezing temperatures decreased.

II. Methods

a. Cookery and Organoleptic Evaluation

Preliminary cooking tests were conducted to develop standard procedures for the organoleptic and objective evaluation of the frozen steaks. Different turning temperatures (60, 70, 80, 90 and 100°F.), as well as various final temperatures (150, 155 and 160°F.), were evaluated. The experimental design for allocating the sixty steaks to methods of cookery is shown in Table I.

Before organoleptic evaluation, the steaks were frozen in an air blast freezer and stored at 0°F. The frozen steaks were thawed at a room temperature of 38 to 40°F. for 24 hours to provide a uniform temperature (32°F.), prior to cooking.

An open face, gas, griddle-broiler was used for cooking the steaks. Before using, the broiler was preheated for 30 minutes to a temperature of 350°F. The steaks were placed in the broiler so that their top surface was approximately four inches from the flame. While cooking, the internal temperature of each steak was recorded by the use of thermocouple leads from a recording micromax (Plate II). Precautions were taken

to locate the tip of the thermocouple in the exact center of each steak so that the true internal temperature would be recorded.

TABLE I

EXPERIMENTAL DESIGN FOR BROILING LOIN STRIP STEAKS

End Temperature[1]	Turning Temperature[2]	Number of Steaks
160°F.	60°F.	4
160	70[3]	4
160	80	4
160	90	4
160	100	4
155	60	4
155	70[3]	4
155	80	4
155	90	4
155	100	4
150	60	4
150	70[3]	4
150	80	4
150	90	4
150	100	4

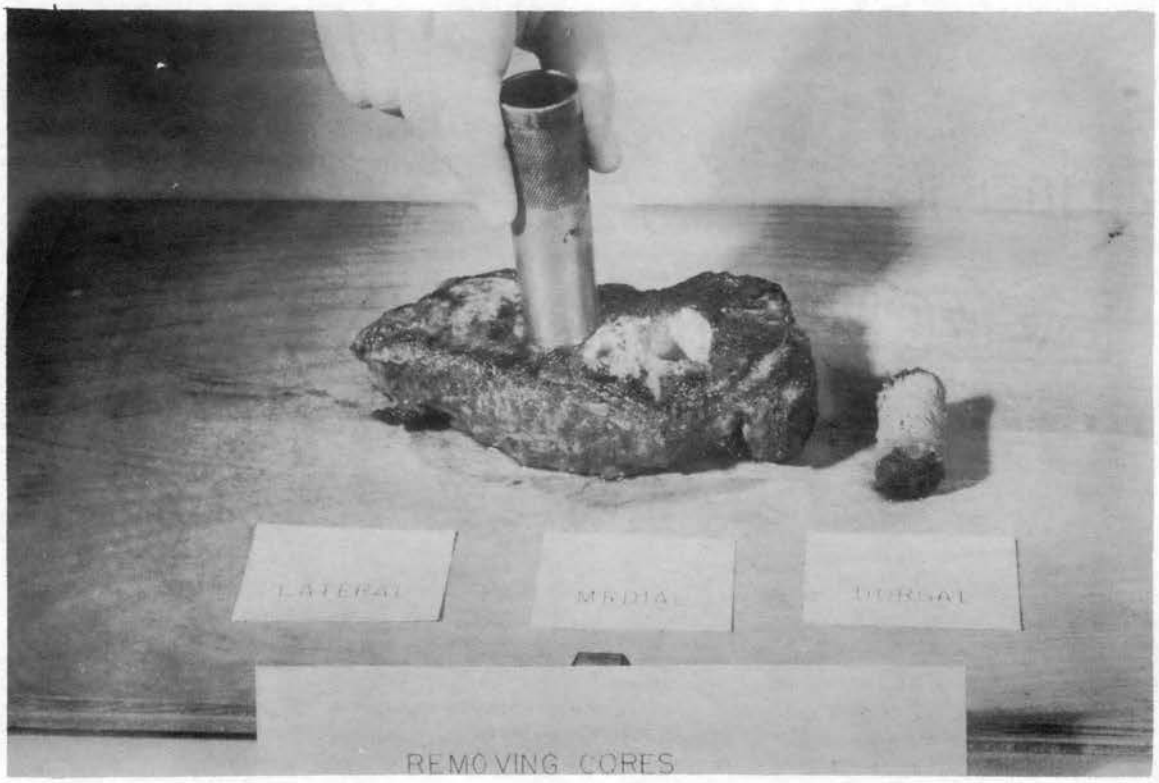
[1]Internal temperature of steak at the time it was removed from the broiler. Temperature taken with a thermocouple inserted into the center of each steak.

[2]Internal temperature at the time the steak was turned.

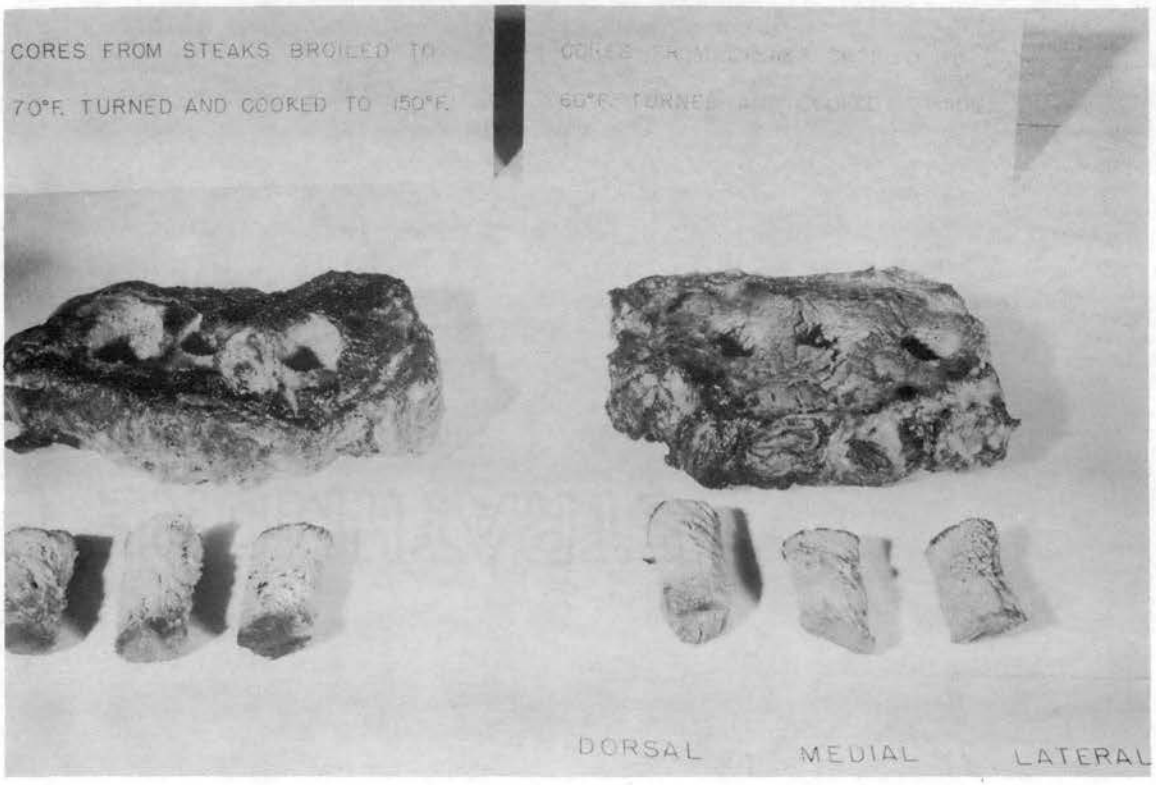
[3]Unfrozen controls - cooked to 70°F. then turned and taken to temperature indicated.

After broiling, three one-inch cores (dorsal, medial and lateral) were removed from each steak and sheared with the Warner-Bratzler shear (Plate I). Two values were obtained from each core giving a total of six readings per steak. These values were recorded to the nearest one-fourth of a pound, averaged, and recorded as the pounds of shear force. These shear values were used as an objective measure of tenderness and were subsequently compared to taste panel scores for tenderness.

PLATE I



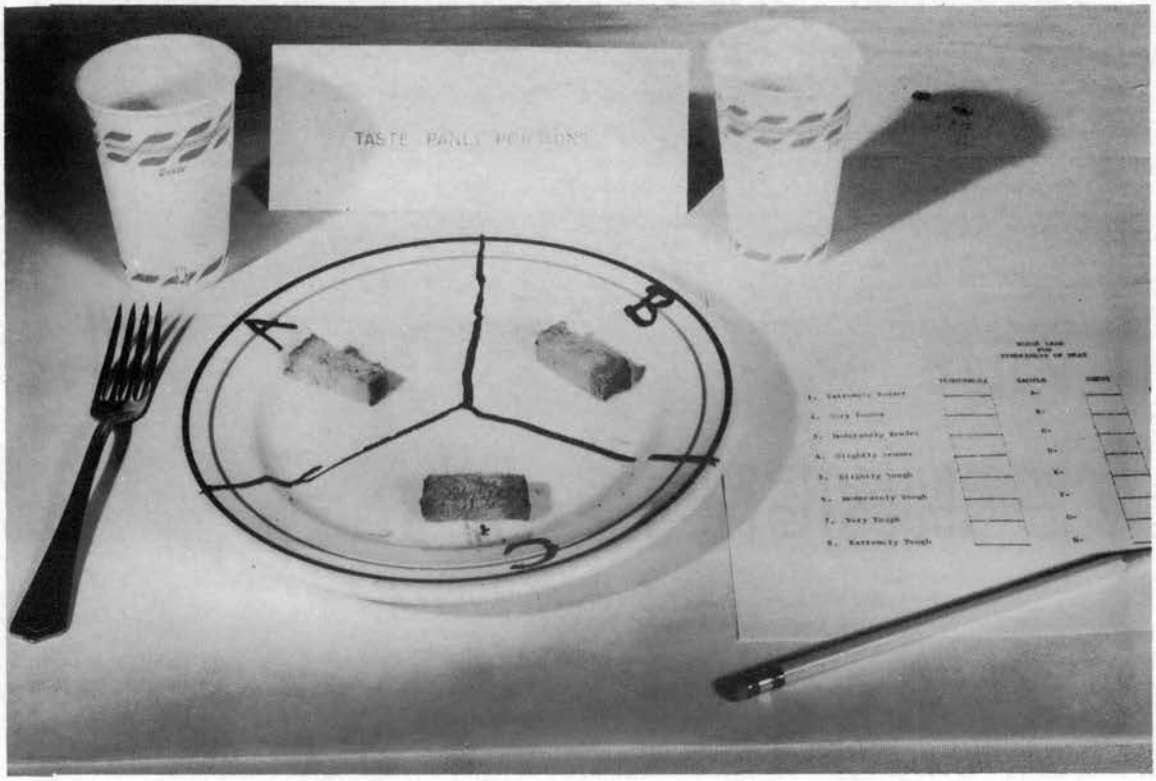
1 - Removing shear cores



2 - Broiled steaks with cores removed

PLATE II

1 - Broiling steaks with thermocouple inserted



2 - Taste panel portions

The remaining portion of the steaks used for shear testing were further sub-divided for organoleptic evaluation. A one-half inch core was used to remove taste panel portions, thus providing each member with a uniform sample (Plate II). Four steaks were tested at each panel sitting. The taste panel consisted of six judges.

The panel evaluated each sample for tenderness, flavor, juiciness and number of chews. A nine point hedonic scale was used to score tenderness, flavor and juiciness. The number of chews was based on the total number required by each judge before the sample was ready to swallow. However, the judges were not permitted to swallow the portion served. The panel members were given bread and water between portions to remove the taste of the previous sample.

b. Wrapping Materials

Two types of wrapping materials were tested to determine their rate of heat conductivity. Duplicate freezing trials were conducted with steaks packaged as follows:

Steak No. 1 - - - - - No packaging.

Steak No. 2 - - - - - Aluminum foil.

Steak No. 3 - - - - - Tite (Kraft paper laminated with polyethylene)

Steak No. 4 - - - - - Aluminum foil overwrapped with Tite.

These steaks were frozen in a Webber Low Temperature Industrial Freezer, which had been previously regulated to -100°F. (air temperature). This unit has an eight cubic foot capacity and is designed to remove 1200 B.T.U.'s per hour from the product load at -100°F. The freezer has an adjustable temperature dial that can be regulated for a temperature range of +75 to -130°F. The air flow varies, but is generally

less than 170 feet per minute. The Webber freezer is equipped with a port hole that permits the insertion of thermocouples into the box for recording purposes. This enabled the internal freezing rates of each steak to be recorded every two and one-half minutes by the recording micromax.

In addition to testing wrapping materials, data were also collected on the influence of freezing with or without surface contact. The first group of steaks was frozen with surface contact. This was accomplished by placing the steaks on the stainless steel floor of the freezer. To test the effects of freezing without surface contact, the steaks were placed on the top of a thin wire basket inside the freezer.

c. Effect of Decreasing Freezer Temperatures

The final phase of the experiment was designed to investigate the effects of freezing on steaks frozen at the following box temperatures: 0, -25, -50, -75, -100 and -125°F. The allocation of the short loins was designed so for each steak frozen, there would be a fresh pair-mate steak for comparison. Table II gives the division of each pair of short loins. The experimental design for the 72 steaks comprising this test is shown in Table III.

The short loins were aged 72 hours after slaughter and then divided into one-inch thick steaks (Table II). The pH readings were taken on all steaks before initial packaging. The fresh pair-mate steaks were packaged and placed in the chill room (38 to 40°F.) for 24 hours before evaluation.

TABLE II

DIVISION OF A PAIR OF SHORT LOINS

Left Anterior		Right Anterior	
Steak No. 1	Non-frozen control	Steak No. 1	Frozen to -125°F.
2	Frozen to 0°F.	2	Non-frozen control
3	Non-frozen control	3	Frozen to -100°F.
4	Frozen to -25°F.	4	Non-frozen control
5	Non-frozen control	5	Frozen to -75°F.
6	Frozen to -50°F.	6	Non-frozen control
7	Non-frozen control	7	Frozen to -50°F.
8	Frozen to -75°F.	8	Non-frozen control
9	Non-frozen control	9	Frozen to -25°F.
10	Frozen to -100°F.	10	Non-frozen control
11	Non-frozen control	11	Frozen to 0°F.
12	Frozen to -125°F.	12	Non-frozen control
Left Posterior		Right Posterior	

TABLE III

EXPERIMENTAL DESIGN FOR FREEZING

Freezing Temperatures	0°	-25°	-50°	-75°	-100°	-125°F.
No. of Steaks for Freezing	6	6	6	6	6	6
No. of Fresh Pair-Mate Steaks	6	6	6	6	6	6

Prior to packaging the steaks allocated for freezing, moisture content was evaluated by press fluid determinations. The press values obtained from the steaks before freezing were compared with the determinations made after the steak had been frozen and thawed. A total of four, 400 mg., samples were removed from each steak for press fluid test. These samples were removed from the dorsal and anterior sections of the steak. After each press sample was removed and weighed, it was placed in the center of a 12 cm., No. 1, Whatman filter paper. This paper had been brought to a constant moisture content by holding it in a desiccator over potassium chloride solution. The filter paper and sample were then placed between two 6 x 6 x $\frac{1}{4}$ inch Plexiglas plates and pressed at a constant pressure of 500 pounds per square inch, for a period of one minute. The Carver Laboratory Press was used for all determinations. After the filter paper with the pressed meat was removed, the inside ring (meat film area) was traced with a soft leaded pencil. The outer ring (free moisture area) was clearly visible and tracing was not necessary. To avoid evaporation of the 400 mg. sample, certain precautions were used. Each sample was removed from the steak, weighed and pressed in a period of less than five minutes at a room temperature of 40°F. The final area measurements of the two rings were made with a compensating polar planimeter. Values were recorded on total moisture, meat film area and moisture area (total area - meat film area).

From each pair of short loins, two steaks were frozen at each of these temperatures: 0, -25, -50, -75, -100 and -125°F., respectively (Table III). While freezing, the internal temperature of one of these steaks was recorded by means of a thermocouple lead and the second steak was equipped with a dial thermometer. After freezing and thawing,

press fluid samples were removed and then the steaks were ready for objective and organoleptic evaluation.

Taste panel information was obtained as described above, except that an eight point hedonic scale was substituted for the nine point scale and flavor was not evaluated (Figure 1). Finally, the use of one inch thick steaks precluded the obtaining of more than one shear value per core, reducing the number of shear values to three per steak. As before, these were averaged and used as objective tenderness evaluations.

SCORE CARD
FOR
QUALITY FACTORS

	TENDERNESS		JUICINESS	SAMPLE	CHEWS
8. Extremely Tender		Extremely Juicy		A-	
7. Very Tender		Very Juicy		B-	
6. Moderately Tender		Moderately Juicy		C-	
5. Slightly Tender		Slightly Juicy		D-	
4. Slightly Tough		Slightly Dry		E-	
3. Moderately Tough		Moderately Dry		F-	
2. Very Tough		Very Dry		G-	
1. Extremely Tough		Extremely Dry		H-	

Figure 1
Taste Panel Score Card

RESULTS AND DISCUSSION

I. Cookery and Organoleptic Results

The object of this phase of the study was to develop standard cooking and organoleptic techniques that would help to control, or minimize, variances in palatability due to thawing and cooking. The careful selection of a method of cookery permitted critical taste panel evaluation of the differences in steak quality due to freezing alone.

The results pointed out that turning and end broiling temperatures had a definite influence on the steak's palatability ratings. The effect of various turning and end temperatures on shear values, taste panel data and cooking losses are given in Table IV. The effect of end (final) temperature on shear values, number of chews and cooking losses was highly significant. Turning temperatures had a significant influence only on the number of chews required. However, neither end temperature nor turning temperature had a statistically significant influence on taste panel ratings for flavor, juiciness or tenderness.

The average ratings for the six pairs of short loins used for the cookery test are given in Table V and VI. A comparison of final temperatures indicates that steaks cooked to a temperature of 150°F. gave a lower shear value than steaks cooked to either 155 or 160°F. However, no consistent differences were noticed in other palatability factors with respect to end temperatures. The mean values for shear force, cooking losses and organoleptic scores for the turning temperature of 60°F.

TABLE IV

ANALYSIS OF VARIANCE OF QUALITY FACTORS AS INFLUENCED BY BROILING PROCEDURES

Variation	d/f	Mean Square					
		Shear Value	No. of Chews	Cooking Loss	Juiciness	Flavor	Tenderness
Total	59						
Replications	3	1.87	4.06	44.12*	0.33	0.34	0.017
End Temperatures	2	37.51**	253.91**	112.99**	0.05	0.39	0.760
Turning Temperature	4	2.41	75.70**	22.60	0.21	0.30	0.235
Replications x End Temp.	6	6.34*	15.55**	11.13	0.26	0.06	0.700*
Replications x Turning Temp.	12	3.31*	3.81	11.25	0.21	0.09	0.183
End Temp. x Turning Temp.	8	2.68	38.02**	31.35*	0.45	0.16	0.491
Error	24	1.22	2.55	10.47	0.24	0.13	0.266

* $P < 0.05$

** $P < 0.01$

TABLE IV-a

AVERAGE RATINGS OF FOUR STEAKS BROILED AT EACH OF THE DIFFERENT TURNING AND END TEMPERATURES

Treatment		Average Ratings					
Turning Temp.[1]	End Temp.[2]	Shear Value[3]	No. of Chews[4]	Cooking Loss[5]	Juici-ness[6]	Flavor[6]	Tender-ness[6]
60 F.	160 F.	12.3	20.9	25.0	7.7	7.8	8.0
70	160	13.9	26.9	25.9	6.6	6.9	7.1
80	160	14.1	21.1	24.2	7.3	7.2	7.4
90	160	14.7	23.2	33.6	6.8	7.3	7.8
100	160	13.7	25.3	30.2	7.1	7.1	7.2
60	155	11.2	28.1	22.8	7.4	6.9	7.1
70	155	13.4	29.8	22.4	7.4	7.0	7.2
80	155	11.7	29.6	27.1	6.8	7.1	6.9
90	155	10.8	32.2	22.0	7.2	7.3	6.8
100	155	12.0	30.2	25.9	7.1	7.3	7.7
60	150	11.5	21.6	28.2	6.9	7.7	7.5
70	150	11.4	33.5	28.6	7.1	7.1	7.2
80	150	10.6	23.1	28.2	7.3	7.4	7.6
90	150	10.7	20.5	27.9	7.1	7.5	7.6
100	150	11.1	21.6	29.3	7.0	7.3	7.4

[1]Internal temperature of the steak at time of initial turning.

[2]Internal temperature of the steak at time of removal from the broiler.

[3]Figures represent an average of the shear force (pounds) for each treatment.

[4]Represents average of six panel members.

[5]Based on weight of steak immediately before and after broiling (% loss).

[6]Average taste panel score based on a nine point hedonic scale. (nine being the highest rating and one the lowest).

were rated higher than those turned at 70, 80, 90, and 100°F. The only statistically significant factor for turning temperature, however, was the number of chews required (Table IV).

These data indicate that the most critical organoleptic and objective evaluations were obtained from steaks broiled to an internal temperature of 60°F., turned, and removed at an internal temperature of 150°F. Since the steaks cooked at the lower temperature were scored higher, this method was adopted for subsequent evaluation of all experimental steaks.

TABLE V

AVERAGE VALUES FOR VARIOUS QUALITY FACTORS AT DIFFERENT BROILING END TEMPERATURES

End Temperatures	160°	155°	150°F.
Shear Values (Pounds)[1]	13.72	11.81	11.07
Number of Chews[2]	23.49	29.91	24.01
Cooking Loss (Per Cent)[3]	27.76	24.04	28.46
Juiciness[4]	7.08	7.16	7.07
Flavor	7.26	7.12	7.38
Tenderness	7.42	7.12	7.43

[1]Six shears for each steak. Figures represent an average of the shear force (pounds) for each treatment.

[2]Represents average of six panel members.

[3]Based on steak weights immediately before and after broiling (per cent loss).

[4]Average taste panel score using a nine point hedonic scale. (nine being the highest and one being the lowest rating).

TABLE VI

AVERAGE VALUES FOR VARIOUS QUALITY FACTORS AT DIFFERENT TURNING TEMPERATURES DURING BROILING

Turning Temperatures	60°	70°	80°	90°	100°F.
Shear Value (Pounds)[1]	11.66	12.90	12.11	12.08	12.27
Number of Chews[2]	23.49	30.50	24.58	25.27	25.65
Cooking Loss (Per Cent)[3]	25.32	25.63	26.52	27.85	28.47
Juiciness[4]	7.34	7.01	7.08	7.05	7.07
Flavor	7.44	7.03	7.22	7.36	7.23
Tenderness	7.51	7.13	7.30	7.36	7.41

[1]Six shears for each steak. Figures represent an average of the shear force (pounds) for each treatment.

[2]Represents average of six panel members.

[3]Based on steak weights immediately before and after broiling (per cent loss).

[4]Average taste panel score using a nine point hedonic scale.

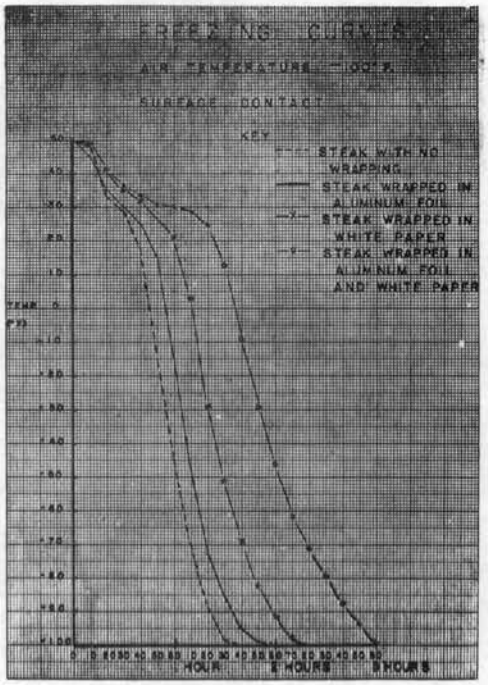
II. Factors Influencing Freezing Rates

Rate of freezing was found to be affected by type of packaging material, location of the package within the freezer and freezing temperature used. Other factors known to affect the time of freezing such as meat composition, size of cut, etc., were considered in this study.

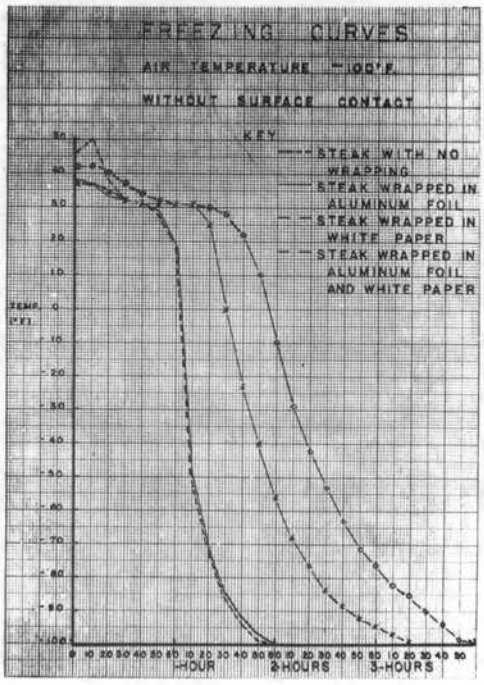
a. Effect of Wrapping Material and Package Location on Freezing Rates

Plate III presents freezing curves of the various wrapping materials. Surface contact was employed in #1, while #2 illustrates the effect of freezing without surface contact. The non-packaged steak in #2 showed a slight increase in internal temperature when it was initially

PLATE III



1 - Freezing with surface contact



2 - Freezing without surface contact

placed in the freezer. Reasons for this rise in temperature remain obscure, but it may have been due to the sudden temperature change causing the steak's initial heat to be trapped internally by the rapid freezing of the surface area of the steak.

Regardless of location within the freezer, steaks packaged in aluminum foil were frozen at a much faster rate than those packaged in either Tite or the double wrap materials. The double wrap increased freezing time over that of aluminum foil as much as 205 per cent.

The location of the package within the freezer was also found to be important in the time required for freezing. The freezing curves indicate that surface contact had about as much influence on the rate of freezing as did the type of packaging material. The comparison of the two curves point out that the time required for all samples to attain -100°F., was significantly shorter when surface contact was employed.

Table VII gives the average freezing rates of steaks packaged in aluminum foil, Tite and double wrap. This table presents a comparison of time (minutes) required for the experimental steaks to reach the internal temperatures of 31, 25, -90 and -100°F.

The data presented in Table VII indicate that the time necessary to pass through the zone of maximum ice formation (31 to 25°F.) was considerably shorter for all samples frozen with surface contact. The length of time required to reach 25°F. was increased considerably when the steaks were double wrapped. The time required for steaks wrapped in aluminum foil to pass through the ice formation zone was significantly shorter than the other materials tested.

TABLE VII

FREEZING TIME REQUIRED BY STEAKS WHEN FROZEN WITH AND WITHOUT SURFACE CONTACT[1]

Internal Temperature	Freezing Technique	Wrapping Materials: No Wrapping	Aluminum Foil	Tite	Aluminum Foil / Tite
31°F.	Surface Contact[2]	24[4]	28	42	50
31	Air Contact[3]	38	40	40	60
25	Surface Contact	34	40	52	80
25	Air Contact	52	54	80	94
-90	Surface Contact	80	94	118	162
-90	Air Contact	95	98	164	210
-100	Surface Contact	97	115	136	180
-100	Air Contact	115	120	200	236

[1]Two inch thick steaks from the longissimus dorsi muscle.

[2]One side of meat in contact with the metal, the opposite side exposed to air.

[3]Both sides of the steak exposed to air.

[4]Time in minutes required for the steaks to reach the listed temperature.

The freezing curves show that steaks packaged in aluminum foil and frozen with surface contact had similar freezing rates to samples frozen without wrapping. The steaks wrapped in aluminum foil and frozen at -100°F., showed no adverse affects such as freezer burn. The color of the meat and its general appearance was not altered by rapid freezing. In fact, freezing at this temperature tended to give the steaks a brighter color. Excessive freezer burn was evident only in those steaks frozen without packaging.

b. Effect of Decreasing Temperatures on Freezing Rates

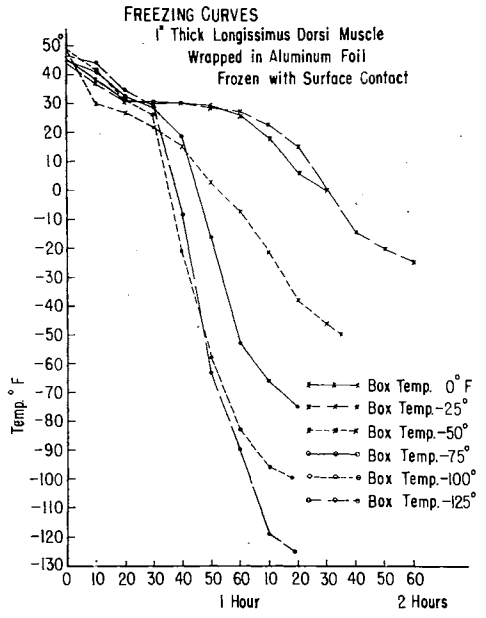
Decreasing freezer temperatures significantly altered the freezing rates of the experimental steaks. The freezing curves of steaks frozen at 0, -25, -50, -75, -100 and -125°F. are shown in Plate IV. A freezing curve was plotted for each pair of short loins used in this phase of the study (#1, 2 and 3). The three figures present similar freezing patterns with the exception of the rate at which steaks passed through the zone of maximum ice formation. In #2, the effect of each freezing temperature is very clearly indicated, whereas in # 1 and 3, the graphical trends are not so clearly demonstrated. Reasons for this variation, although not precisely determined, may be due to a slight fluctuation of box temperature or error in insertion of the thermocouple.

Table VIII gives the average freezing rates from the three figures in Plate IV. In this table, the time required for the steaks frozen at each of the various temperature levels to pass through the zone of maximum ice formation (31 to 25°F.) was recorded.

From the data in Table VIII it is evident that freezer temperature had little effect on time required for steaks to reach 31°F. Differences in time varied only 13 minutes between freezing temperatures of 0° and -125°F. Below 31°F., however, the rate of freezing process appears to be a function of the air temperature in the freezer. Time required for samples to pass through the zone of ice formation varied from 61 minutes for those frozen at 0°F. to four minutes for those frozen at -125°F.

PLATE IV

FREEZING CURVES FOR STEAKS FROZEN AT DECREASING TEMPERATURES



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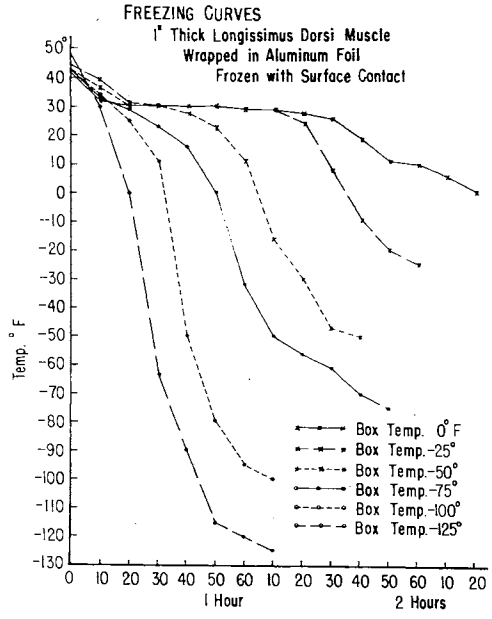

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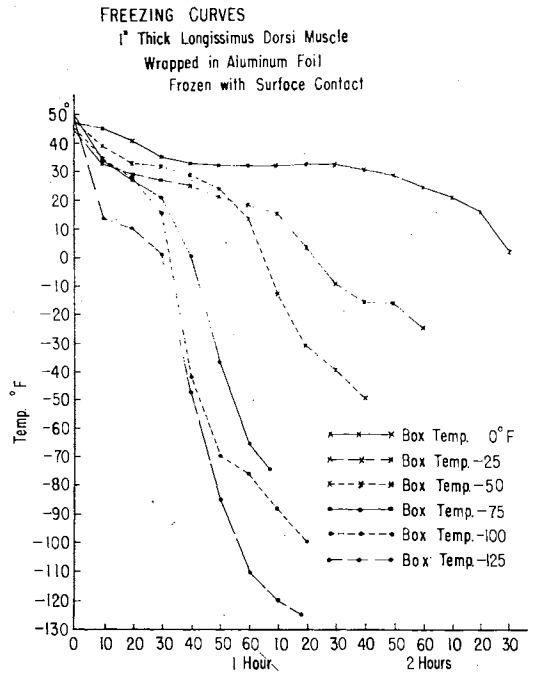

3

TABLE VIII

PERIOD OF FREEZING AS AFFECTED BY DECREASING TEMPERATURES

Initial Meat Temperature (45°F.) to - -	31°	25°F.
Air Temperature of Freezer - - - 0°F.	27*	88
-25	25	63
-50	24	43
-75	16	30
-100	17	25
-125	14	18

*Time in minutes required for the one-inch thick steaks to reach the above internal temperatures.

III. Influence of Freezing on Palatability Factors

a. Effect of Freezing on Tenderness

Tenderness was evaluated from shear values, taste panel ratings and number of chews. By comparing data obtained from frozen steaks with their fresh pair-mates, the extent to which tenderness was altered by decreasing freezer temperature was ascessed.

There was a significant difference in the tenderness of fresh and frozen steaks. In Tables IX and X, the average shear values of the dorsal, medial and lateral cores of the experimental steaks are given. It was noted that the frozen steaks were more uniform in tenderness from dorsal to lateral regions in comparison to their fresh pair-mates. The frozen cores (Table IX) ranged from 12.47 to 15.44 pounds shear force, between dorsal and lateral cores, while their fresh pair-mates (Table X) ranged from 12.91 to 17.56 pounds. Shear values obtained from the dorsal

cores showed much less variation than did those taken from the medial or lateral cores.

TABLE IX

SHEAR VALUES IN POUNDS FOR FROZEN STEAKS FROM SIX SHORT LOINS

Freezing Temperature	Dorsal Core	Medial Core	Lateral Core	Total	Average
0°F.	14.13	13.63	15.22	42.98	14.32
-25	12.14	12.93	16.40	41.47	13.82
-50	13.13	13.12	16.15	42.40	14.13
-75	11.94	13.15	17.36	42.45	14.15
-100	11.72	13.95	13.82	39.49	13.16
-125	11.74	12.01	13.68	37.43	12.47
Average	12.47	13.13	15.44	246.22	13.67

TABLE X

SHEAR VALUES IN POUNDS FOR FRESH PAIR-MATE STEAKS FROM SIX SHORT LOINS

Pair-mates[1]	Dorsal Core	Medial Core	Lateral Core	Total	Average
1	13.10	13.85	17.15	44.10	14.70
2	14.30	15.24	17.91	47.45	15.81
3	11.71	15.90	17.66	45.27	15.09
4	12.18	16.88	18.41	47.47	15.82
5	13.76	15.46	17.87	47.09	15.69
6	12.40	15.28	16.35	44.03	14.67
Average	12.91	15.44	17.56	275.41	15.29

[1]Non-frozen pair-mates of the steaks in Table IX.

The analysis of variance of the shear values for the fresh and frozen steaks are given in Table XI and XII.

TABLE XI

ANALYSIS OF VARIANCE FOR DIFFERENCES IN TENDERNESS OF DORSAL, MEDIAL AND LATERAL CORES FROM THIRTY-SIX FRESH STEAKS

Source	D/F	SS	MS	F
Total	17	77.42		
Pair-Mates	5	4.47	0.89	1.13
Core	2	65.03	35.52	41.16**
Error	10	7.92	0.79	

**$P < .01$

TABLE XII

ANALYSIS OF VARIANCE FOR DIFFERENCES IN TENDERNESS OF DORSAL, MEDIAL AND LATERAL CORES FROM THIRTY-SIX FROZEN STEAKS

Source	D/F	SS	MS	F
Total	17	49.46		
Treatment (Freezing)	5	7.74	1.55	1.55
Core	2	29.19	14.60	14.60**
Error	10	10.03	1.00	

**$P < .01$

Both tables indicate a highly significant mean square value for core differences. However, there was a considerable difference in magnitude of the value for fresh steaks (41.60), than their frozen pair-mates (14.60). This fact, together with the average figures in

Tables IX and X for dorsal, medial and lateral cores, would point out that the frozen steaks tend to be more uniform in tenderness than their fresh pair-mates.

The taste panel was unable to detect differences in tenderness (as rated by hedonic scale and number of chews), due to treatment. The average taste panel rating for tenderness and number of chews were, however, slightly in favor of the frozen steaks (Table XIII).

TABLE XIII

ORGANOLEPTIC RATINGS ON TENDERNESS OF FRESH AND FROZEN STEAKS

Treatment	Tenderness[3]	Number of Chews[4]
Frozen at 0°F.[1]	6.8	20.1
Fresh Pair-Mate[2]	6.8	19.1
Frozen at -25°F.	6.6	20.3
Fresh Pair-Mate	6.6	20.9
Frozen at -50°F.	6.3	20.9
Fresh Pair-Mate	6.2	21.6
Frozen at -75°F.	6.4	20.9
Fresh-Pair Mate	6.2	23.1
Frozen at -100°F.	6.6	21.2
Fresh Pair-Mate	6.2	22.3
Frozen at -125°F.	6.7	20.4
Fresh Pair-Mate	6.6	21.0
Frozen Average	6.5	20.6
Fresh Average	6.4	21.3

[1]Average rating of six steaks for each freezing temperature.
[2]Average ratings of six fresh pair-mate steaks.
[3]Taste panel rating based on an eight point hedonic scale.
[4]Average number of chews taken before swallowing.

b. Effect of Freezing on Juiciness

Moisture differences of the experimental steaks were obtained from data collected on press fluid determinations, cooking losses and taste panel ratings of juiciness.

The meat and moisture rings of the press fluid determinations were measured in square inches by a compensating polar planimeter. The water holding capacities of the fresh and frozen steaks were compared to learn how freezing alters the amount of free water. The free moisture area (the portion of the total moisture that is released by pressing), was determined by subtracting the meat film ring from the outer moisture ring. The results, as shown in Table XIV indicate a larger moisture area is obtained from frozen steaks in contrast to the fresh. This may be due to denaturation of protein during freezing with subsequent release of water from the bound form to free form. The largest moisture area obtained was from samples frozen at -100°F.

Total cooking losses for the frozen steaks were smaller than their fresh pair-mates, although the differences between the means in Table XIV were not great enough to be statistically significant. The lower cooking losses may be partially explained by the fact the frozen steaks received considerably more handling while obtaining the various observations, and the loss of moisture due to dehydration and desiccation during freezing cannot be overlooked. Finally, taste panel ratings for juiciness of the fresh and frozen steaks were very similar with no significant difference due to freezing.

TABLE XIV

A COMPARISON OF MOISTURE RATINGS OF FRESH AND FROZEN PAIR-MATE STEAKS

Treatment	Juiciness[1]	Cooking Loss[2]	Moisture Area[3]
Frozen at 0°F.[4]	5.8	17.5	5.84
Fresh Pair-Mate[5]	6.0	19.9	5.46
Frozen at -25°	5.5	21.3	5.50
Fresh Pair-Mate	5.6	20.7	5.60
Frozen at -50°	5.4	23.4	5.76
Fresh Pair-Mate	5.6	23.1	5.29
Frozen at -75°	5.2	20.1	5.90
Fresh Pair-Mate	5.5	24.6	5.35
Frozen at -100°	5.5	24.0	6.08
Fresh Pair-Mate	5.8	22.7	5.33
Frozen at -125°	5.6	18.7	5.73
Fresh Pair-Mate	5.9	21.7	5.32
Frozen Average	5.5	20.83	5.80
Fresh Average	5.7	22.11	5.39

[1]Average score using an eight point hedonic scale.

[2]Based on steak weights immediately before and after broiling (% loss).

[3]Moisture area as measured in square inches

[4]Average rating for six frozen steaks

[5]Average ratings for six fresh pair-mates

c. Relationships Between Various Experimental Observations

Correlations were computed for the various factors used to evaluate tenderness and moisture of the frozen steaks. The results are given in Table XV. The coefficients of correlation between tenderness and number of chews and juiciness were highly significant. The negative correlation coefficient of (-.721) between tenderness and number of

chews, indicates a strong likelihood that the taste panel associated tenderness ratings with the number of chews required for the sample. It also appears that taste panel members also associated tenderness with an increase in juiciness rating. There was no significant correlation between other experimental observations.

TABLE XV

CORRELATIONS OF MEASUREMENTS RECORDED FROM THIRTY-SIX FROZEN STEAKS

Observations	Column 1	2	3	4	5	6	7
Moisture area Before Freezing	1.000						
Moisture Area After Freezing	-.030	1.000					
pH Values	-.133	-.089	1.000				
Shear Values	.065	.014	-.091	1.000			
Tenderness	-.013	-.008	.099	-.244	1.000		
Number of Chews	-.119	.179	-.032	.199	-.721**	1.000	
Juiciness	-.064	.236	-.221	-.152	.491**	-.231	1.000
Cooking Loss	-.151	.202	-.246	-.124	-.269	.207	-.033

**$P < .01$

SUMMARY

The desirability of a steak is measured principally on its tenderness and juiciness. Therefore, any factor influencing tenderness or juiciness is of definite concern to the consuming public. This study was involved with methods of cookery, wrapping materials and different freezing temperatures, in order to determine how they may alter the palatability of beef steaks.

Methods of cookery were found to have a definite influence on tenderness and moisture losses. Different broiling techniques, i.e., various turning and end temperatures, were analyzed to determine their effect on organoleptic and objective ratings. The end cooking temperatures had a highly significant effect on shear values, number of chews and cooking losses. Turning temperatures had a significant effect on the number of chews required for each portion. An examination of the organoleptic and objective ratings of the broiling techniques indicated a preference for steaks broiled to an internal temperature of 60°F., turned, and removed at an internal temperature of 150°F. These were the lowest rates of heat penetration tested, and they resulted in an end product that was slightly rare in appearance. However, the objection to the rare appearance, was overruled by the increase in tenderness and juiciness of the steak.

Packaging materials and freezing methods were studied in order to develop techniques for freezing steaks at different temperature

levels. The freezing curves indicated that steaks wrapped in aluminum foil and frozen with surface contact, had a freezing rate very similar to the control steaks that were frozen without packaging. Therefore, aluminum foil was chosen because it significantly lowered the resistance to freezing over other packaging materials tested.

Tenderness differences between steaks frozen at various temperatures of 0, -25, -50, -75, -100 and -125°F. were not statistically significant. However, the analysis of variance on shear cores from fresh and frozen steaks pointed out that the frozen steaks were more uniform in tenderness. This uniformity of core tenderness from dorsal to lateral regions of the frozen steak is a highly desirable factor. When fresh and frozen shear values were tested for differences between means, the "t" test indicated that frozen steaks were significantly more tender than their fresh pair-mates. The taste panel ratings were also in favor of frozen steaks in relation to tenderness.

Moisture differences between steaks frozen at different temperatures were small and non-significant. The fresh steaks were slightly favored over frozen samples when juiciness was rated by the taste panel. Press fluid determinations were taken and it was found that frozen steaks had more free moisture than fresh samples. This free moisture, which would be lost during thawing and cooking, is probably due to rupture of the cell membrane during freezing.

Most of the quality factors investigated in this study showed no significant difference between fresh and frozen pair-mate steaks. Organoleptic and objective ratings pointed out that freezing increased tenderness and lowered juiciness ratings. These data bring out the fact that frozen beef is generally of equal quality to its fresh counterpart.

Therefore, this initial phase of the larger study on quality of fresh vs. frozen beef, indicates the consumers question as to the quality of frozen meats can be favorably answered.

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