SHORT-TERM FREEZER STORAGE EFFECT ON U.S. GOOD INSIDE ROUND OF BEEF

by

MARY PATRICIA WORTHAM

B. S., Loretto Heights College,
Denver, Colorado, 1959

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Institutional Management

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1962

TABLE OF CONTENTS

INTRODUCTION

Accounting for at least 30 per cent of the total food budget, meat is one of the most popular menu items used in food services. For reasons of convenience and/or cost control, the use of frozen meat continues to increase in institutions. Such meat may have been purchased either fresh or frozen and held in freezer storage for varying periods of time.

Unpublished studies done at Kansas State University indicated that the grade of meat did not determine necessarily the quality of the edible portion as measured by palatability. U.S. Good top round beef roasts compared favorably with U.S. Choice top round roasts in eating quality and might offer an opportunity for some savings in the purchase cost of beef roasts for food service institutions.

The purchase of poor quality meat for freezing is not an economical practice, because freezing does not improve the product. A search of the literature has established that freezing before cooking has little or no effect on color, flavor, odor, or juiciness of meat. Frozen and properly stored fresh meats lose little of their original palatability for several months. Little information is available in the literature concerning the effect of freezing on cost and portion yield of institutional cuts of meat.

Since the use of short-term freezer storage in certain situations would appear to be advantageous, the objective of this study was to determine the effect of short-term freezer storage on cooking losses, slicing yields, and cost per three-ounce serving of U.S. Good inside top round roasts.

REVIEW OF LITERATURE

Freezing is a method of preserving used universally and is of great importance in the stabilizing of markets. Beef can be kept for many months in the frozen state even though it does undergo some changes (Tressler and Evers, 1957).

Preservation of meat by freezing includes the control of deteriorative changes brought about by microorganisms and post-mortem modifications. Lowe (1955) reported that in general, the quality of food was not improved by freezing or freezer storage but is dependent upon the quality as it goes into the freezer. Therefore, products should be processed and frozen before deteriorative alterations lower quality. Freezing alone has no evident effect upon color, flavor, odor, or juiciness of meat as judged after cooking. Properly prepared, frozen, and stored meats lose little of their original palatability for several months (Amer. Meat Inst. Found., 1960).

Changes Occurring During Freezing

Three general types of changes occur during freezing according to Tressler and Evers (1957). These are physical, chemical, and physio-chemical in nature.

Physical Changes. Desiccation is the chief physical change and occurs mostly on the surface of foods. Only after extended periods of desiccation does the interior of the product dehydrate.

Once this has occurred, flavor is affected and the product becomes tough (FAO of U.N., 1950). Other physical changes reported by Tressler and Evers (1957) were crystallization and expansion.

Chemical Changes. Many types of chemical changes were noted by Tressler and Evers (1957). Frequently these occurred simultaneously with each of the other two types. Chemical changes usually are classed in three groups: (1) ordinary chemical actions, (2) enzymatic actions, (3) actions caused by microorganisms, such as bacteria, yeasts, and molds.

Examples given of chemical changes occurring in frozen foods were oxidation of pigments and catechol-tannins, hydrolysis of fats and other esthers, and denaturation of proteins or dehydration (Tressler and Evers, 1957). Hydrolysis and oxidation were accelerated by enzyme actions both in living tissues and in uncooked meats.

Denaturation is probably a combination of physical and chemical actions reported the FAO of the U.N. (1950). When foods were frozen, water separated as pure ice and not as a simple solution of the natural cell contents. The extent of denaturation or dehydration of proteins was dependent upon the rate of freezing. The faster the freezing rate, the less opportunity the water had to crystallize as pure ice.

Freezing and cold storage at low temperatures do not inactivate any of the common enzymes. The enzymatic action is found to be unimpaired when returned to ordinary temperatures. In general, the lower the temperature, the slower the rate of enzymatic action

(Tressler and Evers, 1957). The FAO of U.N. (1950) stated that even with the least possible breakdown of tissues, enough change occurs to permit abnormal enzymatic actions. Autolysis is the enzyme action occurring in frozen foods. Low temperatures of -40° C. are required to control these enzyme actions.

Action of microorganisms is a hazard only before freezing and during and after defrosting. The growth of bacteria, yeasts, and molds, active at room temperature, is almost negligible at about 15° F. (Tressler and Evers, 1957).

Physio-chemical Changes. The physio-chemical or colloidal chemical changes are probably equal in importance to the chemical changes. Many changes in the colloidal condition of frozen foods are profound, but at present are not well understood. Meat is composed of a jelly-like protoplasm called a gel by colloidal chemists. In order to fix the original spatial distribution of the colloid, the freezing rate must be rapid enough to form minute crystals which are uniformly distributed throughout the tissue. Upon defrosting such a quick frozen product, the moisture is reabsorbed from the melting crystals. If the freezing is slow or if the quick frozen product is held under conditions which permit either the growth of crystals or the irreversible dehydration of some of the proteins, the product does not return to its original gel condition. As the crystals melt, the liquid that is not reabsorbed leaks out as "drip" (Tressler and Evers, 1957). This drip contains much of the flavor of the meats as well as the nutrients (FAO of U.N., 1950).

According to Tressler and Evers (1957) the cell rupture theory is the most widespread hypothesis accounting for changes that occur in frozen plant and animal tissue. During slow freezing, growing ice crystals puncture the cell walls of the tissues and upon defrosting, the cell contents leak out. Tissues that are quick frozen appear to form crystals so small that no tearing of the walls occurs.

Tressler and Evers (1957) stated that sharp freezing bulk beef cuts to obtain a solid freeze required about 72 hours at a temperature of -5° F. Slow freezing at 5° F. required about twice that time. Quick freezing of meat can be done only on cuts rather than carcasses and usually requires less than six hours for solid freezing.

Even when freezing was extremely fast, the smallest ice crystals were much larger than the individual cells. One crystal contained many cells and a continuous crystal lattice was apparent both inside the cell and in the intercellular spaces (Woolrich and Bartlett, 1942). No tearing of the cell walls was noted by these workers regardless of the freezing method utilized. However, they suggested that ice crystals might cause mechanical damage to the cellular structure of some products. They also stated that osmotic injury possibly occurred, but was of minor importance in the destruction caused by freezing. The principal cause for slow freezing damage appeared to be a result of the irreversible changes in the colloidal system.

Effect of Freezing and Freezer Storage

For many years the belief was prevalent that if any reaction occurred in the solid state it was very slow. At present there are several types of recognized changes occurring during freezing.

Rate of Freezing. The extent of physical change produced in muscle tissues of meat is affected by the rate of freezing. Popular belief is that slow freezing results in rupture of cells, whereas rapid freezing prevents this.

Size of Ice Crystal. During freezing, ice crystals are formed as a result of a progressive separation of water. Rapid freezing forms small ice crystals within the muscle fibers, whereas in slow freezing, large ice crystals are formed outside the muscle fibers. Only the outer few millimeters of a cut of meat are really "Flash" frozen regardless of the freezing rate. Most of the ice crystals within the meat are intercellular. The majority of authorities report little or no mechanical damage to fibers even during slow freezing (Amer. Meat Inst. Found., 1960).

According to Winter (1952) the rate of freezing required to distribute small ice crystals uniformly within the cell structure was much more rapid than possible when using locker plant and home freezer facilities. The product should be frozen before deterioration in quality occurs.

Only the surface areas of the large cuts of meat are frozen fast enough to produce small ice crystals (Ramsbottom, 1947). He found that the size and distribution of ice crystals depended largely on the rate at which the temperature of the product fell from above the freezing point to about 25° F. Winter (1952) reported that many workers found that size of ice crystals and rate of freezing were of minor importance in relation to quality of the frozen product when freezing was reasonably rapid.

Color. Rate of freezing affected the color of beef according to Ramsbottom et al. (1949). Meats frozen slowly were dark and had an unattractive appearance, whereas meat frozen rapidly and with small ice crystals was light in color. The freezing rate should be fast enough to maintain the color of the lean as it was prior to freezing. When meat is sold in the frozen state this would be of primary importance.

Pearson and Miller (1950) observed that, as the rate of freezing increased from slow to rapid, the color of the lean became progressively lighter. According to the American Meat Institute Foundation (1960), the color of frozen meat brightens when exposed to air.

Quality. Roasts frozen at slow rates were good; and when cooked they were tender, juicy, and palatable reported DuBois et al. (1940). However, the more rapidly meat was frozen, the better was its all-round quality. Results obtained in a study done by Pearson and Miller (1950) indicated that the rate of freezing did not alter measurably cooking losses, total weight losses, expressible fluid, tenderness, or palatability. Nevertheless, they concluded that rapid freezing didn't improve the overall quality of beef. This was corroborated by Brady and co-workers

(1942) who observed no palatability differences between slow frozen and quick frozen steaks. A study by Lee et al. (1950) demonstrated that the rate of freezing had little effect on the flavor, odor, texture, juiciness, or appearance of the beef. The American Meat Institute Foundation (1960) reported that when thoroughly chilled meat is frozen the quality of the product is not affected by the rate of freezing.

Nutritive Value. Lee et al. (1950) indicated that the rate of freezing did not alter measurably the thiamine, riboflavin, niacin, pantothenic acid, or pyridoxine content of beef.

Shrinkage. Factors that determine extent of shrinkage during freezing and freezer storage, as cited by Tressler and Evers (1957), are the temperature of the freezer, the moisture content of the meat, and its protection from the air. The higher the moisture content of the meat the greater the shrinkage. Meat that has been protected by some packaging material will not shrink as fast or as much as unpackaged meat.

Simpson and Chang (1954) conducted a study to determine the effects of low freezer storage temperature and wrapping material on the quality of frozen meats. Hamburger samples were wrapped in one of four packaging materials: (1) heavy aluminum foil, (2) a glassine-laminated paper, (3) polyethylene-coated paper, and (4) a good grade butcher paper; and frozen at 0° F., -20° F., -30° F., and -40° F.

Moisture loss from hamburger samples was insignificant at any storage temperature when packaged properly using aluminum foil, glassine-laminated paper, or polyethylene-coated paper concluded Simpson and Chang (1954). Moisture loss from samples was significant only when using butcher paper. Definite surface desiccation was noted after only a few weeks' storage at 0° F. The lower storage temperatures employed greatly reduced moisture loss. Hiner et al. (1951) observed that vacuum-packed beef samples had no moisture loss. Other factors being similar, the longer meat was left in storage the greater the total shrinkage (Tressler and Evers, 1957).

Freezerburn. The primary problem in frozen meats is moisture evaporation from the surface of the product. This phenomenon is referred to as freezerburn. Meat affected in this manner not only has an unattractive and bleached appearance, but its palatability also is affected adversely (Amer. Meat Inst. Found., 1960). According to Desrosier (1950), freezerburn alters irreversibly the color, texture, flavor, and nutritive value of frozen foods. Adequate packaging controls and prevents such a condition.

To avoid freezerburn, the product to be frozen should be packaged in skin-tight, moisture-proof material. The packaging material should be durable at freezing temperature, have wet strength, and be impermeable to oxygen even though this would result in a product with a darker, less desirable color (Amer. Meat Inst. Found., 1960).

Hiner and Kauffman (1944) studied the use of lard, beef tallow, and combinations of each as a protective coating for meats against freezerburn. Meats that were frozen, dipped in melted lard at 100° to 200° F., and stored at 0° F. for 64 weeks had small weight losses.

Desiccation of exposed frozen stored meat was retarded by a high fat content of muscle tissue and by a low storage temperature reported Hiner and co-workers (1951). Cellophane and lard coating were satisfactory protectants against desiccation. Desiccation appeared to cause some decrease in lean flavor, desirability, and juiciness. The period of time meta could be kept in frozen storage before becoming unpalatable was increased by shortening the ripening period, lowering the temperature of storage, or by protection from air.

Denaturation. Protein denaturation was one of the most important problems in the freezing and storage of animal tissues (Winter, 1952). It is evidenced by a coagulation of the proteins and a disrupting of the colloidal state of the cells which may take place during freezing and subsequent storage according to Tressler and Evers (1957). Winter (1952) pointed out that little was known about this process other than the fact that the rate of protein denaturation was reduced when the temperature was low. The phenomenon occurs with either slow or fast freezing reported Tressler and Evers (1957).

Rancidity. The development of rancidity in the fat was considered by Lowe (1955) to be possibly the most devastating deteriorative change in meat. Because fat of different animals varies in unsaturated fatty acid content, the fat of different animals varies in susceptibility to oxidative rancidity. Pork fat becomes rancid more readily than beef. The fat of beef and lamb, which is mostly saturated, is more resistant to this type of deterioration than pork, which consists of more unsaturated fats (Amer. Meat Inst. Found., 1960). Fat stability differs greatly from animal to animal within a species. Deterioration of fatty constituents of meat can be detected because of odor and flavor changes that occur in the product (Amer. Meat Inst. Found., 1960).

Properly packaged beef fat stored at 10° to 10° F. showed slight rancidity in four months, whereas properly packaged beef fat stored at 0° F. did not become rancid in 15 months in work done by DuBois et al. (1940). Meat, which either is unpackaged or otherwise inadequately protected against desiccation, may become rancid in shorter periods of time (Tressler and Evers, 1957). Retardation of rancidity development was demonstrated by Simpson and Chang (1954) when freezer storage temperatures were 0° F. or below.

Factors affecting rancidity development listed by Lowe (1955) are: (a) the feed the animal has received, (b) the exposure of cuts to oxygen, (c) the prefreezing treatment, (d) the time and temperature of storage, (e) the addition of substances such as salt, sage, pepper, and antioxidants, and (f) cooking.

Antioxidant compounds used to protect rendered fats against oxidation have not been effective in preventing these changes in frozen meats. The undesirable changes in fat are retarded but not prevented by oxygen impermeable packaging or coatings (Amer. Meat Inst. Found., 1960).

Freezer storage results in a gradual decrease in odor and flavor acceptability; however, fresh meats lose little of their original palatability if properly prepared, frozen, and stored. The freezer storage life of fresh meat is related to the type of feed on which the animal was raised, the postslaughter age, the pH of the meat, contamination by heavy metals, the temperature of holding before freezing, and other similar factors. The nature of and the reasons for the effect of many of these factors are unknown (Amer. Meat Inst. Found., 1960).

Tenderness. The work reviewed to date is contradictory in regard to the tenderizing effect of freezing and freezer storage on meat. Paul and Child (1937) found no significant differences in tenderness between frozen and unfrozen beef.

Steaks frozen at 20° F., -10° F., and -40° F. were more tender than unfrozen steaks. Temperatures of -10° F. and -40° F. resulted in a significant increase in tenderness. No additional tenderizing took place below -10° F. (Hankins and Hiner, 1940).

The maximum tenderizing effect was obtained by aging good grade beef 15 days and freezing at -10° F. Hankins and Hiner (1944) reported that deterioration did not occur with this treatment.

A consistent increase in tenderness of beef samples was observed by Hiner and co-workers (1945) as freezing temperatures were lowered and freezing time shortened. This was caused by an increased rupture of fiber by intrafibrillar ice formation and the stretching and rupturing of the interstitial connective tissue.

Hiner and Hankins (1947) demonstrated that freezing increased tenderness, but the effect decreased as the aging period increased. No noticeable difference in tenderness of steaks after six months' frozen storage was observed by Nicholas et al. (1947).

After studying 282 steaks, Pearson and Miller (1950) concluded that the freezing rates did not alter tenderness measurably. They also noted that freezer storage caused a decrease in tenderness. Hiner and Hankins (1951) claimed that tenderization due to freezing was highly significant between age groups but not within the same age group.

Defrosting

Frozen meats may be defrosted by several different methods. The specific method used is determined by a number of factors (Amer. Meat Inst. Found., 1960). Meats may be defrosted in the refrigerator, at room temperature, in a warming oven, in circulating water, or during the cooking process. According to Tressler and Evers (1957) the defrosting method does not affect the flavor, tenderness, or juiciness of the cooked meat to any appreciable degree.

The effect of different defrosting methods on the quality of pot roasts and broiled steaks was studied by Kalen et al. (1948). Similar products were obtained whether defrosted as a part of the cooking process, at refrigerated temperature, at room temperature, in a warming oven, or by infrared rays. The major difference among these acceptable methods was in the rate of defrosting. Samples defrosted with infrared rays required the shortest time, the warming oven was next, then room temperature, and the refrigerated temperature required the longest time. Products defrosted in running water were of inferior quality.

When studying the effect of various defrosting methods on round steak Westerman and co-workers (1949) found a noticeable difference in the defrosting rate. Of the four methods used, defrosting in the refrigerator required the longest time period, running water the shortest, with room temperature and 73° C. being intermediate. Steaks defrosted in the refrigerator had the smallest cooking loss. Although none of the methods resulted in large differences in vitamin retention, defrosting in the refrigerator and at room temperature gave the best vitamin retention, and defrosting in water the least. All of the defrosting methods gave similar palatability scores.

Two different defrosting temperatures, 24-25° C. and 175° C., used by Paul and Child (1937) did not affect press fluid, drip, total moisture, or tenderness of beef. Total losses, which included the freezing, defrosting, and cooking losses, were significantly greater when roasts were defrosted at 175° C. than

24-25° C. This was attributed partially to the weight gain which occurred in roasts defrosted at 24-25° C. whereas, a weight loss resulted when roasts were defrosted at 175° C.

Vail et al. (1943) observed lower percentage cooking losses for meat defrosted at refrigerated temperatures than for steaks defrosted in the oven. However, when the evaporation and drip losses which occurred during defrosting at room temperature and refrigerated temperature were added to the cooking losses the percentage weight loss was approximately the same as the cooking losses for steaks defrosted in the oven.

For institutional cookery, thin cuts of frozen meats should be cooked from the frozen state to prevent high evaporation and drip losses. Larger cuts can be defrosted at the discretion of the food production manager. Defrosting in the refrigerator is the recommended method. Most roasts will be defrosted sufficiently when held over night in a refrigerator (Tressler and Evers, 1957).

"Drip," the blood-like fluid exuding from frozen meat upon defrosting, was reported by Pearson et al. (1952) to contain approximately 9 per cent protein and considerable amounts of vitamin B complex. The variation in drip has been attributed to various factors according to Hiner (1951). Temperature of freezing was related to the amount of drip, because meat frozen at low temperatures, with resulting fiber breakdown, reabsorbed water when defrosted. At high freezing temperatures the moisture was withdrawn from the fibers and frozen between them, and when defrosted, this moisture exuded as drip.

Ramsbottom and Koonz (1939) observed that regardless of freezing temperature, where the area of cut surface was small in relation to the volume of the meat, little drip was evident. However, in small steaks where the area of cut surface was large in relation to the volume of the meat, the amount of drip was dependent to a large extent on the freezing temperatures. The muscle tissue in large cuts reabsorbed the "frozen-out" water, whereas the fluids were more easily lost as drip by tissues in small cuts.

In further work done by Ramsbottom and Koonz (1941) they concluded that the amount of drip was affected significantly by the temperature of freezing and the length of time the beef was held in freezer storage. The temperature of freezer storage did not appear to influence the amount of drip. Hiner et al. (1945) reported that the amount of drip during defrosting decreased as the freezing temperatures were lowered.

The time required for defrosting meat is influenced by the temperature of the meat and its thermal capacity, the defrosting medium (air or water) and its temperature and circulation, the size of the unit being defrosted, and other minor factors. In situations where defrosting will require a long time, care should be taken to avoid surface temperatures that would permit rapid microbial growth (Amer. Meat Inst. Found., 1960). Microorganisms find a nutritive medium for rapid growth when the ice crystals melt and water pervades the tissues. Jensen (1949) recommended that meats be defrosted under rigidly controlled conditions, those being a temperature of 40° F. and a relative humidity of 95 per cent. Meat is perishable as soon as the surface temperature rises above 0° C. However, microorganisms do not grow faster on defrosted meat than on fresh. Frozen meat should not be defrosted too long prior to cooking. To realize the best results of any freezing operation care must be given to methods of preparation, packaging, freezing, and storage (Amer. Meat Inst. Found., 1960).

EXPERIMENTAL PROCEDURE

Design of Experiment

Twenty pairs of trimmed U.S. Good top round beef roasts were used for this study. The carcasses, each assigned a number drawn at random, were selected at a local wholesale distributor as they came from the supply truck of a national packer. Each pair of top inside round roasts was cut from the carcass and trimmed in the form to be used for roasting. A flip of the coin determined which side of the pair was to be frozen. At this time, the individual roasts were marked with an identification tag to indicate treatment and roasting period. Roasts to be frozen were wrapped in the freezer paper used by the meat company, taped, tied, placed in wire baskets, put into the freezer locker, and held for approximately two weeks at -20° F. Fresh roasts were wrapped in brown butcher paper, tied, and placed in the walk-in refrigerator until the specified delivery time.

The meat was obtained from the local wholesale distributor to approximate the most probable meat source available to the majority of institutions. Roasts ranged from 11 pounds 6 ounces to 19 pounds 5 ounces. Although pairs of roasts from the same animal were used, the past history of the animal from which the pairs came was unknown.

All roasts, both fresh and frozen, were cooked to an internal temperature of 65° C. (149° F.) in ten roasting periods. Four roasts were cooked during one period. The fresh roasts were cooked in the first five periods and the roasts which had been frozen in the last five periods (Table 1). The data were analyzed using paired comparisons.

Roasting Procedure

The roasts were delivered from the wholesale distributor to the laboratory 48 hours before each scheduled roasting period. Immediately upon delivery, weights were recorded and the roasts were held at 36° F. in a reach-in refrigerator equipped with a fan. In the case of the frozen roasts, the 48-hour refrigerator storage period was the method employed for defrosting.

One hour before roasting, the meat was removed from the refrigerator and placed fat side up on racks in individual aluminum roasting pans. A right-angle Centigrade thermometer was inserted into the center of the thickest portion of each cut. Initial internal temperatures ranged from 1° C. to 4° C. The panned roasts were placed into a gas-fired institutional Reed Reel oven preheated to 300° F. The internal temperature of each roast and the time interval required for each 10° C. rise were recorded until the internal temperature reached 45° C. and thereafter for

Table 1. Experimental design.

Roasting period	Pair number*	Side of carcass	Treatment
1	14	Right	
	7	Right	
	6	Left	
	10	Left	
2	1	Right	
	18	Left	
	20	Right	
	4	Right	
3	3	Right	
	13	Left	
	2	Left	Fresh
	5	Right	
4	9	Right	
	17	Left	
	12	Left	
	15	Right	
5	8	Left	
	16	Left	
	19	Right	
	11	Left	
6	14	Left	
	7	Left	
	6	Right	
	10	Right	
7	1	Left	
	18	Right	
	20	Left	
	4	Left	
8	3	Left	
	13	Right	
	2	Right	Frozen
	5	Left	
9	9	Left	
	17	Right	
	12	Right	
	15	Left	
10	8	Right	
	16	Right	
	19	Left	
	11	Right	

* Identification numbers assigned to each pair of roasts when procured.

every 2° C. rise until the end point cooking temperature was reached. Upon removal from the oven, the roasts were allowed to cool for one hour.

Weights of the roasts and equipment were taken at appropriate periods throughout the procedure to determine storage losses, volatile losses, dripping losses, and total cooking losses. The roasts were covered with aluminum foil and stored in the reach-in refrigerator (36° F.) until ready for slicing the following day.

Slicing Procedure

Roasts were sliced the day following roasting. After approximately 18 hours, they were removed from the reach-in refrigerator and weighed to ascertain losses occurring in the cooked meat during refrigerated storage. Prior to slicing, the hard outer fat covering was trimmed. A Hobart gravity food slicer, Model 1512, was used for slicing. The dial on the slicer was set at position 16 in order to cut a slice 3/8-inch thick.

Excess fat and visible connective tissue were removed from the slices, which were then portioned into three-ounce servings with the aid of a Pelouze, Jr. Portion-Controller scale. One to two pieces of meat were used per serving. The total weight and number of three-ounce portions per roast were recorded.

The weight of all fat and connective tissue trimmings from the roasts was combined and recorded as waste. All small pieces of lean trimmed from slices, as well as lean from the ends of the roasts, were combined, weighed, and recorded as usable scrap. Small amounts of lean and fat difficult to remove from the slicer blade, and unmeasurable amounts of juices which had dripped from the meat during slicing were included arbitrarily in the total volatile loss.

Calculation of Cost

A serving was three ounces of meat consisting of not more than two pieces. The combined weight of all three-ounce servings for each roast constituted the edible portion. Cost per pound of the edible portion equaled the total "as purchased" cost divided by the total pounds of edible portion. Actual cost per serving was obtained by dividing the total number of three-ounce servings into the "as purchased" cost of each roast. The cost of edible scrap obtained during the slicing process was not deducted from the cost per serving of the three-ounce portions.

Statistical Analysis

Paired comparisons were made from data collected in this study for the following characteristics: preroasting storage loss, volatile cooking loss, dripping cooking loss, total cooking loss, total cooking time, preslicing storage loss, volatile slicing loss, slicing waste, usable scrap, total slicing loss, percentage slicing yield, and number of three-ounce servings.

Correlation coefficients were determined for total slicing losses and percentage portion yield, usable scrap and percentage portion yield, and waste and percentage portion yield.

RESULTS AND DISCUSSION

Storage Losses

Two days prior to the scheduled roasting period, roasts were received from the local wholesale distributor and placed in a pass-through refrigerator at 36° F. The average storage losses during this period for the 20 fresh and 20 frozen U.S. Good top round roasts are shown in Table 2. Detailed data are in Table 7, Appendix. Storage losses for fresh roasts ranged from 0.2 to 2.2 per cent and averaged 0.5 per cent, whereas those for frozen roasts ranged from 0.01 to 0.6 per cent and averaged 0.1 per cent. The preroasting storage loss was statistically greater ($.05 > P > .02$) in fresh roasts than in frozen roasts.

Table 2. Average 48-hour storage losses of fresh and frozen top round roasts.

Roast	Storage loss	
	g.	%
Fresh	33.8	0.5
Frozen	14.2	0.1

Rate of Heat Penetration

The greatest difference in rate of heat penetration between fresh and frozen roasts occurred during the time interval required for the first 10 degree (C.) rise in internal temperature (Table 3). An average of 76 minutes was required for the first 10 degree rise in temperature for the fresh roasts, whereas an average of

Table 3. Average time intervals required for rise in internal temperatures (° C.) for fresh and frozen U.S. Good top round roasts.

Fresh		Frozen	
Internal temperature (° C.)	Time interval (min.)	Internal temperature (° C.)	Time interval (min.)
-	-	1	0
4	0	11	106
14	76	21	33
24	38	31	25
34	34	41	26
44	35	43	8
46	7	45	6
48	9	47	7
50	9	49	7
52	8	51	6
54	8	53	7
56	8	55	7
58	8	57	7
60	9	59	8
62	10	61	9
64	10	63	9
65	7	65	10
Total	276		281

106 minutes elapsed for the frozen roasts. The average time interval for the next 30 degree rise in internal temperature was greater for the fresh than for the frozen roasts and was 38 minutes and 33 minutes, respectively.

After the internal temperature of the roasts had risen 40° C. from the initial internal temperature (fresh 44° C.; frozen 41° C.), the time interval required for every two degree rise in temperature was recorded until the end point temperature of 65° C. was reached. The average time interval after the first 40° C. rise in temperature until the end point temperature was reached was approximately the same for fresh and frozen roasts, being 95 minutes for fresh and 92 for frozen roasts.

Cooking Time

Total Cooking Time. The average total cooking time for fresh and frozen U.S. Good top round roasts cooked to an internal temperature of 65° C. was 276 and 281 minutes, respectively. Statistical analysis indicated that the total cooking time was approximately equal for both fresh and frozen roasts. Detailed data are given in Table 8, Appendix.

Cooking Time in Minutes Per Pound. Average cooking time in minutes per pound was statistically equal ($.30 > P > .20$) for fresh and frozen roasts. The fresh roasts had an average cooking time of 17.6 minutes per pound and the frozen roasts 18.1 minutes per pound.

The range in size of the roasts, both fresh and frozen, appeared to have no evident effect upon cooking time in minutes per pound. Nine roasts, which had an average cooking time of 18.0 to 18.7 minutes per pound, ranged in size from 11.2 to 18.3 pounds. Seven roasts with an average cooking time of 16.3 to 16.8 minutes per pound ranged in size from 14.1 to 19.6 pounds. Six roasts, which weighed from 13.2 to 13.8 pounds, had a range of 13.3 to 21.8 minutes per pound for cooking. These data would appear to indicate that there was no relationship between cooking time in minutes per pound and size of roasts. However, other factors usually reported as affecting length of cooking time are the cooking temperature, the interior temperature to which the meat is cooked, the distance to the thickest portion of the meat, the composition of the meat, the temperature of the meat at the start of the cooking period, and the method of cooking.

Cooking Losses

Total Cooking Losses. Average cooking losses, total, volatile, and dripping, from U.S. Good top round roasts, fresh and frozen, cooked to an internal temperature of 65° C. are listed in Table 4. The average total cooking loss for the fresh roasts was 18.5 per cent and 23.7 per cent for the frozen roasts. Cooking losses for fresh roasts ranged from 12.8 to 22.1 per cent, whereas those for frozen roasts ranged from 19.0 to 27.8 per cent. The total cooking loss was significantly greater ($P < .001$) for frozen roasts than for fresh roasts. Detailed data are given in Table 9, Appendix.

Table 4. Average total cooking losses for fresh and frozen U.S. Good top round roasts.

	Cooking losses					
	Total		Volatile		Drip	
Roast	g.	%	g.	%	g.	%
Fresh	1275.8	18.5	828.0	11.7	490.5	6.8
Frozen	1675.5	23.7	1117.6	15.8	555.5	7.9

Volatile Cooking Losses. The average volatile cooking loss was significantly greater ($P < .001$) for frozen roasts than for fresh roasts. The average percentage volatile cooking loss for frozen roasts was 15.8 per cent and the range for individual roasts was from 13.3 to 19.3 per cent. Volatile cooking losses for fresh roasts ranged from 8.5 to 14.0 per cent and the average volatile cooking loss was 11.7 per cent. In no case were the volatile cooking losses greater for the fresh roasts than for the frozen roasts. Data are given in detail in Table 9, Appendix.

Drip Cooking Losses. The average drip loss for fresh roasts was 6.8 and 7.9 per cent for frozen roasts. Drip losses ranged from 4.3 to 10.7 per cent for fresh roasts and for frozen roasts from 5.7 to 10.3 per cent. In five pairs the drip losses were greater for the fresh roasts than for the frozen roasts. Another pair of roasts had the same percentage drip loss. However, statistical analysis indicated that the average drip loss was greater ($.05 > P > .02$) for frozen roasts than for fresh roasts. Detailed data are given in Table 9, Appendix.

Roast size did not appear to have any effect on the amount of drip. The fresh roast's average weight was 15 pounds 8 ounces. Roasts ranged from 19 pounds 6 ounces to 11 pounds 2 ounces. The weights for the frozen roasts were 18 pounds 3 ounces to 12 pounds 3 ounces, with an average weight of 15 pounds 5 ounces.

Slicing Losses

Storage Losses, Preslicing. Prior to slicing, the cooked roasts were held overnight in a reach-in refrigerator at 36° F. Appropriate weights were taken to calculate losses occurring during this storage period. The average preslicing storage loss for fresh U.S. Good top round roasts was 2.6 per cent with a range from 1.0 to 4.0 per cent. Frozen roasts had an average preslicing storage loss of 1.6 per cent with a range from 0.5 to 3.1 per cent. Statistical analysis of the data indicated that preslicing storage losses for fresh roasts were significantly greater ($P < .001$) than for frozen roasts (Table 10, Appendix).

Total Slicing Losses. Total slicing loss included volatile slicing loss, waste slicing loss, and usable scrap. Total slicing loss was calculated by subtracting the weight of the three-ounce portions obtained after slicing from the weight of the roast prior to slicing. Total slicing loss for fresh roasts ranged from 15.5 to 24.8 per cent with an average total slicing loss of 19.7 per cent. The average total slicing loss for frozen roasts was 16.3 per cent and ranged from 11.8 to 22.2 per cent. Table 11, Appendix gives detailed data. Total slicing losses were greater ($.01 > P > .001$) for fresh roasts than for frozen roasts (Table 5).

Table 5. Average total slicing losses for fresh and frozen U.S. Good top round roasts.

	Slicing losses							
	Total		Volatile		Usable scrap		Waste	
Roasts	g.	%	g.	%	g.	%	g.	%
Fresh	1400.0	19.7	77.9	1.1	482.8	6.7	1222.7	11.7
Frozen	1149.5	16.3	40.7	0.6	349.8	6.8	759.1	10.9

Volatile Slicing Loss. The average volatile slicing loss for fresh roasts was 1.1 per cent with a range from 0.5 to 4.6

per cent. The range in volatile slicing loss for frozen roasts was 0.3 to 0.8 per cent with the average volatile slicing loss of 0.6 per cent. Detailed data are given in Table 11, Appendix. Fresh roasts had greater ($.05 > P > .02$) volatile slicing losses than frozen roasts.

Waste Slicing Loss. All fat, connective tissue, or unusable scrap obtained from trimming the roast prior to slicing and the trimming of the individual slices constituted the waste slicing loss. The fresh and frozen roasts had waste slicing losses that were equal ($.30 > P > .20$). Data are given in detail in Table 11, Appendix. The average waste slicing loss for fresh roasts was 11.7 per cent and for frozen roasts 10.9 per cent. The range in waste slicing losses for fresh roasts was from 3.6 to 17.5 per cent, whereas the range for frozen roasts was from 7.5 to 15.6 per cent (Table 5).

Usable Scrap Slicing Loss. Usable scrap included all edible meat that could not be used in the three-ounce portions. Average usable scrap slicing loss was 6.7 per cent and 4.8 per cent for fresh and frozen roasts, respectively. Usable scrap slicing loss for fresh roasts ranged from 2.9 to 15.9 per cent and 2.7 to 9.5 per cent for frozen roasts. Fresh roasts, when compared statistically to frozen roasts, had greater ($.05 > P > .02$) usable scrap slicing losses than frozen roasts. Detailed data are in Table 11, Appendix.

Slicing Yield

The per cent slicing yield for each roast was calculated using the total weight of the three-ounce portions and the "as purchased" weight of the roast. The usable scrap was not included in the slicing yield.

The average weight of the three-ounce servings for the fresh roasts was 9 pounds five ounces and 8 pounds 14 ounces for frozen roasts. Fresh roasts had an average slicing yield of 59.1 per cent, whereas for the frozen roasts the yield was 58.3 per cent. Analysis of the data indicated that the fresh and frozen roasts had approximately equal ($.40 > P > .30$) slicing yields.

The average number of three-ounce servings per fresh roast was 50, whereas for the frozen roasts it was 48. Fresh roasts averaged 5.6 servings per pound of edible portion, and frozen roasts averaged 5.5 servings per pound. The average servings per pound for the roasts as purchased weight was 3.2 for fresh and 3.0 for frozen. Analysis of data indicated that the number of three-ounce servings per roast were approximately equal ($.10 > P > .05$) for fresh and frozen roasts. Detailed data for fresh roasts are in Table 12, Appendix, and for frozen roasts Table 13, Appendix.

A significant ($P < .05$) negative correlation coefficient was obtained from data for total slicing loss and percentage portion yield (Table 6). This would indicate that as the total slicing losses increased, the percentage portion yield decreased or vice versa which is logically what would be expected.

Table 6. Correlation coefficients.

Variables correlated	r and significance
Total slicing losses and percentage portion yield	-.694*
Usable scrap and percentage portion yield	-.290 ns
Waste and percentage portion yield	-.506*

* - significant at the 5% level.
ns - nonsignificant.

Percentage portion yield and usable scrap data showed a nonsignificant negative correlation coefficient (Table 6). In this instance there was little relationship between usable scrap and percentage portion yield. However, the negative correlation coefficient obtained indicated, as might be expected, the more usable scrap the less the percentage portion yield.

A significant ($P < .05$) negative correlation coefficient was observed between waste and the percentage portion yield (Table 6). As the waste increased, the percentage portion yield decreased.

Cost

Purchase price per pound of U.S. Good top round roasts was $0.85 for the duration of this study. Cooked fresh roast increased a mean 172 per cent in cost per pound over the original purchase price, whereas cooked frozen roasts increased a mean 180 per cent. Average cost per pound of the edible portion of the fresh roast was $1.48 and ranged from $1.32 to $2.01. Cooked frozen roasts averaged $1.53 edible portion and ranged from $1.33

to $2.23. A three-ounce portion of the cooked fresh roasts had an average cost of $0.27 and of the cooked frozen roasts, $0.28. Tables 12 and 13, Appendix, give detailed data for fresh and frozen roasts, respectively.

SUMMARY

Twenty pairs of U.S. Good inside round beef roasts were obtained from a local wholesale distributor to study the effect of short-term freezer storage on cooking losses, slicing yield, and cost per three-ounce serving. Paired comparisons were used to analyze the data obtained.

When the carcasses were selected, the roasts to be frozen were wrapped in freezer paper and held in the freezer locker for approximately two weeks at -20° F. At the same time, the fresh roasts were wrapped in brown butcher paper, stored in a walk-in refrigerator, and delivered 48 hours before the proper cooking period. Fresh roasts were processed in five periods as were frozen roasts for a total of 10 cooking periods.

All roasts were cooked in a gas-fired institutional, Reed Reel oven preheated to 300° F. The internal temperature of each roast and the time interval required for each 10° C. rise was recorded until the internal temperature reached 45° C., and thereafter for every 2° C. rise until the end point cooking temperature of 65° C. (149° F.) was reached. Storage losses and volatile, dripping, and total cooking losses were determined.

After cooling for one hour, the roasts were covered with aluminum foil and stored in a reach-in refrigerator (36° F.). Approximately 18 hours later, the meat was portioned into three-ounce servings, each consisting of not more than two slices of meat.

The greatest difference in rate of heat penetration between fresh and frozen roasts occurred during the time interval required for the first 10° C. rise in internal temperature. An average of 76 minutes was required for the first 10° C. rise in temperature for fresh roasts and an average of 106 minutes for frozen roasts. The total cooking time was approximately the same for fresh and frozen roasts, being 276 minutes for fresh and 281 for frozen. Both the fresh and the frozen roasts had similar average cooking times in minutes per pound. The fresh roasts had an average cooking time of 17.6 minutes per pound and the frozen roasts, 18.1 minutes per pound.

Total cooking losses were significantly ($P < .001$) greater for frozen roasts, which averaged 23.7 per cent, than for fresh roasts, which were 18.5 per cent. Volatile cooking losses were significantly ($P < .001$) greater for frozen roasts than for fresh roasts. The average volatile cooking loss was 15.8 per cent for frozen roasts and only 11.7 per cent for fresh roasts. Frozen roasts also had greater drip cooking losses than did fresh roasts. Average dripping cooking losses for fresh roasts were 6.8 per cent and 7.9 per cent for frozen roasts.

Storage losses were calculated for the 48-hour period prior to cooking and the 18-hour period after cooking and before slicing. The mean storage loss for the period prior to roasting was significantly ($.05 > P > .02$) greater for fresh roasts than for frozen roasts, being 0.50 and 0.10 per cent, respectively. Pre-slicing storage losses were significantly ($P < .001$) greater for fresh roasts than for frozen roasts. Average preslicing storage losses for fresh roasts were 2.6 per cent and for frozen roasts were only 1.6 per cent.

Average total slicing loss for fresh roasts was 19.7 per cent and 16.3 per cent for frozen roasts. Total slicing losses were significantly ($.01 > P > .001$) greater for fresh than for frozen roasts. Fresh roasts had an average volatile slicing loss of 1.1 per cent, whereas that for frozen roasts was 0.60 per cent. Waste slicing losses were similar for fresh and frozen roasts. The average waste slicing losses for fresh roasts were 11.78 per cent and 10.86 per cent for frozen roasts. The fresh roasts had greater usable scrap slicing losses than the frozen roasts, being 6.67 and 4.42 per cent, respectively.

Fresh roasts had an average slicing yield of 59.1 per cent, whereas for the frozen roasts the yield was 58.3 per cent. The average slicing yields for fresh and frozen roasts were equal. A significant negative correlation coefficient was found for total slicing losses and percentage portion yield. Usable scrap and percentage portion yield showed a nonsignificant negative correlation coefficient, whereas a significant negative correlation coefficient was demonstrated for waste and percentage portion yield. The average number of three-ounce servings per edible portion of roast for both fresh and frozen was approximately equal being 50 and 48, respectively. The average number of servings per pound for roasts as purchased was 3.2 for fresh and 3.0 for frozen.

The average cost per pound of the cooked fresh roasts was $1.48 and for the cooked frozen roasts, $1.53. A three-ounce portion of the cooked fresh roasts had an average cost of $0.27 whereas for the frozen roast it was $0.28. On the basis of cost per pound or per serving, little difference was apparent between the fresh and the frozen roasts.

CONCLUSIONS

Fresh roasts had greater storage losses, both preroasting and preslicing, total slicing losses, volatile slicing losses, and usable scrap than did frozen roasts. Frozen roasts had greater total cooking losses, drip cooking losses, and volatile cooking losses. The losses of the fresh roasts appeared to counterbalance the losses of the frozen roasts; as the roasts, both fresh and frozen, had similar percentage portion yields, waste slicing losses, and number of three-ounce portions.

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Mrs. Marjorie M. Hemphill, Assistant Professor of Institutional Management, for her guidance in planning this project and for her encouragement and help in the preparation of this manuscript; and to Dr. H. C. Fryer, Director of the Statistical Laboratory, for his help with the statistical analysis of the data.

LITERATURE CITED

American Meat Institute Foundation.
The science of meat and meat products. San Francisco: W. H. Freeman and Co., 1960. pp. 33-37, 281-288.

Brady, D. E., P. Frei, and C. W. Hickman.
Effect of freezing rate on quality of broiled steaks. Food Research 7: 388-393. 1942.

Desrosier, Norman W.
The technology of food preservation. Westport, Conn.: The Avi Publishing Co., Inc., 1959. pp. 19-20.

DuBois, C. W., D. K. Tressler, and F. Fenton.
Influence of rate of freezing and temperature of storage on quality of frozen meat. Proc. 1st. Food Conf. Inst. Food Technologist 1, 167-179. 1940.

Food and Agriculture Organization of the United Nations Food Agriculture Study. Some aspects of food refrigeration and freezing. Edited by Donald K. Tressler, Washington, D.C.: Food and Agriculture Organization of the United Nations. No. 12, 1950 (Nov.). pp. 2-8.

Hankins, O. G., and R. L. Hiner.
Freezing makes beef tenderer. Food Inds. 12(1): 49-51. 1940 (Jan.).

______________.
Evidence strong that freezing tenderizes meat. Quick Frozen Foods 7(5): 37, 82. 1944 (Dec.).

Hiner, R. L., and O. G. Hankins.
Temperature of freezing affects tenderness of beef. Food Inds. 19: 1078-1081. 1947 (Aug.).

______________.
Effects of freezing on tenderness of beef from different muscles and from animals of different ages. Food Tech. 5: 374-376. 1951.

Hiner, R. L., and W. R. Kauffman.
Coating of fat protects meat against freezer-burn. Food Inds. 16: 275-278, 328. 1944.

Hiner, R. L., L. L. Madsen, and O. G. Hankins.
Histological characteristics, tenderness, and drip losses of beef in relation to temperature of freezing. Food Research 10: 312-324. 1945.

Hiner, R. L., A. M. Gaddis, and O. G. Hankins.
Effect of methods of protection on palatability of freezer-stored meat. Food Tech. 5: 223-229. 1951.

Jensen, Lloyd B.
Meat and meat foods - processing and preservation from meat plant to consumer. New York: The Ronald Press Company, 1949. pp. 23-26.

Kalen, J. K., E. L. Miller, G. L. Tinklin, and G. E. Vail.
The effect of various thawing methods upon the quality of pot roasts and braised steaks. Quick Frozen Foods 11(2); 55-57, 78, 80. 1948.

Lee, F. A., R. F. Brooks, A. M. Pearson, J. I. Miller, and F. Volz. Effect of freezing rate on meat - appearance, palatability, and vitamin content. Food Research 15: 8-15. 1950.

Lowe, B.
Experimental cookery. 4th ed. New York: John Wiley and Sons, Inc., 1955. pp. 103-105.

Nicholas, J. E., P. T. Ziegler, and M. C. Parsner.
Effect of very rapid freezing on beef tenderness. Refrig. Eng. 54: 438-440. 1947.

Paul, P. C., and A. M. Child.
Effect on freezing and thawing beef muscle upon press fluid, losses, and tenderness. Food Research 2: 339-347. 1937.

Pearson, A. M., and J. I. Miller.
The influence of rate of freezing and length of freezer storage upon the quality of beef of known origin. J. Animal Sci. 9: 13-19. 1950.

Pearson, A. M., J. E. Burnside, H. M. Edwards, R. S. Glasscock, T. J. Cunhc, and A. F. Novak. Vitamin losses in drip obtained upon defrosting frozen meat. Food Research 16: 85-87. 1952.

Ramsbottom, J. M.
Freezer storage effect on fresh meat quality. Refrig. Eng. 53: 19-23. 1947.

Ramsbottom, J. M., and C. H. Koonz.
Freezing temperature as related to drip of frozen-defrosted beef. Food Research 4: 425-431. 1939.

____________.
Freezer storage temperature as related to drip and to color in frozen-defrosted beef. Food Research 6: 571-580. 1941.

Ramsbottom, J. M., P. A. Goeser, and E. J. Strandine.
Factors affecting the freezing rate of meats. Refrig. Eng. 57: 1188-1191. 1949 (Dec.).

Simpson, J. I., and I. C. L. Chang.
Effect of low freezer storage temperature and wrapping material on the quality of frozen meats. Food Tech. 8: 246-252. 1954.

Tressler, D. K., and C. F. Evers.
The freezing preservation of foods. Vol. I. Freezing of fresh foods. 3rd ed. Westport, Conn.: The Avi Publishing Co., Inc., 1957. pp. 317-329, 679-697, 1020-1025.

Vail, G. E., M. Jeffery, H. Forney, and C. Wiley.
Effect of method of thawing upon losses, shear, and press fluid of frozen beefsteak and pork roasts. Food Research 8: 337-342. 1943.

Westerman, B. D., G. E. Vail, G. L. Tinklin, and J. Smith.
B-complex vitamins in meat. The influence of different methods of thawing frozen steaks upon the palatability and vitamin content. Food Tech. 3: 184-187. 1949.

Winter, J. D.
Changes that occur in meat during freezing and storage. Quick Frozen Foods 15(4): 170-171. 1952 (Nov.).

Woolrich, W. R., and L. H. Bartlett.
Quick and flash freezing of foods. Mech. Eng. 64: 647-653. 1942.

APPENDIX

Table 7. Forty-eight-hour refrigerated storage losses for fresh and frozen U.S. Good top round roasts.

48-hour storage loss					
Fresh			Frozen		
Roast number	g.	%	Roast number	g.	%
14	18	0.23	14	18	0.22
7	45	0.51	7	6	0.07
6	31	0.58	6	7	0.11
10	22	0.29	10	15	0.20
1	27	0.39	1	14	0.20
18	41	0.51	18	6	0.10
20	21	0.30	20	20	0.31
4	123	2.03	4	8	0.12
3	17	0.24	3	15	0.21
13	19	0.24	13	1	0.01
2	16	0.24	2	18	0.32
5	20	0.25	5	2	0.02
9	35	0.40	9	13	0.17
17	16	0.23	17	20	0.31
12	17	0.22	12	49	0.64
15	111	2.18	15	13	0.21
8	16	0.26	8	15	0.22
16	22	0.32	16	9	0.15
19	20	0.26	19	12	0.16
11	31	0.40	11	22	0.28
Av.	33.4	0.5		14.2	0.2

Table 8. Total cooking time and cooking time in minutes per pound, of fresh and frozen U.S. Good top round roasts.

Fresh			Frozen		
Roast No.	Total cooking time (min.)	Minutes per pound	Roast No.	Total cooking time (min.)	Minutes per pound
14	293	16.7	14	332	18.1
7	325	16.6	7	344	20.4
6	229	19.6	6	293	21.2
10	290	17.9	10	315	19.0
1	281	18.4	1	330	21.7
18	299	17.0	18	288	21.8
20	294	19.5	20	293	20.6
4	265	20.0	4	301	19.8
3	252	16.6	3	283	18.0
13	308	18.0	13	309	17.6
2	281	19.5	2	209	17.0
5	317	18.0	5	313	17.4
9	342	17.6	9	284	16.5
17	283	18.3	17	233	16.5
12	256	15.3	12	273	16.3
15	206	18.4	15	244	18.1
8	256	18.7	8	218	14.5
16	237	15.7	16	209	15.5
19	223	13.0	19	245	15.0
11	285	16.8	11	300	17.0
Av.	276	17.6		281	18.1

Table 9. Cooking losses of fresh and frozen U.S. Good top round roasts.

Fresh							Frozen						
Roast	Total cooking loss		Volatile loss		Dripping loss		Roast	Total cooking loss		Volatile loss		Dripping loss	
No.	g.	%	g.	%	g.	%	No.	g.	%	g.	%	g.	%
14	1328	16.79	920	11.63	406	5.13	14	1712	20.63	1230	14.82	477	5.74
7	1697	19.21	1005	11.38	688	7.79	7	1809	23.60	1198	15.63	610	7.96
6	809	15.39	522	9.93	285	5.42	6	1307	21.86	883	14.09	483	7.71
10	1332	18.21	914	12.50	418	5.72*	10	1432	19.03	998	13.27	430	5.72*
1	1430	20.70	895	12.95	533	7.71**	1	1662	24.22	1163	16.95	497	7.24
18	1708	21.50	967	12.17	737	9.28**	18	1345	22.44	870	14.51	472	7.87
20	1433	20.97	893	13.07	538	7.87	20	1689	26.23	1098	17.05	588	9.13
4	1217	20.54	583	9.84	633	10.69**	4	1630	23.62	1104	16.00	523	7.58
3	1219	17.69	755	10.96	467	6.78	3	1910	26.78	1379	19.34	531	7.45
13	1503	19.45	923	11.94	577	7.47	13	2225	27.78	1403	17.52	821	10.25
2	1241	19.04	792	12.15	449	6.89	2	1364	24.44	865	15.50	498	8.92
5	1760	22.08	1101	13.81	654	8.21**	5	2093	25.67	1467	17.99	622	7.63
9	1786	20.39	1230	14.04	551	6.29	9	1938	24.85	1283	16.45	653	8.37
17	1360	19.43	850	12.14	507	7.24	17	1354	21.17	882	13.79	471	7.36
12	1126	14.90	675	8.93	448	5.93	12	1857	24.50	1153	15.21	700	9.23
15	817	16.38	614	12.31	202	4.05	15	1401	22.90	836	13.67	564	9.22
8	1186	19.19	757	12.25	428	6.91	8	1635	24.14	953	14.07	680	10.04
16	1087	15.96	700	10.28	385	5.65	16	1281	20.90	914	14.91	366	5.97
19	993	12.80	657	8.47	333	4.29	19	1892	25.55	1326	17.91	563	7.60
11	1484	19.33	908	11.83	571	7.44**	11	1911	24.00	1347	16.92	561	7.05
Av.	1276	18.50	828	11.65	491	6.84		1676	23.7	1118	15.78	556	7.90

* Drip losses - same for fresh and frozen.

** Drip losses - greater for fresh than frozen.

Table 10. Preslicing storage losses for fresh and frozen U.S. Good top round roasts.

Fresh			Frozen		
Roast number	g.	%	Roast number	g.	%
14	268	3.38	14	257	3.09
7	301	3.39	7	189	2.46
6	196	3.71	6	122	1.94
10	220	3.00	10	161	2.14
1	112	1.61	1	124	1.80
18	172	2.15	18	113	1.88
20	136	1.98	20	76	1.18
4	94	1.55	4	128	1.86
3	163	2.36	3	89	1.25
13	313	4.04	13	137	1.71
2	221	3.38	2	30	0.54
5	304	3.80	5	139	1.70
9	225	2.56	9	124	1.59
17	150	2.14	17	75	1.17
12	134	1.77	12	135	1.77
15	53	1.04	15	67	1.09
8	154	2.49	8	68	1.00
16	139	2.03	16	64	1.04
19	156	2.01	19	137	1.85
11	303	3.93	11	102	1.28
Av.	190.1	2.6		116.9	1.6

Table 11. Slicing losses of fresh and frozen U.S. Good top round roasts.

Fresh									Frozen								
Roast	Total slicing loss		Volatile loss		Usable loss		Waste loss		Roast	Total slicing loss		Volatile loss		Usable loss		Waste loss	
No.	g.	%	g.	%	g.	%	g.	%	No.	g.	%	g.	%	g.	%	g.	%
14	1549	19.59	53	.67	646	8.15	850	10.73	14	1252	15.09	32	.38	599	7.20	621	7.47
7	1610	18.23	54	.61	345	3.89	1211	13.64	7	1429	18.65	53	.69	639	8.33	737	9.61
6	1278	24.31	47	.89	453	8.57	778	14.71	6	1309	20.89	28	.45	303	4.83	978	15.59
10	1378	18.84	61	.83	564	7.69	753	10.26	10	1406	18.69	57	.76	334	4.43	1015	13.47
1	1196	17.31	68	.98	478	6.89	650	9.37	1	874	12.73	31	.45	199	2.89	644	9.36
18	1942	24.44	43	.54	790	9.89	1109	13.89	18	936	15.62	18	.30	206	3.43	712	11.87
20	1159	16.96	64	.93	360	5.25	735	10.72	20	890	13.82	46	.71	174	2.69	670	10.37
4	1443	24.36	59	.98	324	5.36	1060	17.53	4	890	12.90	35	.51	274	3.97	581	8.41
3	1161	16.85	35	.51	369	5.34	757	10.96	3	840	11.78	28	.39	252	3.53	560	7.84
13	1665	21.55	255	3.29	387	5.00	1023	13.21	13	1358	16.96	36	.45	382	4.77	940	11.74
2	1284	19.70	46	.71	385	5.89	853	13.06	2	1046	18.74	33	.60	201	3.59	812	14.50
5	1372	17.21	70	.88	445	5.57	857	10.73	5	1471	17.38	58	.71	777	9.53	636	7.80
9	1519	17.34	64	.73	397	4.51	1058	12.03	9	1159	14.86	43	.55	372	4.76	744	9.52
17	1343	19.18	110	1.57	407	5.80	826	11.77	17	1096	17.13	30	.47	330	5.14	736	11.47
12	1552	20.54	79	.04	1203	15.89	270	3.57	12	1049	13.84	54	.71	259	3.40	736	9.65
15	935	18.74	232	4.55	211	4.14	492	9.65	15	873	14.27	47	.77	214	3.50	612	9.98
8	960	15.54	31	.50	182	2.94	747	12.06	8	1459	21.54	39	.57	379	5.58	1041	15.33
16	1181	17.34	39	.57	354	5.18	788	11.53	16	875	14.27	40	.65	181	2.95	654	10.65
19	1926	24.83	92	1.18	671	8.63	1163	14.95	19	1013	13.68	54	.73	310	4.18	649	8.75
11	1547	20.15	55	.71	685	8.89	807	10.47	11	1764	22.16	51	.64	610	7.64	1103	13.82
Av.	1400	19.7	77.9	1.1	482.8	6.7	1222.7	11.7		1149.5	16.3	40.7	.6	349.8	4.8	759.1	10.9

Table 12. Slicing yields and costs for fresh U.S. Good top round roasts.

Roast identification number	A.P. weight	Cost A.P. weight	Weight cooked E.P.	No. 3-oz. portions per roast	Per cent portion yield	Servings per pound A.P.	Servings per pound E.P.	Cost per pound E.P.	Percentage increase	Cost per serving E.P.
14	17.5	$14.88	10.5	54	60.1	3.1	5.14	$1.42	167	$0.28
7	19.5	16.58	11.5	63	58.9	3.2	5.48	1.44	169	0.26
6	11.6	9.86	6.6	35	56.9	3.0	5.30	1.49	175	0.28
10	16.2	13.77	9.7	52	59.8	3.2	5.36	1.42	167	0.27
1	15.3	13.01	9.2	48	60.1	3.1	5.22	1.41	166	0.27
18	17.6	14.96	9.1	47	51.6	2.7	5.16	1.64	193	0.32
20	15.1	12.84	9.0	48	59.9	3.2	5.33	1.43	168	0.27
4	13.3	11.31	7.0	39	52.4	2.9	5.57	1.62	191	0.29
3	15.2	12.92	9.6	50	62.9	3.3	5.21	1.35	159	0.26
13	17.1	14.54	9.8	53	57.4	3.1	5.41	1.48	174	0.27
2	14.4	12.24	6.1	44	57.7	3.1	7.21	2.01	295	0.28
5	17.6	17.60	10.0	52	56.8	3.0	5.20	1.76	207	0.34
9	19.4	16.49	11.5	63	59.5	3.2	5.48	1.43	168	0.26
17	15.5	13.18	9.1	53	59.1	3.4	5.82	1.45	112	0.25
12	16.7	14.20	10.4	57	62.6	3.4	5.48	1.37	161	0.25
15	11.2	9.52	7.0	41	62.4	3.7	5.86	1.36	160	0.23
8	13.7	11.65	8.5	45	62.6	3.3	5.29	1.37	161	0.26
16	15.1	12.84	9.7	50	64.5	3.3	5.15	1.32	96	0.26
19	17.1	14.54	10.3	55	60.2	3.2	5.34	1.41	166	0.26
11	17.0	14.45	9.6	49	56.5	2.9	5.10	1.51	178	0.30
Av.	15.8	13.57	9.3	50	59.1	3.2	5.46	1.48	172	0.27

Table 13. Slicing yields and costs for frozen U.S. Good top round roasts.

Roast identification number	A.P. weight	Cost A.P. weight	Weight cooked E.P.	No. 3-oz. portions per roast	Per cent portion yield	Servings per pound A.P.	Servings per pound E.P.	Cost per pound E.P.	Percentage increase	Cost per serving E.P.
14	18.3	$15.56	11.2	60	61.1	3.3	5.36	$1.39	167	$0.26
7	16.9	14.37	9.3	50	55.2	3.0	5.38	1.55	182	0.29
6	13.8	11.73	7.6	41	55.2	3.0	5.39	1.54	181	0.29
10	16.6	14.11	10.0	54	60.0	3.3	5.40	1.41	166	0.26
1	15.2	12.92	9.3	45	61.1	3.0	4.84	1.39	164	0.29
18	13.2	11.22	8.0	39	60.0	3.0	4.88	1.40	165	0.29
20	14.2	12.07	8.3	44	58.6	3.1	5.30	1.45	171	0.27
4	15.2	12.92	9.4	46	61.6	3.0	4.89	1.37	161	0.28
3	15.7	13.35	9.5	51	60.1	3.2	5.37	1.41	166	0.26
13	17.6	14.96	7.2	51	53.5	2.9	7.08	1.85	218	0.26
2	12.3	10.46	4.7	37	56.1	3.0	7.87	2.23	262	0.28
5	18.0	15.30	9.8	54	54.6	3.0	5.51	1.56	184	0.28
9	17.2	14.62	10.1	53	58.6	3.1	5.23	1.45	171	0.28
17	14.1	11.99	8.5	45	60.3	2.5	5.29	1.41	166	0.27
12	16.8	14.28	10.0	51	59.5	3.0	5.10	1.43	168	0.28
15	13.5	11.48	8.3	43	61.6	3.2	5.18	1.38	162	0.27
8	15.0	12.75	8.0	43	53.2	2.9	5.38	1.59	187	0.30
16	13.5	11.48	8.6	47	63.7	3.5	5.47	1.33	156	0.24
19	16.3	13.86	7.4	51	58.8	3.1	6.89	1.87	220	0.27
11	17.6	14.96	9.2	48	52.4	2.7	5.22	1.63	192	0.31
Av.	15.6	13.22	8.9	48	58.3	3.0	5.55	1.53	180	0.28

SHORT-TERM FREEZER STORAGE EFFECT ON U.S. GOOD INSIDE ROUND OF BEEF

by

MARY PATRICIA WORTHAM

B. S., Loretto Heights College,
Denver, Colorado, 1959

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Institutional Management

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1962

For reasons of convenience and/or cost control, the use of frozen meat continues to increase in institutions. Frozen and properly stored fresh meats lose little of their palatability for several months. The use of short-term freezer storage in certain situations appears to be advantageous.

Twenty pairs of U.S. Good inside round beef roasts were obtained from a local wholesale distributor to study the effect of short-term freezer storage on cooking losses, slicing yields, and cost per three-ounce serving. Paired comparisons were used to analyze the data obtained.

When the carcasses were selected, roasts to be frozen were wrapped in freezer paper and held in the freezer locker for approximately two weeks at -20° F. At the same time, fresh roasts were wrapped in butcher paper, stored in a walk-in refrigerator, and delivered 48 hours before the proper cooking period. The roasts were processed in ten cooking periods using a gas-fired institutional reel oven preheated to 300° F. The internal temperature of each roast and the time interval required for each 10° C. rise were recorded until the internal temperature reached 45° C., and thereafter for every 2° C. rise until the end point cooking temperature of 65° C. (149° F.) was reached. Storage losses and volatile, dripping, and total cooking losses were determined.

Roasts were cooled one hour, covered with aluminum foil, and stored in a reach-in refrigerator (36° F.). Approximately 18 hours later, the meat was portioned into three-ounce servings, each consisting of not more than two slices of meat.

The greatest difference in rate of heat penetration between fresh and frozen roasts occurred during the time interval required for the first 10° C. rise in internal temperature. Total cooking time was approximately the same for fresh and frozen roasts, being 276 and 281 minutes, respectively.

Total cooking losses were greater for frozen roasts (27.3 per cent) than for fresh roasts (18.5 per cent). Frozen roasts had greater drip and volatile cooking losses than did fresh roasts.

The mean storage loss for the period prior to roasting was greater for fresh roasts than for frozen. Preslicing storage losses were greater for fresh roasts than for frozen roasts.

Total slicing losses were greater for fresh roasts (19.7 per cent) than for frozen roasts (16.3 per cent). Volatile slicing losses were greater for fresh roasts than for frozen while the waste slicing losses were similar. Fresh roasts had greater usable scrap slicing losses.

The average slicing yields for fresh and frozen roasts were equal. A significant negative correlation coefficient was found for total slicing losses and percentage portion yield. Usable scrap and percentage portion yield showed a nonsignificant negative correlation coefficient, whereas a significant negative correlation was demonstrated for waste and percentage portion yield. The average number of servings per pound for roasts as purchased was 3.2 for fresh and 3.0 for frozen.

A three-ounce portion of the cooked fresh roasts had an average cost of $0.27 whereas for the frozen roast it was $0.28. On the basis of cost per pound or per serving, little difference was apparent between the fresh and the frozen roasts.

Fresh roasts had greater storage losses, both preroasting and preslicing, total slicing losses, volatile slicing losses, and usable scrap than did frozen roasts. Frozen roasts had greater total cooking losses, drip cooking losses, and volatile cooking losses. The losses of the fresh roasts appeared to counterbalance the losses of the frozen roasts; as the roasts, both fresh and frozen, had similar percentage portion yields, waste slicing losses, and number of three-ounce portions.