EFFECTS OF A COMMERCIAL AND THREE HOME FREEZING METHODS ON SELECTED CHARACTERISTICS OF PORK LOIN CHOPS

by 837

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INTRODUCTION

Advances in cryogenic freezing technology have improved quality in many food products available on the frozen food market (Aref, 1967). Many early researchers investigated the effects of freezing on the quality of meat, stressing the value of rapid freezing rates and low storage temperatures. Hankins et al. (1938) reported increased tenderness in steaks frozen at -10°F and -40°F compared to those frozen at 20°F. Brady et al. (1942) found that the smallest total cooking losses in steaks resulted from "quick" freezing at -15°F and cooking from the frozen state compared to those frozen at 0°F and/or thawed before cooking. Dubois et al. (1940) reported that storage of pork at temperatures of 10°F and 15°F resulted in rancidity in four months. Those studies did not include extremely rapid rates of freezing achieved in modern commercial cryogenic freezing processes.

Gray (1967) claimed advantages of decreased moisture loss, improved color and absence of dehydration when using a liquid nitrogen system for commercial freezing of hamburger patties. When frozen lamb chops were thawed before cooking, Lind (1969) reported significantly higher tenderness scores for chops frozen in moving air at -20°F and by liquid nitrogen vapor at -160°F than for those frozen in still air at 0°F. However, when the lamb chops were cooked from the frozen state, there was no significant difference in the tenderness scores of chops frozen by the three methods. Warner-Bratzler shear values indicated no significant differences in tenderness of the same lamb chops. Research is needed to evaluate the relative effects of cryogenic freezing and freezing by methods available in the home on the acceptability of red meats. The objective of the work

reported here was to investigate the effects of a commercial liquid nitrogen method and three home freezing methods on selected characteristics of pork loin chops after storage under home conditions for 1 and 4 weeks.

REVIEW OF LITERATURE

Advantages of Commercial Freezing of Meats

Enochian (1968) pointed out that commercially frozen meats comprise only a small proportion of the total meat consumption. In 1965 this amount was only 2 lb per capita of the 170 lb per capita total annual meat consumption, and a large part of this was used by institutions. The meat packing industry and retailers are interested in further expansion of the frozen meat market and centralization of meat cutting and packaging processes. Centralized processing saves the retailer the expense of space and sanitation required for meat cutting, labor costs and problems of inventory. Packers can make more efficient use of the carcass by-products and save shipping expenses by retaining trimmings, offal, fat and bones in a central location (Enochian, 1968; Ziemba, 1959).

The Consumer and Frozen Meats

Consumer acceptance of frozen meats. Although meats are frequently frozen in the home, consumers often are hesitant to purchase prepackaged frozen meat. Williams (1966) reported that 80% of all meat purchased fresh in supermarkets was frozen in the home and stored until used. Weidenhamer et al. (1969) found that 87% of the respondents in a survey sometimes froze fresh meat at home. Relatively few (13%) of this group said they would like to purchase frozen raw meat, 6% said "it would depend" and

only 1% indicated that they already purchased frozen meat. The remainder of the group (68%) were not interested in purchasing frozen meat. Reasons generally cited were: they thought there would be lack of standards for judging frozen meats, they wouldn't know how long the meat had been frozen before purchase and they would not be able to judge its quality. The dark color of some frozen meats often makes them unappealing to consumers (Sulzbacher et al., 1968; Townsend et al., 1958). Respondents in a survey by Kansas Agricultural Experiment Station workers (1969) indicated that if consistent "quality" were guaranteed, 83% would purchase frozen beef; 72%, pork; 54%, lamb.

Because cryogenic processes have been used successfully to improve the quality of other frozen food products, researchers now are exploring the use of these extremely rapid freezing methods to produce prepackaged frozen meats that will satisfy the demands of consumers.

Frozen meats in the home. Handling of frozen meats in the home varies with facilities available, knowledge of using frozen meats and personal preference. In a survey among those who purchased frozen meats (Anon., 1967), it was reported that 45.4% had a chest or upright home freezer available, 42.9% a two-door refrigerator-freezer combination, and 27.4% a compartment type freezer, indicating some respondents had more than one type of freezer facility; and 6.1% had no freezer storage space at all. Respondents in the survey of Weidenhamer et al. (1969) indicated lengths of home storage time for frozen meats from a week or less to six months or more. The meats most commonly frozen were beef, chicken, and fresh pork. Two-thirds of those who froze meats said they usually thawed the meat completely before cooking it, while only 5% generally cooked meat

from the frozen state. Kansas Agricultural Experiment Station workers (1969) reported that over 94% of all respondents in a local survey knew frozen meat could be cooked without thawing. They found that less than one-fourth of the low income (less than $3,000) group started to cook meat while it was frozen, whereas about one-half of all other income groups ($3,000 to $10,000 and over) used this procedure.

Basic Principles of Freezing

Ice formation. Freezing foods reduces molecular mobility and changes water to the solid or crystalline state, thus reducing the rate of deteriorative processes (Luyet, 1968). Many characteristics of frozen foods can be attributed to the rates at which they are frozen and physical phenomena affected by the rate of freezing. Ice crystallization was defined by Meryman (1956) as the removal of water from solution and isolation into biologically inert foreign bodies. He pointed out that the ultimate size of the ice crystals is dependent upon rates of crystal nucleation and crystal growth, which are temperature dependent. Crystal nucleation is the aggregation of a group of molecules into a tiny ordered particle (Fennema et al., 1964). At low temperatures the critical size, the size at which there is an equal chance for the nucleus to grow or diminish, is small and thus nucleation occurs rapidly. In contrast to crystal nucleation rates, crystal growth rates decrease with low temperatures. If heat is not removed from the material faster than it can be supplied by a few growing crystals, those few crystals will continue to grow and further nucleation will be at a minimum. As the rate of freezing is increased, large numbers of ice crystals of small size are formed (Fennema et al.,

1968; Meryman, 1956). As frozen materials are thawed, recrystallization of the ice structure may occur. At or near the melting point, molecules tend to become mobile and some ice crystals may grow at the expense of smaller ones, giving the ice structure a coarse grain (Luyet, 1968).

Ice formation in muscle tissue. Meryman (1956) stated that ice crystallization in muscle tissue is wholly or predominantly extracellular until rather rapid rates of freezing are obtained and crystallization occurs throughout the tissue. He used these criteria to define the terms "rapid" and "slow" rather than arbitrary temperatures or freezing times. This is a useful classification, as there is wide variation in the literature using the terms "quick," "rapid" or "slow." Each researcher has used those terms as comparative values within his own work. Hiner et al. (1945) reported from histological examination that freezing at 18°F resulted in formation of large ice crystals between the muscle fibers in beef longissimus dorsi and pushed them into irregular groups. In samples frozen at -10°F, ice crystals formed within the fibers and some fibers were ruptured by expansion on freezing. At -40°F and -114°F, fibers remained more nearly parallel, and rupturing became more extensive than at the higher temperatures. Dubois et al. (1940) reported similar results with frozen beef. Beef "quick" frozen at -25°F appeared much like unfrozen meat, but that frozen in still air at 0°F indicated a "breakdown" of the tissue.

Effects of Rate of Freezing and Freezer Storage on Selected Characteristics of Meat

Meat proteins and structure. Freezing and subsequent thawing results in increased loss of fluid from meat. Researchers generally have

attributed the amount of fluid loss to the rate of freezing and its effect on protein denaturation, water holding capacity and mechanical action by the ice crystals. Paul et al. (1937) compared fresh beef rib roasts with those frozen at -18°C. They found that frozen beef had greater ($p < 0.01$) total cooking losses and less ($p < 0.05$) press fluid than the fresh beef. Brady et al. (1942) reported consistently higher total cooking losses (drip and evaporation) for 0.6 in. thick beef, lamb and pork steaks "slow" frozen at 0°F compared to those "quick" frozen at -15°F. Dubois et al. (1940) reported fluid losses during thawing of beef rib roasts of approximately 3.5% for those "rapidly" frozen at -25°F, 6.0% for those "moderately rapid" blast frozen at -10°F and 0°F, and 8.0% for those "slow" frozen in still air at -10°F and 0°F. Hiner et al. (1945) froze 1.5 in. thick pieces of beef longissimus dorsi at 18°F, -10°F, -40°F and -114°F in still air, and at -40°F in moving air. Drip during thawing decreased as freezing temperatures were lowered from 18°F to -114°F. They believed that at -114°F, the moisture was frozen largely within the fibers and was almost entirely reabsorbed during thawing, and because freezing occurred mainly outside the fibers at 18°F, the moisture was not reabsorbed as completely and dripped from the meat. Crigler et al. (1968) froze broiler breast muscle at rates varying from 0.5 min to 1,497 min total freezing time, and studied the amount and composition of drip during thawing as a measure of cell disruption. Generally, as time of freezing increased, cell disruption increased; however, they noted several exceptions. Maximum drip and solids in drip were found for meat frozen in 87, 252 and 1,042 min, whereas relatively low amounts were reported for meat frozen in 1 to 18 min, 132 to 225 min and longer than 1,044 min. When muscles were frozen in 0.5 min in

liquid nitrogen, an increase in amount of drip and solids was noted, indicating greater cell disruption.

Proteins are the principle water binding substance of muscle tissue. Water molecules are attracted to the charged groups of the proteins and held there in a rigid, ordered state (Fennema et al., 1964). Luyet (1968) stated that the "change produced by freezing and thawing seems to be the separation of water molecules from other components with which it is normally associated." Sulzbacher et al. (1968) stated that freezing results in denaturation or changes in the muscle proteins, and that the drip from frozen meats contains proteins, peptides, amino acids, lactic acid, purines, B-vitamins and salts. He concluded that in slow freezing, proteins are denatured by the high ionic strength of the extracellular fluid, and lose water holding capacity. Miller et al. (1968) studied soluble protein and water holding capacity as measures of protein denaturation during freezing. More soluble protein was lost through dripping during cooking from frozen meat than from unfrozen meat. Water holding capacity was expressed as grams of extracted liquid per 100 g of protein, measured by centrifuging 20 g samples of meat, and as g of liquid per 100 g protein lost by cooking 25 g samples of meat in glass tubes for 10 min at 90°C. They found that frozen meat had a higher water holding capacity when measured by the cooking procedure than when measured by centrifuging. They hypothesized that this result occurred because the soluble protein may have been denatured when cooked and remained with the mass. Deatherage et al. (1960) reported that "quick" freezing at -55°C of both ground and small cubes of meat resulted in a small but significant increase in water holding capacity, whereas "slow" freezing at -15°C decreased water holding capacity

slightly. There was a small but significant increase in charged groups (0.5 equivalents per 10^4 g protein) of the muscle proteins caused by "quick" freezing and thawing of meat. They theorized that formation of tiny ice crystals in "quick" freezing resulted in "loosening" the protein structure with an increase in charged water binding groups. Huber et al. (1970a, b) froze 1 cm cubes of chicken and turkey muscle at -10°C and by immersion in liquid nitrogen for 45 sec. Total protein solubility was greater ($p < 0.01$) for samples of raw muscle frozen at -10°C than for those frozen in liquid nitrogen, indicating greater damage to proteins of tissue frozen in liquid nitrogen.

Color. Ramsbottom et al. (1941) stated that the large ice crystals formed when meat is frozen slowly cause the meat to appear dark, whereas small crystals formed in more rapidly frozen meat produce more light scattering and a lighter appearance. Hamre et al. (1967) reported that diced chicken appeared lighter with faster rates of freezing. Light meat samples frozen by immersion in liquid nitrogen or carbon dioxide appeared "nearly as white as chalk." Samples frozen with liquid nitrogen spray or carbon dioxide snow were intermediate in color, whereas samples frozen in still air at -10°C and blast air at -28.9°C were darkest. Kansas Agricultural Experiment Station researchers (1969) reported that the surface color of lamb chops was somewhat "bleached" by liquid nitrogen freezing at -40°F and became more serious at temperatures of -60°F to -70°F. On this basis, they recommended using a programmed series of temperature decreases in cryogenic processes to temper the product.

During storage, the myoglobin of muscle is oxidized to metmyoglobin, producing a darkened, brownish color. Hankins et al. (1941) reported that

during storage at 0°F and 18°F for 10 months, the black color components of unexposed lean of pork increased in percentage, whereas the white components decreased. Ramsbottom (1947) stored beef at six temperatures ranging from 26°F to -20°F. Meat was discolored in less than 30 days at 26°F, in 60 days at 20°F, in 120 days at 10°F, and 180 days at 0°F. Meat stored at -10°F and -20°F was still good in color and appearance after one year of storage. Ramsbottom et al. (1941) froze steaks at 10°F and -30°F and stored lots of each at those two temperatures for one year. Steaks frozen and stored at 10°F appeared darkest, which they attributed to the combined effects of large ice crystals formed during freezing and accelerated oxidation of myoglobin to metmyoglobin at the higher temperature of storage. Cuts frozen and stored at -30°F were relatively light in both the frozen and defrosted states. Ice structure was not affected in samples frozen at -30°F and stored at 10°F, indicating that no recrystallization occurred and color changes during the storage period were a result of oxidation of myoglobin.

Tenderness. Sulzbacher et al. (1968) stated that freezing improves the tenderness of meat through physical action on the meat. Hiner et al. (1945) reported that as temperatures of freezing were lowered from 18°F to -114°F, resistance to shearing decreased. They attributed this change to fiber splitting and breaking or stretching of interstitial connective tissue surrounding the muscle fibers and bundles caused by the ice crystals. Hankins et al. (1938) also reported greater tenderness in steaks frozen at -10°F than for steaks frozen at 20°F. Lind (1969) reported that tenderness scores for lamb chops frozen by moving air at -20°F and by liquid nitrogen vapor at -160°F were higher ($p < 0.05$) than for chops frozen at 0°F.

Flavor. The chief flavor problem encountered with frozen meats is the deterioration of flavor caused by development of rancidity during prolonged freezer storage. Rancidity is a more serious problem in pork than in other meats, and is dependent upon both time and temperature of storage. Dubois et al. (1940) reported that pork chops stored at 15°F became undesirably rancid in two months as measured by active oxygen and taste panel scores. Pork stored at 10°F became rancid in four months, that stored at 0°F showed some rancidity after 12 months, but no rancidity developed in meat stored at -8°F or -40°F for a 14 month period.

Hall et al. (1948) stored pork loin roasts at 10°F, 0°F, and -10°F. They noted a progressive increase of free fatty acids between 0 and 72 weeks in raw and cooked fat at 10°F, no increase between 0 and 56 weeks at 0°F and no increase during 72 weeks at -10°F. Flavor scores for lean and fat of roasts subjected to all treatments were about the same for the first 12 weeks, after which the flavor of roasts stored at 0°F and 10°F deteriorated at about the same rate. Scores for roasts stored at -10°F remained high. They also noted a low concentration of free fatty acids at -10°F and -20°F. Hankins et al. (1941) reported an increase between 0 and 24 weeks in free fatty acids in lean and fat of pork loins stored at 18°F, but no appreciable change for those stored at 0°F for the same period. They noted from additional work that less free fatty acid developed in samples after 48 weeks of storage of -10°F and 0°F than after 13 weeks of storage at 20°F. Free fatty acid development is a measure of hydrolytic fat decomposition, and although it does not necessarily parallel oxidative rancidity development, it usually accompanies this reaction and is an indication of rancidification (Shrewsbury et al., 1942).

EXPERIMENTAL PROCEDURE

Experimental Design and Statistical Analysis

Pork loins from each of four animals were removed posterior to the 11th thoracic vertebra and anterior to the 6th lumbar vertebra and cut into 13 pair of chops 1 in. thick, numbered 1 to 13 from the anterior to the posterior end of the loin. A pair consisted of one chop from the left loin and one from the same region of the right loin. Pairs from each animal were randomly assigned to the 13 treatment combinations shown in Table 1. The specific experimental design is given in Table 2. One pair from each animal was held unfrozen and cooked fresh to provide a basis for studying the effects of the freezing treatment combinations. Each of the remaining 12 pair were processed by a commercial liquid nitrogen freezing procedure or a home freezing procedure. All frozen chops were stored for 1 or 4 weeks under home conditions (Table 1).

For home freezing treatments, six pair of chops per animal were packaged in styrofoam trays with an overwrap of polyvinyl film 0.0055 in. thick, as they might be wrapped if purchased fresh in the market. Home treatments employed three household freezers, for which temperature fluctuation ranges and average temperatures were determined in preliminary work. These were: H_1, the freezing compartment of a one-door refrigerator-freezer combination with a temperature range of 14°F to 18°F and an average temperature of 15.8°F; H_2, the freezing section of a two-door refrigerator-freezer combination with a temperature range of -8°F to 4°F and an average temperature of -3.4°F; and H_3, an upright household freezer with a temperature range of -18°F to 6°F and an average temperature of -8.3°F.

Table 1. Freezing-storage treatment combinations for pork loin chops.

Treatment combination number	Treatment combinations		
	Freezing conditions	Storage conditions	Storage time, weeks
1	Unfrozen	R	0
2	C	H_1	1
3	C	H_1	4
4	C	H_2	1
5	C	H_2	4
6	C	H_3	1
7	C	H_3	4
8	H_1	H_1	1
9	H_1	H_1	4
10	H_2	H_2	1
11	H_2	H_2	4
12	H_3	H_3	1
13	H_3	H_3	4

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 Household upright freezer.

Table 2. Experimental design with chop codes for treatment and evaluation of pork loin chops.

Treatment combination	Animal I		Animal II		Animal III		Animal IV	
	Sen-sory	Objec-tive	Sen-sory	Objec-tive	Sen-sory	Objec-tive	Sen-sory	Objec-tive
1	L5	R5	R6	L6	L13	R13	L3	R3
2	L7	R7	L2	R2	L6	R6	L2	R2
3	R9	L9	R4	L4	L5	R5	R5	L5
4	L2	R2	L1	R1	L9	R9	L4	R4
5	L13	R13	L13	R13	L11	R11	L12	R12
6	L3	R3	R12	L12	L4	R4	R8	L8
7	R1	L1	L7	R7	R10	L10	L1	R1
8	R6	L6	R8	L8	R12	L12	R11	L11
9	L4	R4	R9	L9	R8	L8	R13	L13
10	L11	R11	L3	R3	L3	R3	R7	L7
11	L12	R12	L5	R5	R7	L7	R6	L6
12	R10	L10	L11	R11	R1	L1	R10	L10
13	R8	L8	R10	L10	R2	L2	L9	R9

Chop codes:

L, Left loin.

R, Right loin.

1-13, Chop numbers from anterior to posterior of the loin.

Six pair of chops per animal were packaged and frozen by a commercial process at the Kansas State University Department of Animal Science and Industry. Chops were packaged in Dupont Iolon skin tight film with gas permeability values ranging from 46.5 to 77.5 cc per sq. meter per 24 hr and frozen in a simulated liquid nitrogen freezer. Freezing required 8 to 9 min using the following temperature program: 0°F, 1/2 min; -50°F, 1/2 min; -100°F, 1 min; -150°F, 1 min; -200°F, 1 min; temper 1 min with no more vapor entering the cabinet. The time in each case was taken when the cabinet reached a given temperature.

One chop from each pair was randomly selected for sensory evaluation of the longissimus dorsi (LD) muscle and the matching chop was used for objective measurement of the LD muscle (Table 2). Back fat from both chops was used for measurement of free fatty acids (Fig. 1). Data for each measurement were analyzed by the following analysis of variance:

Source of variation	DF
Animals	3
Treatments	12
Fresh vs. frozen	1
Freezing treatment, liquid nitrogen vs home (FT)	1
Storage conditions (SC)	2
Storage time (ST)	1
FT X SC	2
FT X ST	1
SC X ST	2
FT X SC X ST	2
Error	36
Total	51

A separate analysis of cooking time for frozen chops was made to determine differences among freezing and storage treatments. The analysis of variance was:

Source of variation	DF
Animals	3
Treatments	11
Freezing treatment, liquid nitrogen vs. home (FT)	1
Storage conditions (SC)	2
Storage time (ST)	1
FT X SC	2
FT X ST	1
SC X ST	2
FT X SC X ST	2
Error	33
Total	47

Cooking and Evaluation

The sampling plan used for objective measurements and sensory evaluation is shown in Fig. 1.

Cooking. Two pair of fresh chops were cooked and evaluated at each of two experimental periods, and four pair of frozen chops were cooked and evaluated at each of 12 experimental periods. Fresh chops were held in the original package in a refrigerator at 5°C for 48 hr before cooking; frozen chops were cooked from the frozen state. Each pair of chops was placed on a 4 in. high wire rack set in a shallow pan and cooked in a rotary hearth oven at 350°F to an internal temperature of 75°C measured in one chop of each pair.

EXPLANATION OF FIGURE I

Fig. 1. Sampling plan for cooked pork loin chops.

1. 1/2 in. cubes for taste panel evaluation.
2. 1/2 in. cores for Warner-Bratzler shear and water holding capacity measurements.
3. Ground muscle for total moisture determination.
4. Fat sample for titration of free fatty acids.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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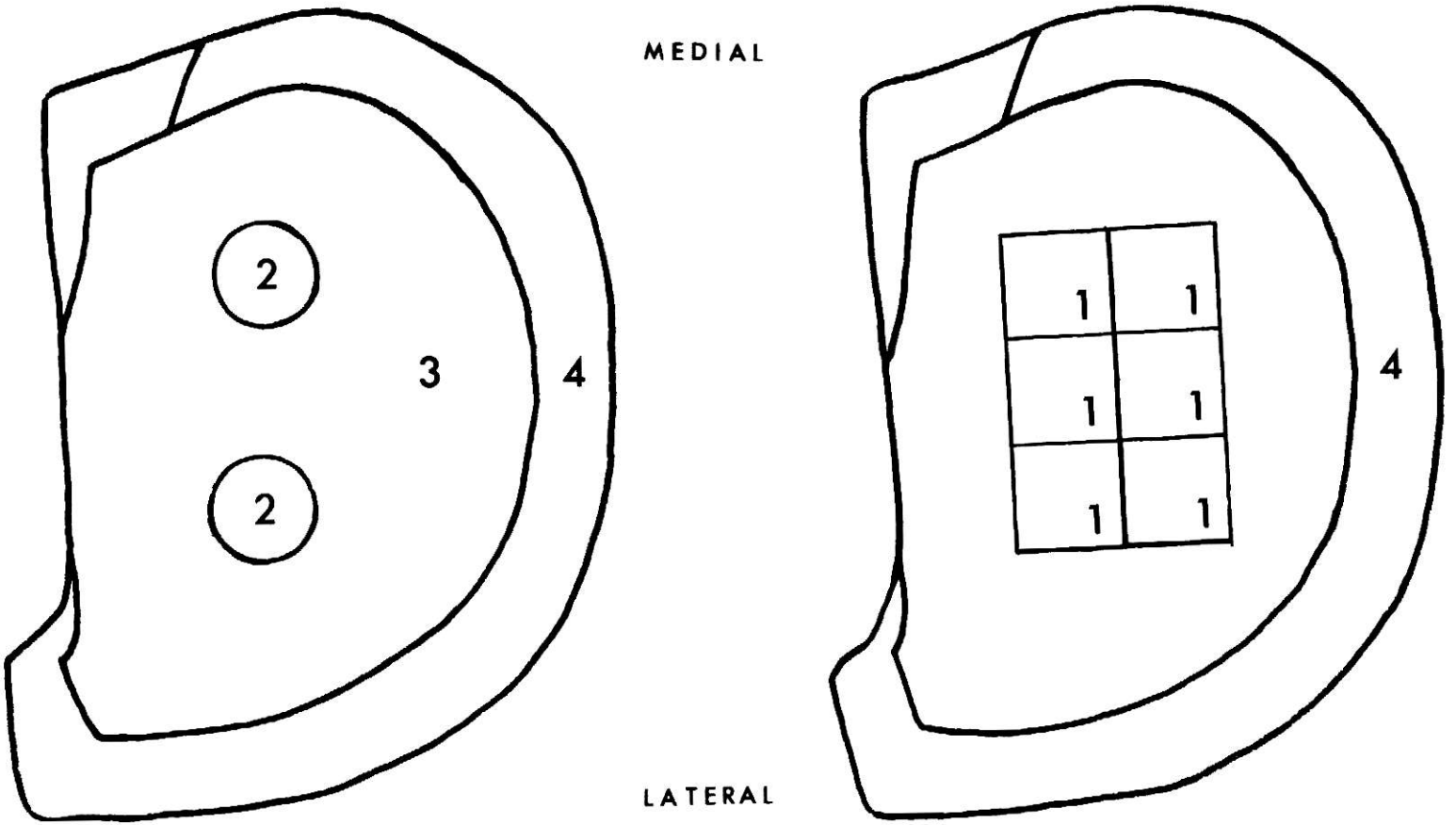

OBJECTIVE

SUBJECTIVE

Cooking time. Cooking time for chops was recorded as the minutes required to reach an internal temperature of 75°C. Time for frozen chops to reach 5°C also was recorded to provide a base for comparison to the fresh chops with an initial internal temperature of 5°C.

Cooking losses. Cooking losses, total, volatile and dripping, were calculated as the percentage of the initial fresh or frozen weight of a pair of chops.

Warner-Bratzler shear values. Two 1/2 in. cores from lateral and medial points in the LD muscle were sheared once on the Warner-Bratzler shearing apparatus with a 25-lb dynamometer.

Water holding capacity. Water holding capacity (WHC) was measured by the method described by Miller et al. (1965) using two samples of LD per chop and pressing the samples from four chops at one time. Samples were taken from the center of the cores used for Warner-Bratzler shear values.

Total moisture. Percentage total moisture was determined by drying duplicate 10-g samples of ground LD muscle in a C. W. Brabender Semiautomatic Rapid Moisture Tester for 60 min at 121°C.

Free fatty acids. The outside fat covering on the chops was ground and extracted by the method of Watts et al. (1947). Free fatty acids were measured by titrating an aliquot of the fat extracts in neutral alcohol. Results are expressed as percentage oleic acid and acid number (mg KOH per g extracted fat).

Sensory evaluation. The LD muscle was cut into 1/2 in. cubes. A five-member taste panel selected cubes at random and evaluated them for flavor, juiciness, tenderness and over-all acceptability. Flavor and over-all acceptability were evaluated on a desirability scale of 7

(extremely desirable) to 1 (extremely undesirable). Juiciness and tenderness were scored on an intensity scale of 7 (extremely juicy or tender) to 1 (extremely dry or tough). Panelists were asked to record the number of chews required to completely masticate each cube and to describe noticeable flavor characteristics (Form I, Appendix, p. 35). Instructions given to panel members are presented in Form II, Appendix, p. 36.

RESULTS AND DISCUSSION

Throughout the discussion, H_1 refers to a one-door refrigerator-freezer combination; H_2, a two-door refrigerator-freezer combination; H_3, an upright household freezer. Tables containing detailed data for individual measurements and analyses of variance are presented in the Appendix.

Effects of Freezing and Storage Treatments

Appearance of frozen chops. All chops frozen by liquid nitrogen appeared much like fresh chops and had a desirable color. No "bleaching" or cracking was observed in any of the chops as in earlier work reported by the Kansas Agricultural Experiment Station (1969). During storage, commercially frozen chops stored in H_1 darkened and developed a grayish color; those in H_2 also darkened, but to a lesser degree, whereas those in H_3 maintained their original light color. The color of commercially frozen chops was superior to that of home frozen chops after freezing and after 1 and 4 weeks' storage in each of the freezers. Among home frozen chops, those frozen in H_1 were dark immediately after freezing in comparison to chops frozen in the other two types of home freezers, which were light and had good color. During storage, chops in both H_1 and H_2

darkened some, whereas chops in H_3 retained good color. Occasionally, spots of dehydration or frosting were observed on both liquid nitrogen frozen and home frozen chops, but neither dehydration or frosting were extensive.

Cooking time. The mean total cooking time for fresh chops was 36 min and for frozen chops was 51 min (Table 3), a significant ($p < 0.01$) time increase of about 1/3 for cooking from the frozen state over that for fresh chops. This is consistent with reports of time differentials of 1/3 to 1/2 generally found when cooking meat from the frozen state and fresh or thawed meat (Lowe et al., 1952; Lind, 1969; Vail et al., 1943). Analysis of variance of cooking time for frozen chops (Table 9, Appendix, p. 40) showed no significant difference in total cooking time between liquid nitrogen and home frozen chops, among storage conditions (H_1, H_2, H_3), between 1 and 4 weeks' storage or for any of the interactions for those factors. However, time required to reach 5°C was significantly less ($p < 0.05$) for chops stored in H_1 (14 min) than for those stored in H_2 and H_3 (16 min).

Cooking losses, total moisture, water holding capacity and juiciness. Total, volatile and dripping losses were higher ($p < 0.01$) for frozen than for fresh chops (Table 3). The method of freezing also affected cooking losses (Table 4). Total and dripping losses were higher ($p < 0.05$ and $p < 0.01$, respectively) for chops frozen by liquid nitrogen than for chops frozen by home methods. Lind (1969) reported higher cooking losses for lamb rib chops frozen by liquid nitrogen vapor at -160°F than for those frozen in moving air at -20°F or in still air at 0°F.

Total and volatile losses increased between 1 and 4 weeks' storage,

Table 3. Means and F-values for objective and subjective measurements of fresh vs frozen pork loin chops.

Measurement	Fresh	Frozen	F-value
Cooking time, min	36	51	60.00 **
Cooking losses, %			
Total	15.71	21.31	29.90 **
Volatile	10.07	13.39	13.50 **
Dripping	5.26	7.58	23.56 **
Total moisture, %	66.5	65.9	<1
Water holding capacity[a]	0.71	0.75	6.91 *
Juiciness score[b]	5.3	4.5	2.50
Shear value, lb/1/2-in. core	6.5	6.8	<1
Tenderness score[b]	5.2	4.8	2.42
% oleic acid	0.72	0.54	20.27 **
Acid number[c]	1.02	0.79	7.32 *
Flavor score[b]	5.5	4.7	9.22 **
Over-all acceptability score[b]	5.4	4.5	11.68 **

[a] 1.0 (expressible moisture index).

[b] 7 (extremely desirable, juicy or tender) to 1 (extremely undesirable, dry or tough).

[c] mg KOH per g fat.

* $p < 0.05$.

** $p < 0.01$.

Table 4. Means and F-values for objective and subjective measurements of liquid nitrogen vs home frozen pork loin chops.

Measurement	Liquid nitrogen	Home frozen	F-value
Cooking losses, %			
Total	21.92	20.71	4.52 *
Volatile	13.50	13.27	<1
Dripping	8.07	7.08	13.92 **
Total moisture, %	65.5	66.4	4.26 *
Water holding capacity[a]	0.75	0.75	<1
Juiciness score[b]	4.4	4.7	2.39
Shear value, lb/1/2-in. core	6.9	6.6	1.55
Tenderness score[b]	4.8	4.8	<1
% oleic acid	0.56	0.52	6.36 *
Acid number[c]	0.84	0.74	5.04 *
Flavor score[b]	4.8	4.6	1.93
Over-all acceptability score	4.5	4.5	<1

[a] 1.0 (expressible moisture index).

[b] 7 (extremely juicy, tender or desirable) to 1 (extremely dry, tough or undesirable).

[c] mg KOH per g fat.

* $p < 0.05$.

** $p < 0.01$.

whereas dripping losses decreased. Differences between storage periods were significant ($p < 0.05$) only for volatile losses (Table 5).

Total moisture of the LD was practically the same for fresh and frozen chops (Table 3), but was higher ($p < 0.05$) for home frozen chops than for liquid nitrogen frozen chops (Table 4).

Taste panel evaluation indicated greater juiciness in fresh than in frozen meat, in home frozen than in liquid nitrogen frozen meat and a decrease in juiciness between 1 and 4 weeks' storage, but the differences were not significant (Tables 3, 4 and 5).

Shear values and tenderness scores. Tenderness, as measured by Warner-Bratzler shear values, was not affected significantly by freezing per se, by method of freezing, or storage conditions, although there was a slight decrease in tenderness between 1 and 4 weeks' storage (Tables 3, 4 and 5). Taste panel scores for tenderness were affected significantly only by storage conditions and time (Tables 3, 4, 5 and 6). Mean scores were higher ($p < 0.05$) for chops stored in H_1 than mean scores for those stored in H_2 or H_3. Tenderness scores decreased ($p < 0.01$) between 1 and 4 weeks' storage.

Percentage oleic acid, acid number and flavor scores. Values for both percentage oleic acid and acid number (mg KOH per g fat) are measurements of hydrolytic decomposition of the fat around the LD muscle. Although the same titration data were used to calculate both, higher F-values were obtained when the data were analyzed as percentage oleic acid than when analyzed as acid number. Free fatty acid was higher in fat in fresh chops when reported by both percentage oleic acid ($p < 0.01$) and acid number ($p < 0.05$) than for all frozen chops (Table 3), and values for

Table 5. Means and F-values for objective and subjective measurements of pork loin chops after 1 and 4 weeks storage.

Measurement	1 wk	4 wk	F-value
Cooking losses, %			
Total	20.75	21.88	3.94
Volatile	12.72	14.06	7.01 *
Dripping	7.60	5.57	<1
Total moisture, %	66.4	65.6	4.02
Water holding capacity[a]	0.74	0.76	3.64
Juiciness score[b]	4.7	4.3	2.83
Shear value, lb/1/2-in. core	6.6	7.0	3.05
Tenderness score[b]	5.0	4.5	10.05 **
% oleic acid	0.52	0.56	4.67 *
Acid number[c]	0.74	0.84	4.05
Flavor score[b]	4.9	4.6	<1
Over-all acceptability score[b]	4.8	4.2	11.61 **

[a] 1.0 (expressible moisture index).

[b] 7 (extremely juicy, tender or desirable) to 1 (extremely dry, tough or undesirable).

[c] mg KOH per g fat.

* $p < 0.05$.

** $p < 0.01$.

Table 6. Means, F-values and LSD for objective and subjective measurements of pork loin chops stored in three types of home freezers.

Measurement	Storage conditions H_1	H_2	H_3	F-value	LSD[a]
Cooking losses, %					
Total	21.36	20.90	21.98	<1	---
Volatile	13.52	13.11	13.54	<1	---
Dripping	7.44	7.48	7.83	<1	---
Total moisture, %	65.6	66.1	66.3	1.16	---
Water holding capacity[b]	0.76	0.74	0.75	<1	---
Juiciness score[c]	4.6	4.7	4.4	<1	---
Shear value, lb/1/2-in. core	6.8	6.8	6.7	<1	---
Tenderness score[c]	5.3 *	4.5 *	4.8	3.86 *	0.4
% oleic acid	0.57	0.51	0.55	1.98	---
Acid number[d]	0.86	0.72	0.78	2.13	---
Flavor score[c]	5.2	4.5	4.6	<1	---
Over-all acceptability score[c]	4.8 *	4.3 *	4.4	5.86 *	0.4

[a] LSD, least significant difference at 5% level.

[b] 1.0 (expressible moisture index).

[c] 7 (extremely juicy, tender or desirable) to 1 (extremely dry, tough or undesirable).

[d] mg KOH per g fat.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 upright household freezer.

* $p < 0.05$.

both measurements were higher ($p < 0.05$) for liquid nitrogen frozen chops than for home frozen chops (Table 4). Taste panel scores for flavor were higher ($p < 0.01$) for fresh than for frozen chops (Table 3), and were higher ($p < 0.05$) for liquid nitrogen frozen than for home frozen chops (Table 4).

Percentage oleic acid values increased significantly ($p < 0.05$) between 1 and 4 weeks' storage, and although acid numbers also increased, the amount was not significant. Flavor scores did not change significantly during this time (Table 5). The interaction between storage conditions and storage time (Table 7) had a significant effect on free fatty acids, flavor and over-all acceptability scores. Free fatty acids increased significantly ($p < 0.05$) between 1 and 4 weeks' storage for chops stored in H_1; increased slightly for those in H_2; and decreased slightly for chops in H_3. Mean flavor and over-all acceptability scores decreased ($p < 0.05$) between 1 and 4 weeks for chops stored in H_1 and H_2, but were practically the same for those stored in H_3.

Hall et al. (1961) reported that high free fatty acid did not always result in low flavor scores for pork fat. In fresh pork fat, high flavor scores often were found for samples with high free fatty acids. After freezer storage for 24 weeks, samples with free fatty acid levels in the same range as the fresh samples were given lower flavor scores. Those researchers pointed out that the direct effect of free fatty acids on flavor and aroma would depend on the type of acids liberated as a result of a treatment. This idea may explain the results obtained in this study, i.e., that the highest free fatty acids in external fat and highest flavor scores for LD muscle were for fresh chops held in the refrigerator 48 hrs

Table 7. Mean values for percentage oleic acid, acid number, flavor and over-all acceptability scores attributable to the interaction of storage conditions and time.

Storage conditions and time	% oleic acid	Acid[a] no.	Flavor[b] score	Over-all[b] acceptability
H_1				
1 wk	0.50 *	0.70 *	5.4 *	5.3 *
4 wk	0.64	0.99	4.9	4.4
H_2				
1 wk	0.50	0.70	4.8 *	4.6 *
4 wk	0.51	0.76	4.1	3.9
H_3				
1 wk	0.57	0.80	4.4	4.3
4 wk	0.53	0.75	4.6	4.4
LSD[c]	0.07	0.16	0.5	0.5

[a] mg KOH per g fat.

[b] 7 (extremely desirable) to 1 (extremely undesirable).

[c] LSD, Least significant difference at 5% level.

H_1 One-door refrigerator-freezer combination.

H_2 Two-door refrigerator-freezer combination.

H_3 Upright household freezer.

* $p < 0.05$.

before cooking and evaluating, whereas increases in free fatty acid between 1 and 4 weeks' freezer storage were accompanied by decreases in flavor scores for the LD muscle.

Over-all acceptability. Each source of variation that caused a significant difference in flavor or tenderness scores also resulted in a significant difference in over-all acceptability scores (Table 8, Appendix, p. 39). Over-all acceptability scores were higher ($p < 0.01$) for fresh chops than for frozen chops (Table 3), but were not significantly different between home and liquid nitrogen frozen chops (Table 4). Scores decreased ($p < 0.01$) between 1 and 4 weeks' storage (Table 5). The type of storage affected over-all acceptability (Table 6), scores for chops stored in H_1 were higher ($p < 0.05$) than scores for those stored in H_2 or H_3. Over-all acceptability was affected ($p < 0.05$) by the interaction between storage conditions and time (Table 7). Mean scores for chops stored in H_1 and H_2 decreased ($p < 0.05$) between 1 and 4 weeks' storage, whereas mean scores for chops stored in H_3 were approximately the same after 1 and 4 weeks' storage.

SUMMARY AND CONCLUSIONS

Thirteen pair of pork loin chops from each of four animals were randomly assigned to 13 treatment combinations to study the effects of freezing by liquid nitrogen and three home methods and the effects of 1 and 4 weeks' storage in three types of home freezers.

Irrespective of method of freezing, total, volatile and dripping cooking losses were higher ($p < 0.01$) and water holding capacity of the LD muscle was lower ($p < 0.05$) for frozen than for fresh chops. Free fatty

acid, flavor and over-all acceptability scores were higher ($p < 0.05$ and $p < 0.01$) for fresh than for frozen chops.

Commercial freezing with liquid nitrogen produced chops superior in appearance to chops frozen under home conditions, immediately after freezing and after 1 and 4 weeks of storage. Total and dripping cooking losses were greater ($p < 0.05$ and $p < 0.01$, respectively), and total moisture of the LD was lower ($p < 0.05$) for liquid nitrogen frozen than for home frozen chops. Free fatty acid was higher ($p < 0.05$) in liquid nitrogen frozen than in home frozen chops.

Tenderness and over-all acceptability scores were higher ($p < 0.05$) for chops stored in a one-door refrigerator-freezer than for those stored in a two-door refrigerator-freezer or an upright household freezer. Irrespective of freezing method or storage conditions, between 1 and 4 weeks' storage, volatile cooking losses increased ($p < 0.05$), free fatty acids increased ($p < 0.05$) and over-all acceptability and tenderness scores decreased ($p < 0.01$). The interaction between storage conditions and storage time resulted in greater ($p < 0.05$) increase in free fatty acids between 1 and 4 weeks for chops stored in a one-door refrigerator-freezer than for those stored in the other two types. Flavor and over-all acceptability scores decreased ($p < 0.05$) between 1 and 4 weeks for chops stored in both refrigerator-freezer combinations, but not for those stored in the upright household freezer.

Under the conditions of this study, it was shown: Although liquid nitrogen freezing of meats results in superior appearance, home freezing produces comparable quality in the final cooked product. Meat purchased fresh or prefrozen can be stored in the home without repackaging for at

least four weeks in freezers 0°F or below, or at least one week in freezing compartments at about 15°F without loss of quality.

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APPENDIX

Form I SCORE CARD FOR EVALUATING THE PALATABILITY OF PORK LOIN CHOPS

Judge_____ Code_____ Date_____

Sample no.	Desirability of flavor	Juiciness	Tenderness		Over-all acceptability	Comments
			No. chews	Score		
1						
2						
3						
4						

Descriptive terms for scoring

Desirability of flavor	Juiciness	Tenderness	Over-all acceptability
7 Extremely desirable	7 Extremely juicy	7 Extremely tender	7 Extremely desirable
6 Desirable	6 Juicy	6 Tender	6 Desirable
5 Moderately desirable	5 Moderately juicy	5 Moderately tender	5 Moderately desirable
4 Acceptable	4 Acceptable	4 Acceptable	4 Acceptable
3 Moderately undesirable	3 Moderately dry	3 Moderately tough	3 Moderately undesirable
2 Undesirable	2 Dry	2 Tough	2 Undesirable
1 Extremely undesirable	1 Extremely dry	1 Extremely tough	1 Extremely undesirable

Desirability of flavor

If a score of 5 or less is given for flavor, describe any noticeable flavor characteristics such as:

Too bland
Too intense
Metallic
Acid
Oxidized or rancid
Other

Form II

Instructions to Judges for Sensory Evaluation of Pork Loin Chops

Scoring for Flavor and Juiciness

Record a score for flavor and another for juiciness within a range of 7 to 1 that describes your impression of the sample. See the score card for descriptive terms for specific scores within the range of 7 to 1.

Scoring for Tenderness

Count the number of times you chew the 1/2 in. cube of meat before swallowing. Chew until the cube is completely masticated, then swallow. Record the number of chews required to masticate the cube. Record a score from 7 to 1 that describes your impression of the tenderness of the cube. See the score card for descriptive terms for specific scores within the range of 7 to 1. Use the number of chews to help you standardize your tenderness scores from day to day. Set up for yourself a range of number of chews for each score from 7 to 1. For example, if you chew from 15 to 25 times, you might record a score of 7; if you chew 25 to 35 times, a score of 6; 35 to 45 a score of 5; continuing to reduce the score by a given number of increased chews. Each judge sets his own range of chews for a given score.

Comments

Comments about a sample or explaining your reason for giving a particular score are helpful.

Table 8. Analysis of variance for effects of freezing and storage treatments on objective and subjective measurements of pork loin chops.

Source of variation	DF	Weight	Cooking losses		
			Total	Volatile	Dripping
		F-values			
Animal	3	10.44**	4.63**	1.49	7.34**
Treatments	12	<1	3.78**	2.29*	3.57**
Fresh vs frozen	1	<1	29.90**	13.50**	23.56**
Freezing treatment (FT)	1	<1	4.52*	<1	13.94**
Storage conditions (SC)	2	<1	<1	<1	<1
Storage time (ST)	1	<1	3.94	7.10*	<1
FT X SC	2	<1	1.12	1.20	<1
FT X ST	1	<1	<1	<1	2.23
SC X ST	2	<1	<1	<1	<1
FT X SC X ST	2	<1	1.05	<1	<1
Error	36				
Total	51				

Table 8. (continued)

Source of variation	DF	Total moisture	Water holding capacity	Juiciness score	Shear value	Tenderness score
		F-values				
Animal	3	2.81*	2.33	6.28**	31.89**	18.83**
Treatments	12	1.22	1.76	<1	1.43	1.99
Fresh vs frozen	1	<1	6.91*	2.50	<1	2.42
Freezing treatment (FT)	1	4.26*	<1	2.39	1.55	<1
Storage conditions (SC)	2	1.16	÷1	<1	<1	3.86*
Storage time (ST)	1	4.02	3.64	2.83	3.15	10.05**
FT X SC	2	<1	÷1	<1	<1	<1
FT X ST	1	<1	÷1	<1	<1	<1
SC X ST	2	<1	2.1	<1	2.04	1.64
FT X SC X ST	2	<1	<1	<1	2.61	<1
Error	36					
Total	51					

Table 8. (concluded)

Source of variation	DF	% oleic acid	Acid number	Flavor score	Over-all acceptability score
		F-values			
Animal	3	29.29**	9.51**	1.96	6.46**
Treatments	12	4.41**	2.95**	3.65**	4.05**
Fresh vs frozen	1	20.27**	7.32*	9.22**	11.68**
Freezing treatment (FT)	1	6.36*	5.04*	1.93	<1
Storage conditions (SC)	2	1.98	2.13	<1	5.86*
Storage time (ST)	1	4.67*	4.05	<1	11.61**
FT X SC	2	2.51	1.68	≒1	<1
FT X ST	1	<1	1.04	<1	<1
SC X ST	2	5.79*	4.50*	3.72*	4.83*
FT X SC X ST	2	<1	<1	<1	1.26
Error	36				
Total	51				

Level of probability	DF	F-value
* p < 0.05	1,36	4.13
** p < 0.01	1,36	7.43
* p < 0.05	2,36	3.27
** p < 0.01	2,36	5.28
* p < 0.05	3,36	2.86
** p < 0.01	3,36	4.38
* p < 0.05	12,36	2.03
** p < 0.01	12,36	2.78

Table 9. Analysis of variance for effects of freezing and storage conditions on cooking time.

Source of variation	DF	Cooking time	
		To 5°C	To 75°C
		F-values	
Animal	3	2.87	2.73
Treatments	11		
Freezing treatment (FT)	1	3.71	<1
Storage conditions (SC)	2	4.40*	<1
Storage time (ST)	1	1.27	<1
FT X SC	2	1.35	<1
FT X ST	1	1.94	<1
SC X ST	2	1	<1
FT X SC X ST	2	1.60	<1
Error	33		
Total	47		

Level of probability	DF	F-value
* $p < 0.05$	1,33	4.14
* $p < 0.05$	2,33	3.29
* $p < 0.05$	3,33	2.89

Table 10. Initial weight per pair, g.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	448	450	497	544	485
C	H_1	1	480	448	420	579	482
C	H_1	4	480	451	427	462	455
C	H_2	1	507	493	415	522	484
C	H_2	4	566	464	430	545	501
C	H_3	1	482	471	450	477	470
C	H_3	4	500	448	421	598	492
H_1	H_1	1	447	434	471	530	471
H_1	H_1	4	452	457	405	588	476
H_2	H_2	1	507	463	468	464	476
H_2	H_2	4	532	434	418	491	469
H_3	H_3	1	495	482	503	492	493
H_3	H_3	4	447	446	477	484	464
Mean			488	457	446	521	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator freezer combination.

H_3 household upright freezer.

Table 11. Cooking time to 5°C, min.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	0	0	0	0	0
C	H_1	1	13	9	17	16	14
C	H_1	4	14	14	12	12	13
C	H_2	1	14	15	15	19	16
C	H_2	4	20	16	17	15	17
C	H_3	1	16	13	19	16	16
C	H_3	4	13	13	17	17	15
H_1	H_1	1	13	9	15	17	14
H_1	H_1	4	15	17	16	21	17
H_2	H_2	1	16	14	17	17	16
H_2	H_2	4	17	16	17	15	16
H_3	H_3	1	17	18	16	17	17
H_3	H_3	4	21	18	18	14	18

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 12. Cooking time to 75°C, min.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	35	36	37	36	36
C	H_1	1	45	48	49	56	50
C	H_1	4	47	50	47	41	49
C	H_2	1	49	52	47	50	50
C	H_2	4	58	48	45	54	51
C	H_3	1	51	52	55	53	53
C	H_3	4	55	47	48	58	52
H_1	H_1	1	50	45	51	54	50
H_1	H_1	4	48	52	47	58	51
H_2	H_2	1	51	45	47	55	50
H_2	H_2	4	54	53	51	47	51
H_3	H_3	1	53	49	51	48	50
H_3	H_3	4	57	49	50	47	51

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 13. Volatile cooking losses, %.

Treatment combinations			Animal numbers				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	9.37	10.22	12.07	8.64	10.07
C	H_1	1	11.04	11.83	12.38	12.43	11.92
C	H_1	4	15.00	14.41	12.88	14.71	14.25
C	H_2	1	11.63	12.37	13.73	12.45	12.55
C	H_2	4	16.60	12.71	13.48	15.04	14.46
C	H_3	1	12.28	14.43	14.66	14.67	14.00
C	H_3	4	15.00	11.60	14.25	14.54	13.84
H_1	H_1	1	13.20	11.06	14.43	13.78	13.12
H_1	H_1	4	13.49	15.09	14.07	16.49	14.79
H_2	H_2	1	13.41	9.19	11.53	15.51	12.44
H_2	H_2	4	14.28	13.36	13.86	10.59	13.03
H_3	H_3	1	14.54	11.41	11.92	11.38	12.31
H_3	H_3	4	19.23	13.00	11.74	11.98	13.99
Mean			13.77	12.37	13.15	13.25	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 14. Dripping cooking losses, %.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	6.91	5.77	3.52	4.96	5.27
C	H_1	1	8.54	6.91	9.28	8.46	8.30
C	H_1	4	8.95	5.90	8.19	7.35	7.60
C	H_2	1	9.07	6.28	9.63	7.27	8.06
C	H_2	4	7.06	7.32	8.12	8.80	7.83
C	H_3	1	8.29	7.64	10.00	8.17	8.53
C	H_3	4	9.40	7.36	8.55	7.35	8.17
H_1	H_1	1	7.38	6.22	7.00	5.66	6.57
H_1	H_1	4	7.96	7.65	6.17	7.48	7.32
H_2	H_2	1	7.29	5.61	9.18	6.25	7.08
H_2	H_2	4	8.08	6.22	6.93	6.51	6.94
H_3	H_3	1	7.67	6.22	8.54	5.89	7.08
H_3	H_3	4	8.50	7.39	7.54	6.81	7.56
Mean			8.08	6.65	7.89	7.00	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 15. Total cooking losses, %.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	16.74	16.44	15.89	13.78	15.71
C	H_1	1	20.20	19.41	22.14	21.24	20.75
C	H_1	4	23.95	20.62	20.84	22.51	21.98
C	H_2	1	21.10	19.06	24.09	20.11	21.09
C	H_2	4	23.49	20.47	21.62	24.03	22.40
C	H_3	1	20.95	22.71	25.11	23.27	23.01
C	H_3	4	24.20	19.64	23.04	22.24	22.28
H_1	H_1	1	21.02	17.97	21.86	20.00	20.21
H_1	H_1	4	22.12	22.97	20.74	24.14	22.49
H_2	H_2	1	21.10	15.33	20.94	22.19	22.49
H_2	H_2	4	22.74	19.58	21.29	17.31	19.89
H_3	H_3	1	22.62	17.84	20.07	17.68	19.55
H_3	H_3	4	28.41	20.62	19.70	18.80	21.88
Mean			22.20	19.44	21.33	20.56	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 16. Total moisture, %.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	67.1	66.9	65.8	66.2	66.4
C	H_1	1	67.9	64.6	65.8	62.9	65.3
C	H_1	4	65.2	64.1	66.6	66.4	65.6
C	H_2	1	64.5	65.6	67.1	66.2	65.8
C	H_2	4	62.7	65.7	66.4	63.9	64.7
C	H_3	1	66.5	65.8	57.6	66.7	66.6
C	H_3	4	64.4	67.7	66.6	62.2	65.2
H_1	H_1	1	67.8	67.2	65.4	63.7	66.0
H_1	H_1	4	67.0	65.1	67.6	61.5	65.3
H_2	H_2	1	66.5	68.1	68.6	66.8	67.4
H_2	H_2	4	65.7	65.8	65.7	67.8	66.2
H_3	H_3	1	65.5	68.2	67.6	67.3	67.1
H_3	H_3	4	65.2	66.7	67.6	65.8	66.3
Mean			65.8	66.3	66.8	65.2	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 17. Water holding capacity (1.0 - expressible moisture index).

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	0.74	0.73	0.70	0.66	0.71
C	H_1	1	0.79	0.75	0.75	0.71	0.75
C	H_1	4	0.75	0.80	0.80	0.80	0.79
C	H_2	1	0.73	0.73	0.71	0.73	0.73
C	H_2	4	0.68	0.75	0.77	0.77	0.74
C	H_3	1	0.76	0.78	0.78	0.76	0.77
C	H_3	4	0.72	0.78	0.78	0.69	0.74
H_1	H_1	1	0.74	0.73	0.76	0.70	0.73
H_1	H_1	4	0.80	0.80	0.80	0.71	0.78
H_2	H_2	1	0.73	0.66	0.83	0.74	0.74
H_2	H_2	4	0.75	0.77	0.78	0.76	0.77
H_3	H_3	1	0.75	0.70	0.76	0.77	0.75
H_3	H_3	4	0.76	0.75	0.77	0.75	0.76
Mean			0.75	0.75	0.77	0.73	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 18. Warner-Bratzler shear values, lb/1/2-in. core.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	5.2	7.8	6.0	7.1	6.5
C	H_1	1	5.8	8.9	6.3	4.4	6.3
C	H_1	4	5.2	11.4	8.6	6.6	7.9
C	H_2	1	6.4	8.7	7.2	6.4	7.2
C	H_2	4	4.0	8.4	7.0	5.6	6.2
C	H_3	1	5.4	8.1	7.7	4.8	6.5
C	H_3	4	6.5	9.8	7.0	6.1	7.3
H_1	H_1	1	5.9	7.3	7.0	5.6	6.4
H_1	H_1	4	6.0	7.5	6.8	5.9	6.5
H_2	H_2	1	4.4	7.9	8.4	6.4	6.8
H_2	H_2	4	4.9	8.5	9.3	5.9	7.1
H_3	H_3	1	5.1	7.6	6.2	5.4	6.1
H_3	H_3	4	6.2	7.9	6.6	6.1	6.7
Mean			5.5	8.4	7.2	5.9	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 19. Percentage oleic acid.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	0.79	0.67	0.70	0.71	0.72
C	H_1	1	0.63	0.70	0.41	0.36	0.53
C	H_1	4	0.79	0.76	0.68	0.49	0.68
C	H_2	1	0.70	0.74	0.35	0.45	0.56
C	H_2	4	0.78	0.61	0.44	0.50	0.58
C	H_3	1	0.60	0.68	0.37	0.53	0.55
C	H_3	4	0.58	0.59	0.44	0.56	0.54
H_1	H_1	1	0.58	0.59	0.32	0.42	0.48
H_1	H_1	4	0.71	0.59	0.54	0.55	0.60
H_2	H_2	1	0.51	0.49	0.35	0.44	0.45
H_2	H_2	4	0.57	0.61	0.38	0.39	0.49
H_3	H_3	1	0.71	0.67	0.56	0.41	0.59
H_3	H_3	4	0.64	0.68	0.34	0.43	0.52
Mean			0.66	0.64	0.45	0.48	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 20. Acid number, mg KOH per g fat.

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	1.12	0.94	0.99	1.00	1.02
C	H_1	1	0.90	0.99	0.58	0.51	0.74
C	H_1	4	1.12	1.08	1.67	0.70	1.14
C	H_2	1	1.00	1.04	0.49	0.64	0.79
C	H_2	4	1.10	0.86	0.63	0.72	0.83
C	H_3	1	0.85	0.97	0.53	0.76	0.78
C	H_3	4	0.83	0.84	0.62	0.79	0.77
H_1	H_1	1	0.82	0.84	0.45	0.60	0.68
H_1	H_1	4	1.00	0.84	0.76	0.78	0.85
H_2	H_2	1	0.72	0.69	0.50	0.62	0.63
H_2	H_2	4	0.82	0.87	0.54	0.55	0.69
H_3	H_3	1	1.00	0.95	0.79	0.58	0.83
H_3	H_3	4	0.91	0.97	0.48	0.61	0.74
Mean			0.94	0.91	0.69	0.68	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 21. Flavor scores, 7 (extremely desirable) to 1 (extremely undesirable).

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	5.4	5.0	6.0	5.8	5.6
C	H_1	1	6.3	5.3	5.0	5.6	5.5
C	H_1	4	4.8	4.8	5.4	4.6	4.9
C	H_2	1	5.8	5.2	4.4	3.6	4.8
C	H_2	4	4.2	4.6	4.2	4.4	4.4
C	H_3	1	4.8	5.4	4.6	4.0	4.7
C	H_3	4	4.8	4.8	4.8	5.2	4.9
H_1	H_1	1	5.8	5.8	4.4	5.4	4.3
H_1	H_1	4	5.0	5.0	4.8	4.8	4.9
H_2	H_2	1	5.0	5.2	4.6	5.4	5.0
H_2	H_2	4	4.4	4.8	3.8	3.0	4.0
H_3	H_3	1	4.4	4.6	4.2	3.6	4.2
H_3	H_3	4	4.8	3.6	4.8	4.4	4.4
Mean			5.0	4.9	4.7	4.6	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 22. Juiciness scores, 7 (extremely juicy) to 1 (extremely dry).

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	5.2	4.6	5.4	5.4	5.2
C	H_1	1	5.8	4.0	4.0	4.6	4.6
C	H_1	4	4.0	3.8	4.0	4.4	4.0
C	H_2	1	5.8	4.2	3.4	5.8	4.8
C	H_2	4	5.4	3.6	4.2	5.0	4.6
C	H_3	1	5.2	3.6	3.0	5.2	4.3
C	H_3	4	3.6	5.0	4.0	3.6	4.0
H_1	H_1	1	4.8	6.3	4.2	5.6	5.2
H_1	H_1	4	4.3	3.8	4.6	5.2	4.5
H_2	H_2	1	5.0	5.4	4.0	4.8	4.8
H_2	H_2	4	4.6	3.0	4.4	6.0	4.6
H_3	H_3	1	4.6	4.4	3.6	6.2	4.7
H_3	H_3	4	3.8	4.4	4.0	6.0	4.6
Mean			4.8	4.3	4.1	5.2	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 23. Tenderness scores, 7 (extremely tender) to 1 (extremely tough).

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	5.0	4.4	5.6	6.0	5.3
C	H_1	1	6.3	5.3	4.2	6.0	5.4
C	H_1	4	4.3	3.7	5.0	5.2	4.6
C	H_2	1	5.6	4.0	4.8	4.8	4.8
C	H_2	4	6.0	2.6	3.2	5.2	4.3
C	H_3	1	5.4	3.6	4.8	5.4	4.8
C	H_3	4	5.0	3.6	4.4	6.0	4.8
H_1	H_1	1	6.3	5.8	4.6	5.8	5.6
H_1	H_1	4	4.3	3.8	4.8	6.0	4.7
H_2	H_2	1	5.6	3.8	4.4	5.2	4.8
H_2	H_2	4	4.6	3.2	4.0	5.0	4.2
H_3	H_3	1	5.0	4.0	4.8	5.8	4.9
H_3	H_3	4	5.6	4.0	4.2	4.8	4.7
Mean			5.3	4.0	4.5	5.5	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-foor refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

Table 24. Over-all acceptability scores, 7 (extremely desirable) to 1 (extremely undesirable).

Treatment combinations			Animal number				
Freezing conditions	Storage conditions	Time, wks.	I	II	III	IV	Mean
Unfrozen	R	0	5.4	4.8	5.7	5.8	5.4
C	H_1	1	6.3	5.1	4.4	5.2	5.2
C	H_1	4	4.3	3.5	5.0	4.6	4.3
C	H_2	1	5.9	4.2	4.0	4.0	4.5
C	H_2	4	4.6	3.6	3.8	4.8	4.2
C	H_3	1	5.0	4.2	3.8	4.4	4.4
C	H_3	4	4.2	4.4	4.2	5.0	4.5
H_1	H_1	1	5.9	6.0	4.0	5.6	5.4
H_1	H_1	4	4.5	4.0	4.6	5.0	4.5
H_2	H_2	1	5.4	4.8	4.2	5.0	4.9
H_2	H_2	4	4.2	3.0	4.0	3.3	3.6
H_3	H_3	1	5.0	4.0	4.0	4.0	4.3
H_3	H_3	4	4.8	3.8	4.4	4.8	4.4
Mean			5.0	4.3	4.3	4.7	

R stored in refrigerator 48 hrs.

C commercially frozen with liquid nitrogen.

H_1 one-door refrigerator-freezer combination.

H_2 two-door refrigerator-freezer combination.

H_3 household upright freezer.

EFFECTS OF A COMMERCIAL AND THREE HOME FREEZING METHODS ON SELECTED CHARACTERISTICS OF PORK LOIN CHOPS

by

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Many consumers freeze meats in the home, but are hesitant to purchase prepackaged frozen meats in the market. The meat packing industry would like to expand the frozen meat market, and many believe cryogenic processes can produce frozen meats that will satisfy the demands of consumers. This study investigated the effects of a commercial liquid nitrogen process and three home freezing methods on selected characteristics of pork loin chops after storage under home conditions for 1 and 4 weeks.

Irrespective of method of freezing, total, volatile and dripping cooking losses were higher ($p < 0.01$) and water holding capacity of the LD muscle was lower ($p < 0.05$) for frozen than for fresh chops. Free fatty acid, flavor and over-all acceptability scores were higher ($p < 0.05$ and $p < 0.01$) for fresh than for frozen chops.

Commercial freezing with liquid nitrogen produced chops superior in appearance to chops frozen under home conditions, immediately after freezing and after 1 and 4 weeks of storage. Total and dripping cooking losses were greater ($p < 0.05$ and $p < 0.01$, respectively), and total moisture of the LD was lower ($p < 0.05$) for liquid nitrogen frozen than for home frozen chops. Free fatty acid was higher ($p < 0.05$) in liquid nitrogen frozen than in home frozen chops.

Tenderness and over-all acceptability scores were higher ($p < 0.05$) for chops stored in a one-door refrigerator-freezer than for those stored in a two-door refrigerator-freezer or an upright household freezer. Irrespective of freezing method or storage conditions, between 1 and 4 weeks' storage, volatile cooking losses increased ($p < 0.05$), free fatty acids increased ($p < 0.05$) and over-all acceptability and tenderness scores decreased ($p < 0.01$). The interaction between storage conditions and

storage time resulted in greater ($p < 0.05$) increase in free fatty acids between 1 and 4 weeks for chops stored in a one-door refrigerator-freezer than for those stored in the other two types. Flavor and over-all acceptability scores decreased ($p < 0.05$) between 1 and 4 weeks for chops stored in both refrigerator-freezer combinations, but not for those stored in the upright household freezer.

Under the conditions of this study, it was shown: Although liquid nitrogen freezing of meats results in superior appearance, home freezing produces comparable quality in the final cooked product. Meat purchased fresh or prefrozen can be stored in the home without repackaging for at least four weeks in freezers 0°F or below, or at least one week in freezing compartments at about 15°F without loss of quality.