PORK STORAGE IN FREEZER LOCKERS

by

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INTRODUCTION

Cold storage and refrigeration have long been used to preserve foods. However, during the last ten years when an economic depression existed, a new branch of the refrigeration industry has developed. This is the refrigerated locker service.

Thomas (1938) suggested that the rise of the refrigerated locker plants was the result of over expansion of the cold storage industry during the World War. Following this over expansion many cold storage plants found themselves with unused storage space. As a result plants which had previously accepted only large quantities of perishables, adopted the policy of taking in small lots on a monthly or yearly rental basis. Thus frozen food preservation became available for family use.

With many patrons storing their products in the same cooler, confusion resulted. This was overcome by screening off compartments with wire netting and placing each compartment under the patron's lock and key. In this manner lockers were formed. Warner (1938) described such lockers as "safety deposit boxes" kept in a room with a temperature near 0° F. in which families may freeze and

store food supplies grown at home or purchased. In the newer plants, steel cabinet type lockers have been substituted for the wire mesh type.

Cold storage service for the general public first appeared in 1903 on the Pacific Coast, but it was not until 1935 that the service was introduced extensively into the Middle West (Mann, 1938). The number of refrigerated locker plants increased enormously after the movement was under way. In Iowa there was an increase from seven plants in 1934 to an estimated number of over 350 plants by August 1939 (Jackson, 1939). Minnesota likewise had an increase from four plants in 1935 to 213 plants by October 1939 (Dowell, Warrington, Eggert, and Fenske, 1940). Eggert[1] found freezer locker service in Kansas as follows: 1 plant in 1929, 4 in 1930, 4 in 1931, 5 in 1932, 8 in 1933, 13 in 1934, 22 in 1935, 36 in 1936, 58 in 1937, 78 in 1938, and 92 in 1939. The service is being offered in most of the states. Table 1 shows the number of plants by states according to Warner's[2] survey of July 1939.

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[1]Unpublished data.

[2]Correspondence with the author.

Table 1. Number of freezer locker plants in the United States in July, 1939.[2]

Alabama	2	Maine	0	Ohio	32
Arizona	1	Maryland	2	Oklahoma	25
Arkansas	3	Massachusetts	0	Oregon	160
California	22	Michigan	15	Pennsylvania	20
Colorado	33	Minnesota	179	Rhode Island	0
Connecticut	0	Mississippi	1	S. Carolina	0
Delaware	2	Missouri	13	S. Dakota	34
Florida	1	Montana	15	Tennessee	12
Georgia	2	Nebraska	130	Texas	20
Idaho	85	Nevada	0	Utah	15
Illinois	113	New Hampshire	0	Vermont	1
Indiana	9	New Jersey	1	Virginia	3
Iowa	350	New Mexico	0	Washington	260
Kansas	95	New York	12	W. Virginia	1
Kentucky	0	North Carolina	3	Wisconsin	153
Louisiana	0	North Dakota	25	Wyoming	11

This rapid growth of the freezer locker service created new demands for technical information on the locker industry (Warner, 1935). Information was lacking in relation to plant organization, housing, equipment, business management, and public relations. Likewise little was known regarding the proper handling of the products. Products of all types and in small lots were being stored together under new conditions. Special methods were developed for handling fruits and vegetables, and certain

[2]Correspondence with the author.

varieties were found to lend themselves better to storage than others (Diehl, Wiegand, and Berry, 1939). Many problems also arose in the freezing, storage, and cooking of meats.

The principle involved in preserving meat by freezing is that bacterial action, yeasts, and molds can be inhibited or retarded by sub freezing temperatures. However, undesirable changes sometimes take place in the meat during freezer locker storage. Disagreeable odors are frequently imparted to meat. Pork fat is especially susceptible during storage to oxidation and the accompanying rancidity. Desiccation or drying out of the product is difficult to prevent since the humidity of the air in the cooler is reduced by freezing.

The rate of freezing meat has been a matter for consideration. It has been proposed that quick freezing meat renders it more nearly like the fresh product (Mackintosh, 1938; Warner, 1939). However, Stewart (1939) stated that in the case of poultry quick freezing in itself is of no importance. The length of time that meat can be stored under average locker room conditions has been a question. Likewise numerous problems in sanitation have not been settled. These and many other problems have yet

to be answered satisfactorily for this new food industry.

The present investigations were conducted to secure more knowledge of problems pertaining to freezer locker storage of fresh pork. Studies were made on pork loin roasts and sausage to determine (1) the relative effectiveness of several types of wrappers, (2) the effectiveness of oat flour as an anti-oxidant or oxidation inhibitor with pork, (3) the length of time pork can be stored, and (4) the general changes in the quality of the pork during the storage period.

REVIEW OF LITERATURE

Only a small amount of work has been carried on to study methods of treating and wrapping meat for freezer locker storage. However a limited amount of work has been done in associated fields which is applicable to this investigation.

Desiccation

Birdseye (1929) reported the main causes of deterioration of flesh products during freezing as being desiccation or drying out, oxidation, and off odors. Desiccation he pointed out takes place because the product is

warmer than the cooling pipes and the saturation point of the air is lower at the pipes than at the product. Thus moisture is constantly absorbed from the product, carried by convection currents to the pipes, and deposited here in the form of frost. It is more or less directly proportional to the surface area exposed. Cook (1939) emphasized the fact that most of the moisture in frozen products is in the frozen state and its rate of movement to the surface is reduced to negligible proportions. This allows surface drying to occur. The over-all loss of weight may be small, but it may have a serious effect on the appearance of the product. Cook's results showed that humidities less than 95 per cent at atorage temperatures of -13.5° C. and -22° C. (7.5° F. and -7.5° F.) were unsatisfactory as the product, in this case poultry, was seriously affected in from two to three months. Humidities of 98 to 100 per cent maintained the poultry in a satisfactory condition with respect to surface drying during 83 weeks of storage. Cook found that the rate of evaporation varied directly with the temperature and inversely with the relative humidity.

The ideal wrapper would prevent all desiccation. Warner (1939) stated that a good wrapper should be moisture

proof, easily folded, tough to resist breaking, and capable of being marked with a pencil or stamp. Doubois and Tressler (1939) reported that a paper may be water proof without being water vapor proof. A water vapor proof material is one that will prevent moisture from diffusing through it.

Birdseye (1929) made tests on various types of papers by stretching them over a dish of water, placing the covered dishes in an oven and determining the weight of water lost. Regular cellophane proved very unsatisfactory because it was not moisture proof. However the improved moisture proof cellophane was the most effective paper tested. He found that waxed papers had a tendency to become relatively less vapor proof at low temperatures, probably because at low temperatures the paraffin tends to contract or crystallize, thereby less completely covering the paper. He recommended vegetable parchment wrappers because they will not disintegrate in the presence of water. Birdseye made no tests of this type at temperatures lower than 10° C. (50° F.). Doubois and Tressler (1939) tested papers for moisture-vapor transmission at -15° C. (5° F.). Their method was similar to Birdseye's method. The papers were sealed over the top of a crystallizing

dish containing water. They were allowed to come to equilibrium at -15° C. and 50 per cent humidity, were weighed, and the loss in weight found. The grams of water lost per square meter of paper per day were computed. Twenty-five papers were tested. Parchment papers gave by far the greatest moisture loss in grams per square meter per day, namely 115 gm. Waxed papers lost from 22 to 26 gm., and transparent viscose sheets (moisture proof cellophane) lost from .5 to 1.3 gm. Pork chops, lamb chops, veal cutlets, and cuts of beef roasts were wrapped in the papers thus tested and the packages stored at 5° to 10° F. The per cent weight loss and appearance of the meat at six months was recorded. The per cent loss of moisture ranged from .08 to 5.0. In every case meat became desiccated that was wrapped in papers showing a high moisture loss per square meter per day, while meat wrapped in transparent vapor-proof viscose sheets was recorded as satisfactory. These latter sheets were also found superior upon testing for heat sealing, stain proofness from blood, condition at 0° F., and brittleness.

Cook (1939) demonstrated that by sealing the joints of a wrapper the moisture loss could be decreased considerably. Finnegan (1939) however pointed out that dehydration

could be minimized by sealing but never eliminated. When the temperature rises there is more rapid evaporation of moisture from the product to the air in the container. When the temperature becomes lower this moisture is deposited from the air onto the inner surface of the container. As the action is only slightly reversible, a hermetically sealed can would not prevent dehydration from this source.

Griswold and Blakeslee (1939) studied the effect of different wrappings, temperatures, and length of storage on the keeping qualities of frozen pork chops. Wrappings had little effect on the palatability of the chops but a decided effect on moisture loss. Some chops were glazed with lard and some with a mixture of lard and tallow. Kraft wrapping paper permitted the greatest moisture loss, lard and lard tallow about the same, while moisture proof cellophane allowed less moisture to escape than any of the other materials tested. Several palatability factors seemed superior in chops stored at 15° F. than those stored at 0° F., probably due to temperature fluctuations in the 0° F. lot. Little difference was found between chops stored at 5° F. and 15° F. Most of the chops were still edible after 180 days storage, although the fat of some of the chops was rancid.

From these studies it appears that for the best protection against dehydration the product should be wrapped tightly in water-vapor proof paper with a minimum amount of air space and with all joints sealed.

Rancidity

The term rancidity according to Gortner (1938) has two meanings: "(1) the hydrolysis of the glycerides, with the liberation of free fatty acids; and (2) the oxidation of fats and oils containing unsaturated acids, resulting in the formation of aldehydes, ketones, and acids." As a general rule hydrolysis and oxidation occur simultaneously, however a fat may have a very marked rancidity with a low acidity or a high acidity with little or no rancidity (Koch, 1937). Oxygen is necessary in order to produce the oxidation type of rancidity. Heat, light, moisture, and the presence of certain metals hasten the oxidative process. Likewise substances have been found which inhibit rancidity development. Many of those substances are phenolic or amine-like in nature which, for reasons involving their physiological effects cannot be used in food products (Gray and Stone, 1939).

Bulk oat flour has been found effective in retarding rancidity development in pork fat. Bull (1937) showed that the addition of 10 per cent of oat flour made from the entire oat grain to the curing mixture used in box curing bacon materially retards the development of rancidity. Bull likewise found that dusting bacon slices with one per cent by weight of oat flour made from the oat groat, without the hull, not only retarded the development of rancidity but also mold growth. In later studies Bull (1938) compared the rancidity development in lard samples stored in parchment wrappers which had been treated with oat flour with untreated samples. The storage temperature was 34° F. Ten pairs were studied and rancidity tests were made at 120, 273, and 294 days of storage. The results were slightly in favor of the treated wrappers, but there were a number of negative results. Oat flour was added to ground pork back fat in concentrations from .5 per cent to 2 per cent. The samples were frozen and stored at 6° F. for four months. Samples containing 2 per cent oat flour had little rancidity development while 1.5 per cent concentrations had less effect and a .5 per cent concentration had very little effect.

Bull (1939) compared samples of ground unseasoned pork, ground pork containing 1 per cent oat flour, and

ground pork containing salt and pepper. The samples were examined after 74 to 80 days storage at 10° F. The seasoned samples had a stale odor and dark gray color. None of the unseasoned samples or those containing oat flour were rancid. Frozen pork fat cubes to which different amounts of oat flour were added before freezing were examined after 86 to 90 days in the locker at 10° F. In four cases out of five the addition of one per cent oat flour increased the stability of the fat.

Gray and Stone (1939) have demonstrated that ascorbic acid or vitamin C and d-gluco ascorbic acid are effective anti-oxidants for fat emulsions.

Davies (1934) in studying the effect of light transmission of food wrappers found that light passing through cellophane colored a deep blue, deep green, deep brown, and deep red did not cause an appreciable increase in the oxidation of the fat in biscuit meal. Light green and heliotrope cellophane caused some oxidation to occur, while bright blue, pink, lemon, and orange cellophane allowed practically the same degree of oxidation to occur as by direct exposure. Davies likewise studied the relation of the metal content of hard vegetable parchment and rancidity development in fatty foods. He found that the effect of

the copper present in the wrapper is not appreciable within the conditions that fatty foods are commonly stored.

Dubois and Tressler (1939) found that meat wrappers having a low moisture vapor transmission tend to retard the rancidity development of the fat.

Molds and Enzymes

Beckwith (1936) stated that there is no known temperature below which molds do not function. He has observed molds on raspberries after many months at -10° F.

Balls and Lineweaver (1938) concluded that enzyme action at low temperatures not only takes place but is an important factor in problems of frozen food preservation. The enzymes are not destroyed but retarded at low temperatures. With some enzymes the action during freezing is very slight, but it is important since it may complete the first phase of enzyme attack which results in more rapid action than normal when the food is allowed to thaw. Lipase action was significant even at -30° C. (-22° F.). Lipase action was apparently more active than proteinase. Balls, Matlack, and Tucker (1937) have shown that only the shorter chained saturated fats and unsaturated fats are measurably effected by the lipases at low temperatures (0° C.).

MATERIAL AND METHODS

Pork loin roasts and pork sausage samples were used in this study. The carcasses were those of purebred Hampshire gilts and barrows which had been fed in a nutrition experiment. The hogs were fed six months on a balanced ration consisting of 74 per cent hominy, 10 per cent tapioca roots, 4 per cent alfalfa leaf meal, 10 per cent blood meal, 1.5 per cent dried brewers' yeast, .5 per cent iodized salt, and supplemented with calcium, phosphorus, and vitamin D. The hogs averaged 240 pounds when slaughtered. Their marked uniformity before and after slaughter can be noted in Plates I and II.

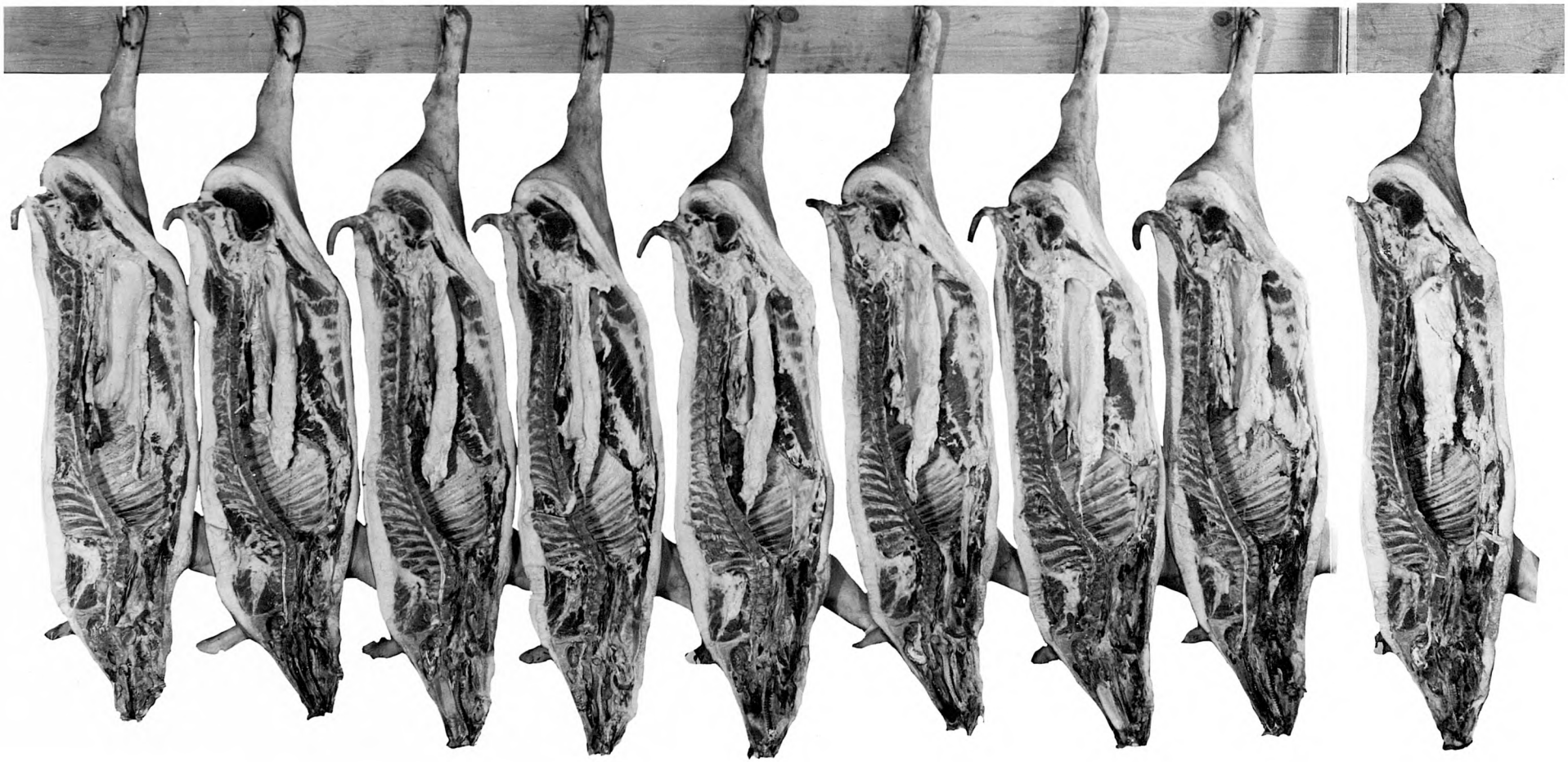
Cutting, Wrapping, and Treatment

The carcasses were broken into the usual wholesale cuts except that all loins were first cut into roasts and then the fat back was removed to leave an equal covering of fat on each roast (Fig. 1). A somewhat thicker covering of fat was retained than that on a commercial loin to provide an adequate sample for chemical tests following storage. The roasts weighed from two to three pounds when wrapped and the roasts from each hog

Explanation of Plate I

The hog carcasses from which the roasts and sausage trimmings were taken.

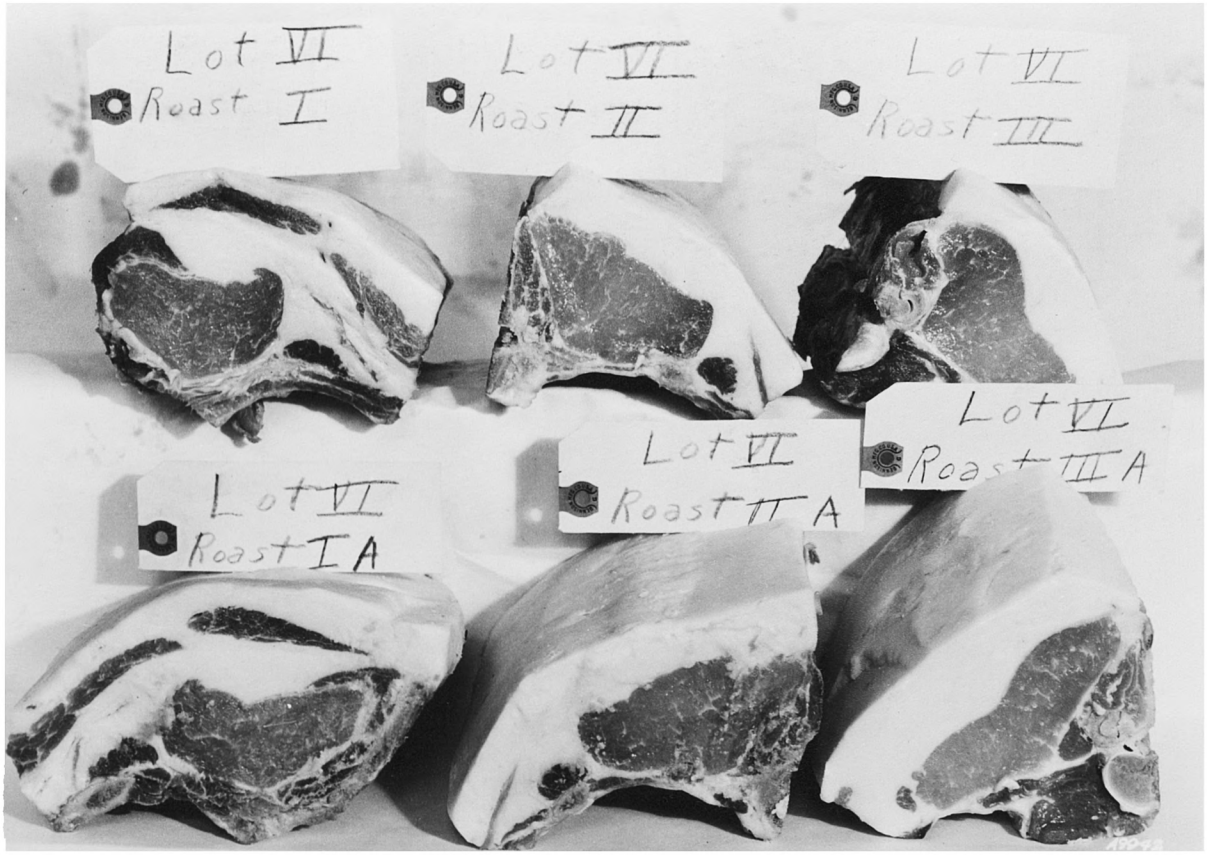
Plate I



Explanation of Plate II

The roasts from one loin. The amount of marbling is indicative to some extent of the quality of the meat. The thickness of the fat covering can be noted.

Plate II


Lot VII
Roast I
Lot VII
Roast II
Lot VII
Roast III
Lot VII
Roast III A
Lot VII
Roast II A
Lot VII
Roast I A

Explanation of Plate III

Fig. 1. The method of separating the roasts from the loin before removing the fat back.

Fig. 2. The method of packaging and labelling.

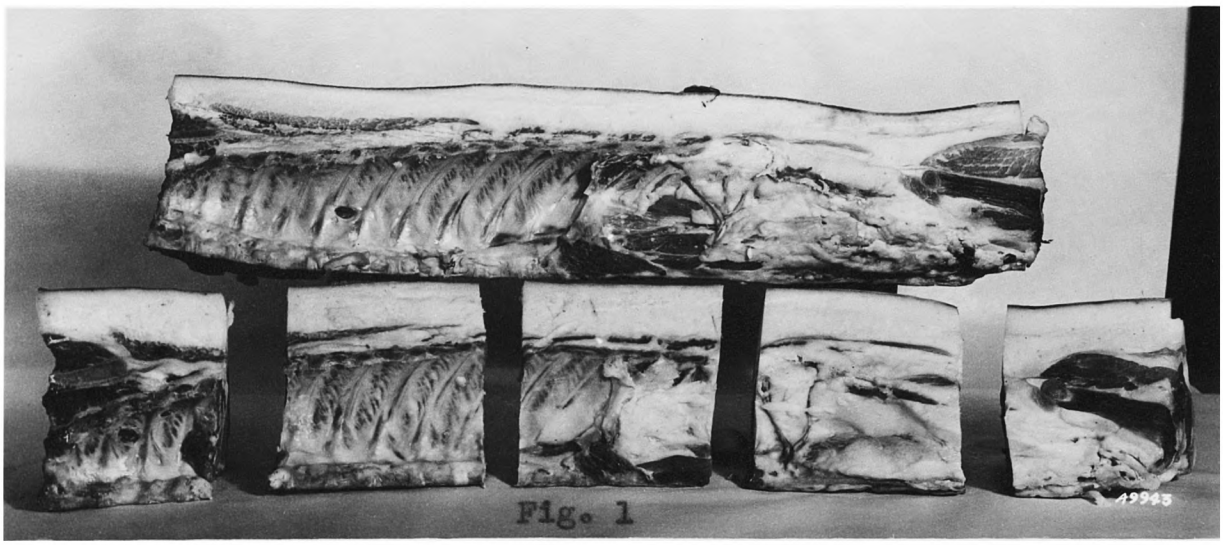


Fig. 1

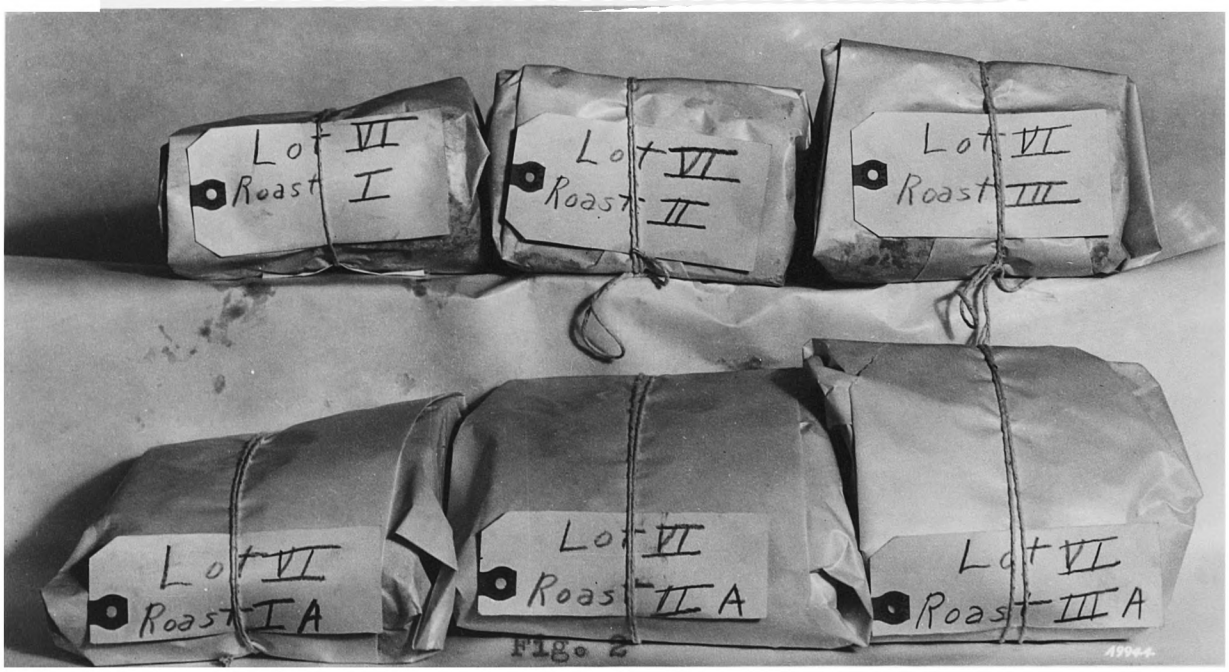

Lot VII
Roast I
Lot VII
Roast II
Lot VII
Roast III
Lot VII
Roast IA
Lot VII
Roast IIA
Lot VII
Roast IIIA

Fig. 2

were designated as a separate lot. The treatment given the various lots is presented in Table 2.

The sausage trimmings used in Lots 9, 10, and 11 were from the above carcasses. The sausage consisted of three parts lean pork trimmings to one part fat and was seasoned with one pound of salt, two ounces of sage, and two ounces of black pepper for every 50 pounds.

The white butcher paper used in Lot 1 was a heavy glazed paper and more water resistant than ordinary butcher paper. The freezer paper used in Lots 2, 6, 7, 8, 9, 10, 11, and 12 was a heavy, white glazed paper recommended by the manufacturer for frozen meat storage. The paper used in Lot 3 was a plain vegetable parchment paper of 40 pound weight and Lot 4 was wrapped in 40 pound vegetable parchment paper sized with oat flour by the manufacturer. The paper used in Lot 5 was a 35 pound paper waxed to 42 pounds with the waxing on both sides. The double waxed round cardboard containers of Lot 11 were the type commonly used for dairy products.

The oat flour used in Lots 6, 9, and 12 was plain oat flour made from the oat groats. In Lot 9 the two per cent of oat flour was mixed in the sausage. The meat was wrapped tightly with the ends folded in and the package tied

Table 2. Treatment of fresh pork roasts and sausage.

Lot with number of samples	Treatment[3]
Lot 1, six loin roasts	Wrapped in white butcher paper
Lot 2, six loin roasts	Wrapped in freezer paper
Lot 3, eight loin roasts	Wrapped in plain vegetable parchment paper
Lot 4, eight loin roasts	Wrapped in vegetable parchment sized with oat flour
Lot 5, eight loin roasts	Wrapped in brown waxed paper
Lot 6, six loin roasts	Wrapped in freezer paper and the tied package dusted with oat flour
Lot 7, six loin roasts	Wrapped in freezer paper and placed in the locker without previous freezing
Lot 8, six loin roasts	Double wrapped with freezer paper
Lot 9, ten one-pound sausage samples	Two per cent oat flour added then wrapped in freezer paper
Lot 10, ten one-pound sausage samples	Wrapped in freezer paper
Lot 11, ten one-pound sausage samples	Sausage patties separated by parchment paper and then wrapped in double waxed round cardboard containers
Lot 12, six loin roasts	Roasts rolled in oat flour and then wrapped in freezer paper

[3]All lots were frozen overnight at -2° F. before being placed in the locker with the exception of Lot 7 which was placed directly in the locker.

with string as shown in Fig. 2. In Lot 8, the double wrapped lot, string was used only around the outside wrapper.

All lots except Lot 7 were frozen overnight at -2° F. before being placed in the freezer locker. Lot 7 was frozen in the locker at about 12° to 15° F. These packages were well spread out in the locker and were frozen nearly as quickly as the other lots. The original plan was to compare slow freezing in Lot 7 with quick or sharp freezing in all other lots. A sharp freezing temperature (-20° F.) was not available so all lots were frozen at nearly the same rate.

The lockers used were the wooden frame, wire mesh type. The locker room was cooled by overhead pipes containing circulating brine. Table 3 gives the temperature as it was recorded by a thermograph from the 30th to the 141st day. A thermograph was available during this period only and a hygrograph could not be obtained until after the close of the experiment. Following the completion of the experiment, the relative humidity of the locker room as indicated by a hygrograph ranged from 87 to 95 per cent over a three week recording.

The per cent change in weight was found at each 30 day period. The weight of the meat was determined by subtracting the original weight of the wrapper from the weight of the meat and wrapper.

At the close of 60 days of storage one sample was removed from each lot for observation, cooking, and palatability tests. This process was repeated each 30 days thereafter through seven months of storage. Chemical tests for rancidity were made on the roasts removed at 90 days and each following period.

Upon removal from the freezer locker, the wrappers and meat were observed for any changes. The odor, bloom, and freezer burn of the meat was noted. The samples were allowed to thaw at 34° F. on porcelain meat trays to catch any moisture or drip that would accompany thawing. A sample of fat was taken from the end of the roasts over the longissimus dorsi (eye) muscle for chemical tests.

Table 3. The temperature of the locker room.

Period (days)	Temperature in degrees F.	
	Range	Average of twice daily readings[4]
30 - 60	+7 to +28	+16.7
60 - 90	+5 to +23	+11.3
90 - 120	+9 to +18	+11.9
120 - 141	+7 to +14	+10.9

[4]Readings taken from thermograph record

Cooking

The roasts were cooked by roasting in a flat uncovered pan. A constant oven temperature of 350° F. was maintained until the roasts reached an internal temperature of 183° F. They had reached their maximum temperature when removed from the oven. Determinations were made of per cent cooking loss due to evaporation and due to drippings and the time required per pound for cooking recorded. The sausage was pan fried in an iron skillet.

Palatability Tests

The cooked roasts were tested for palatability by judges using a grading sheet adapted from the grading

supported in a black box to protect it from light, and a steady stream of nitrogen was passed for two minutes into the air space above the liquid by means of a narrow glass jet which passed loosely through the hole in the stopper. The jet was then removed, the finger placed lightly over the hole, and the tube was heated in an inclined position (rotating to prevent cracking) over a flame applied at the bottom of the tube. When the liquid was bubbling freely, the tube was plunged into a boiling water bath. The liquid boiled rapidly and the chloroform vapor passed through the hole, as could be seen by watching the condensation, the finger was removed and a glass plug was forced into the hole. The closed tube was then vigorously shaken and cooled under cold tap water. The stopper was then removed, the liquid instantly poured into a 150 cubic centimeter Erlenmeyer flask containing 10 cubic centimeters of 5 per cent potassium iodide solution, the tube rinsed out twice with 10 cubic centimeters of the 5 per cent potassium iodide, and the free iodine titrated with N/500 sodium thiosulphate. The peroxide number was recorded as cubic centimeters N/500 sodium thiosulphate per gram of fat.

The acid number was determined according to Koch (1937). Phenolphthalein was added to a supply of 95 per

cent ethyl alcohol and N/20 NaOH was then added until there was a persistent pink tinge. Five grams of fat were weighed into a 250 cubic centimeter Erlenmeyer flask and 50 cubic centimeters of the neutral alcohol was added. The flask was heated to boiling and immediately titrated with N/20 NaOH. The acid number was recorded as the number of mg. of KOH per gram of fat.

Tenderness Test

The Warner-Bratzler Mechanical Shear was used to measure the tenderness of the cooked roasts (Bratzler, 1933). The pounds of force required to shear a one inch cylinder of meat is measured by the machine. Low shear numbers indicate tenderness.

Press Fluid Determination

The quality of press fluid expressible from the cooked longissimus dorsi (eye) muscle was determined according to the method of Vail and Hall (1937) using the Carver Laboratory Press (Hall, 1937). The cubic centimeters of expelled juice and fat at the end of 30 minutes were recorded. Sufficient data have not yet been collected to determine the reliability of the press fluid determination as a measurement of the juiciness of meat.

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OBSERVATIONS

The weight changes of the lots over the 217 days of storage are presented in Table 4 and Figs. 3, 4, 5, and 6. The percentage change in weight given in Table 4 is based upon the total original weight of the roasts in each lot and the total change in weight of the roasts at the various periods. There was considerable variation in the per cent of weight lost by individual roasts within the lots. The lots of sausage gained in weight during the first period. The cause of this has not been determined. Lots 1, 2, 3, 4 and 7 followed very closely the same percentage weight loss over the successive periods, whereas Lots 8 and 12 consistently lost less weight. All lots with the exception of Lot 2 and Lot 6 showed a gain in weight at 180 days over 150 days. This was possibly due to some change in the operation of the locker plant. Lot 11 gained considerably more weight than the other two lots of sausage.

At 60 days all roasts showed desiccation (freezer burn) to the extent that the lean surface at the ends of the roasts were dry and gray in color. This was not as pronounced in Lot 8 as in the other lots. Little could

Table 4. Percentage change in weight during storage.

Lot	Storage Period: 30 days Number samples	30 days Percent change in wt.	60 days Number samples	60 days Percent change in wt.	90 days Number samples	90 days Percent change in wt.	120 days Number samples	120 days Percent change in wt.	150 days Number samples	150 days Percent change in wt.	Number samples	Percent change in wt.	Number samples	Percent change in wt.
1	6	- 1.7	6	- 2.7	5	- 4.1	4	- 5.3	3	- 6.1	2	- 5.9	1	- 7.7
2	6	- 1.2	6	- 2.9	5	- 4.2	4	- 5.5	3	- 6.4	2	- 6.6	1	- 8.2
3	8	- 1.2	8	- 3.3	7	- 4.2	6	- 5.7	5	- 5.7	4	- 4.6	3	- 8.9
4	8	- 1.6	8	- 3.1	7	- 4.5	6	- 5.7	5	- 5.9	4	- 4.5	3	- 7.8
5	8	- 1.0	8	- 2.3	7	- 2.7	6	- 4.1	5	- 4.5	4	- 3.4	3	- 6.8
6	6	- .9	6	- 2.2	5	- 3.0	4	- 4.2	3	- 4.9	2	- 6.1	1	- 7.0
7	6	- 1.7	6	- 3.2	5	- 4.1	4	- 5.5	3	- 6.5	2	- 5.9	1	- 7.8
8	6	- .8	6	- 1.5	5	- 2.0	4	- 2.1	3	- 2.7	2	- 2.2	1	- 4.1
9	10	+ .8	10	+ .2	9	- .8	8	- 1.5	7	- 2.1	6	- .1	5	- 4.1
10	10	+ .8	10	+ .2	9	- .6	8	- 1.6	7	- 2.2	6	- .1	5	- 4.1
11	10	+ 2.6	10	+ 2.3	9	+ 2.2	8	+ 2.3	7	+ 2.0	6	+ 4.5	5	+ 1.6
12	6	- .1	6	- .5	5	- 1.1	4	- 1.3	3	- 1.7	2	- 1.1	1	- 2.6

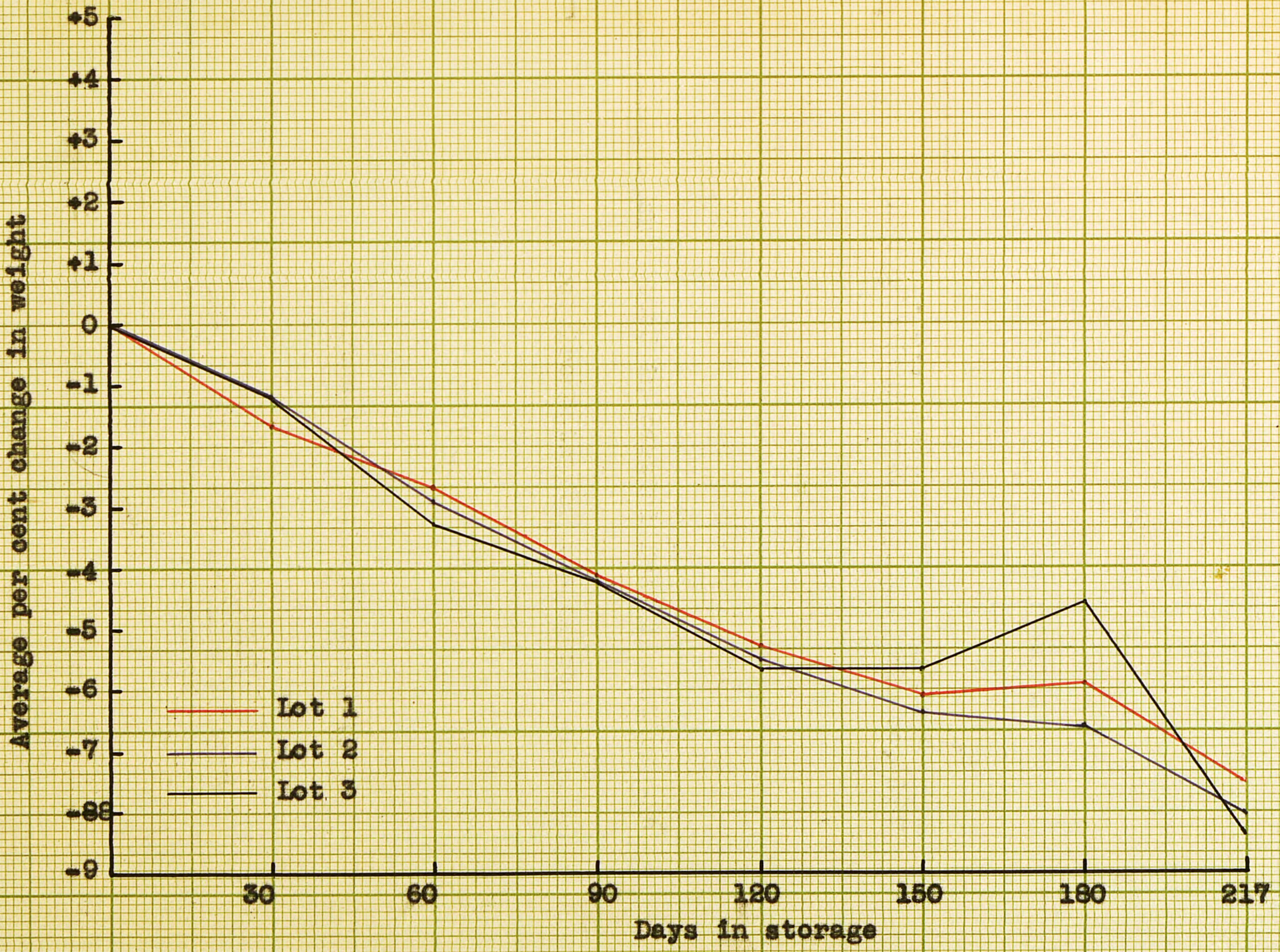

Fig. 2. Comparison of shrinkage of Lots 1, 2, and 3.

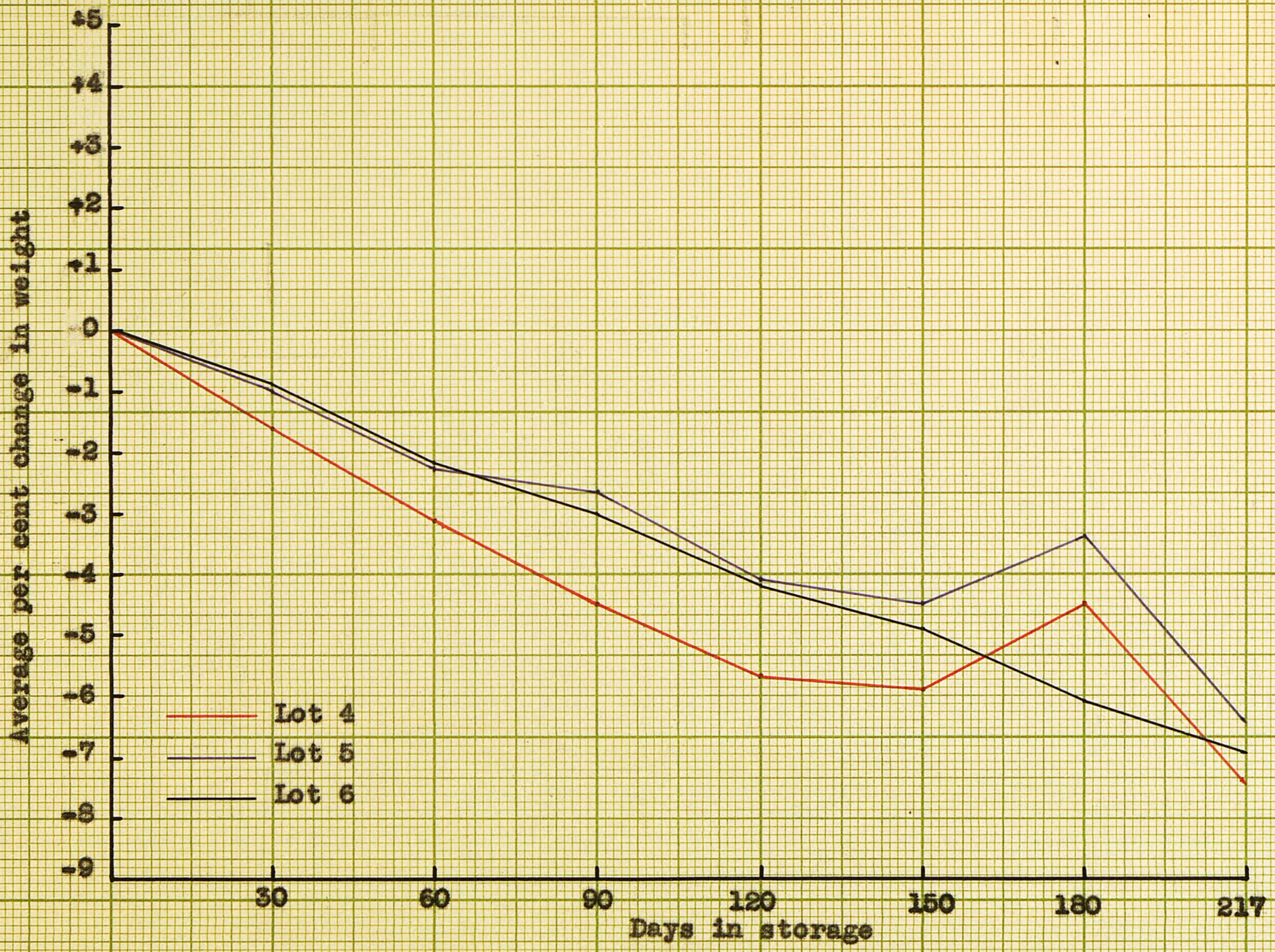

Fig. 4. Comparison of shrinkage of Lots 4, 5, and 6.

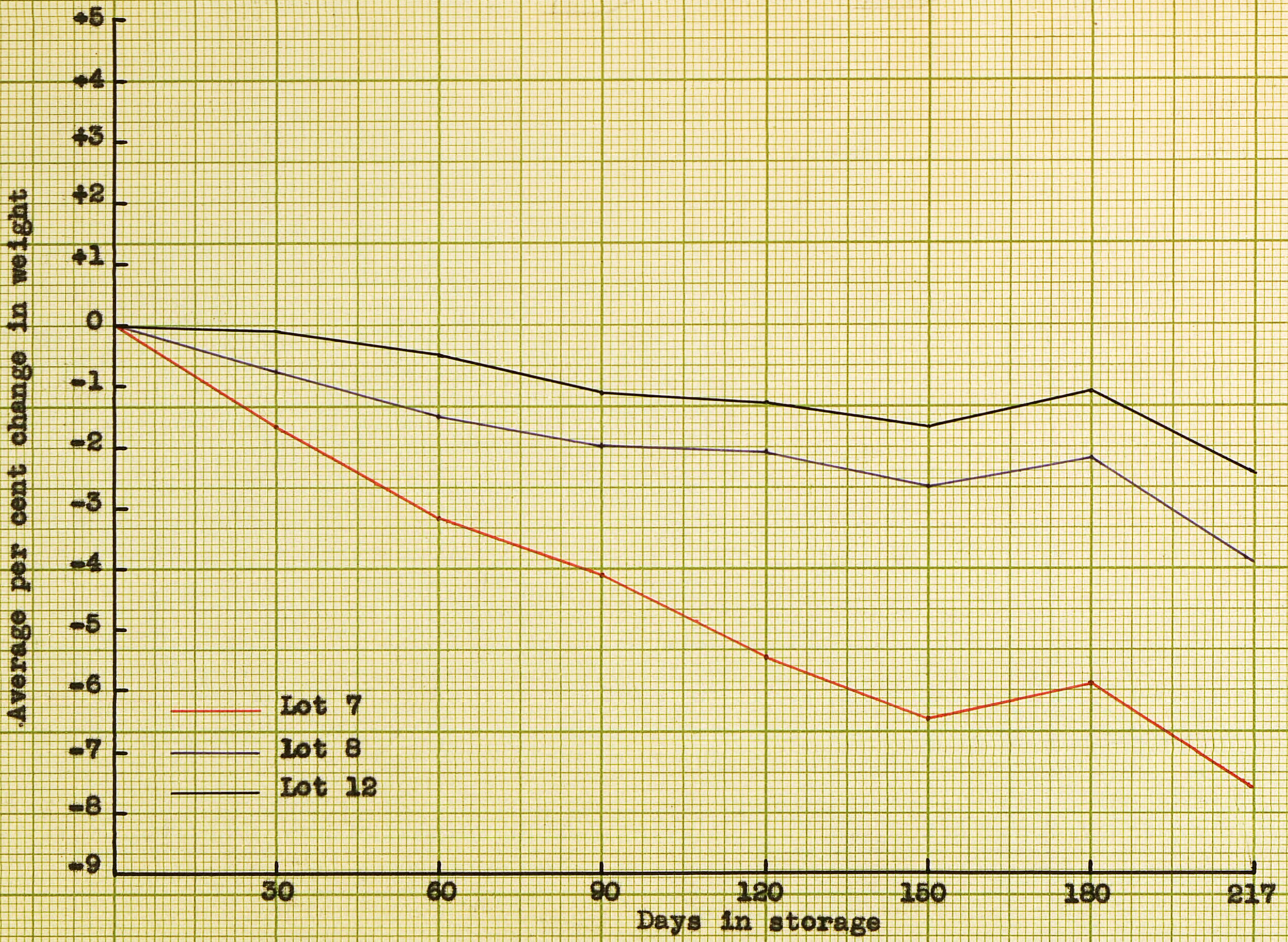

Fig. 5. Comparison of shrinkage in Lots 7, 8, and 12.

Fig. 6. Comparison of shrinkage in Lots 9, 10, and 11.

be told from observing Lot 12 due to its covering of oat flour. At the following periods the roasts appeared very much the same, being dry over the ends, however, this dry layer extended deeper into the meat as the storage period lengthened. The fat covering of some of the roasts showed a slight yellow tinge at the corners and on the under side at the close of the 120-day period. This was not noticeable in Lots 1, 2, 7, and 8 until after further storage.

The roasts and wrappers removed at 60 days had a slight refrigerator or cooler odor. This was apparent at all succeeding periods although it did not become more pronounced as the storage period progressed. The lots of sausage were gray in color at 60 days and at each following period.

The oat flour on the roasts of Lot 12 imparted a desirable odor to the roast before and during cooking. However, at the 180-day and 217-day periods the sausage and paper of Lot 9, which contained the 2 per cent of oat flour, had a decidedly more stale odor than Lot 10 the plain sausage. None of the samples of sausage or their wrappers had a strictly fresh odor after 180 days.

None of the papers broke to any extent. During the entire storage two small breaks were found in the wrappers of Lot 1, two in Lot 2, one in Lot 3, three in Lot 4, three in Lot 5, two in Lot 8, and no breaks in the other lots. All of these were small breaks and usually occurred at the corners of the package.

The vegetable parchment papers used in Lots 3 and 4 stuck slightly to the frozen meat when the wrapper was removed. These papers did not stick to the extent that paper was left on the meat up to 180 days. However, at the 180 and 217-day periods bits of dry lean meat pulled off with the papers. The wrappers in all the other lots separated from the frozen meat readily and the brown waxed paper of Lot 5 came off very easily.

No dripping loss was apparent at any time during the thawing of the roasts.

Table 5 gives the percentage loss in weight during cooking due to evaporation and dripping and time required per pound for cooking. There was considerable variation in the cooking time per pound. There also were differences in browning and odors during cooking and the following notes were made.

Table 5. Cooking data.[7]

Period (days)	Weight Uncooked Roast: Grams	Pounds	Cooked gm.	Per Cent Loss: Evaporation	Drippings	Total	Temperature over ° F.	Total time cooking min.	Time per pound min.
Lot 1									
60	967.0	2.10	734.0	9.8	14.3	24.1	183	85	41
90	751.5	1.66	617.5	8.6	9.3	17.9	183	120	72
120	862.0	1.90	664.5	12.1	10.8	22.9	184	118	62
150	1149.0	2.53	876.0	11.1	12.7	23.8	184	148	59
180	1110.0	2.45	877.5	8.6	12.4	21.0	182	128	52
217	1047.5	2.30	798.0	10.7	12.9	23.6	185	124	54
Lot 2									
60	1135.5	2.50	835.5	15.2	11.3	26.5	182	113	45
90	1084.5	2.39	872.0	11.8	7.8	19.6	185	147	62
120	1057.0	2.33	785.5	17.0	8.6	25.6	183	151	65
150	932.5	2.05	743.0	11.8	8.5	20.3	185	131	64
180	1043.0	2.30	829.5	10.8	9.7	20.5	183	126	55
217	1102.5	2.43	797.0	16.6	11.2	27.8	187	140	62
Lot 3									
60	821.0	1.80	663.0	9.6	9.7	19.3	184	93	52
90	623.0	1.37	514.0	7.5	10.0	17.5	184	115	84
120	692.0	1.52	541.0	11.1	10.9	22.0	185	105	69
150	577.0	1.49	558.0	8.1	9.5	17.6	183	101	68
180	752.0	1.66	598.5	9.5	10.9	20.4	184	103	62
217	593.0	1.30	490.0	8.5	8.5	17.1	186	87	67
Lot 4									
60	847.0	1.90	657.0	10.0	12.5	22.5	184	88	46
90	605.5	1.33	514.0	8.1	7.1	15.2	184	130	90
120	731.5	1.61	577.0	12.3	8.8	21.1	184	109	68
150	636.5	1.40	529.5	8.8	7.9	16.7	183	92	66
180	643.0	1.42	508.5	12.9	8.1	21.0	185	110	77
217	695.7	1.53	557.7	10.2	9.5	19.7	183	103	72
Lot 5									
60	961.5	2.10	722.5	11.6	13.4	24.9	183	85	40
90	666.5	1.47	585.0	7.3	5.1	12.4	184	129	88
120	792.5	1.74	617.5	14.2	7.6	21.8	183	135	78
150	798.0	1.76	623.5	11.8	10.0	21.8	184	123	70
180	805.0	1.77	634.5	11.2	10.0	21.2	182	114	64
217	826.7	1.82	665.5	10.9	9.6	19.0	182	109	60

Table 5 (cont.)

Period (days)	Weight Uncooked Roast: Grams	Pounds	Cooked gm.	Per Cent Loss: Evaporation	Drippings	Total	Temperature oven °F.	Total time cooking min.	Time per pound min.
Lot 6									
60	1064.5	2.30	820.5	10.7	12.2	22.9	183	119	52
90	965.5	2.13	797.0	8.4	9.1	17.5	184	125	59
120	1004.5	2.21	770.0	12.8	10.6	23.4	183	144	65
150	1057.5	2.33	824.5	9.6	12.4	22.0	183	128	55
180	1023.5	2.25	814.0	8.8	11.7	20.5	182	124	55
217	1039.0	2.29	824.5	10.0	10.4	20.4	183	136	59
Lot 7									
60	1045.5	2.30	852.0	10.8	7.8	18.7	186	117	51
90	980.5	2.16	808.0	9.8	7.8	17.6	184	132	61
120	964.5	2.42	784.0	11.0	7.6	18.6	183	129	61
150	1033.0	2.28	820.0	11.7	8.9	20.6	184	137	60
180	980.0	2.16	819.0	10.2	6.3	16.3	183	102	42
217	977.5	2.16	770.5	10.5	10.3	20.8	183	124	57
Lot 8									
60	1208.0	2.70	915.0	12.7	11.5	24.3	183	111	41
90	872.0	1.92	718.0	11.2	6.6	17.8	185	146	76
120	1063.5	2.34	827.0	13.7	8.6	22.3	185	144	62
150	1085.5	2.39	833.0	13.1	10.0	23.1	182	157	66
180	1088.0	2.40	899.5	9.8	7.5	17.3	184	130	54
217	1101.5	2.43	900.5	12.8	5.1	17.9	183	129	53
Lot 12									
60	979.0	2.20	829.0	8.9	6.3	15.3	183	97	44
90	877.5	1.93	744.5	9.2	5.9	15.1	183	117	61
120	917.5	2.02	728.0	12.9	7.8	20.7	184	124	58
150	980.5	2.16	806.5	9.0	8.7	17.7	183	132	61
180	991.5	2.18	824.5	9.5	7.4	16.9	182	108	50
217	1003.0	2.21	802.0	12.8	7.2	20.0	185	130	59

[7]Data at 217 days for Lots 3, 4, and 5 are the average of two roasts.

60 days

The odor of the roasts from Lots 1 and 7 was unpleasant.

The Lot 2 roast browned rapidly.

The Lot 8 roast had an excellent odor.

The Lot 12 roast browned more than most of the others.

90 days

The odor of the roasts from Lots 1 and 7 was unpleasant.

The Lot 2 roast after 40 minutes in the oven browned a great deal and after 90 minutes had browned too much.

The Lot 8 roast had an excellent odor.

The Lot 12 roast browned more than most of the others.

120 days

The Lot 6 roast had a strong odor.

The Lot 12 roast browned more than most of the others.

150 days

The Lot 4 roast browned excessively and had the odor of brown potatoes.

The Lot 7 and 8 roasts had a strong odor.

The Lot 12 roast browned more than most of the others.

180 days

No notes were made.

217 days

The Lot 2 roast had a strong odor and browned quickly.

The Lot 8 roast had a good odor while cooking.

The Lot 12 roast browned more than most of the others.

A summary of the palatability scores for the cooked roasts is presented in Table 6 which also gives the average of the scores of the judges. The individual scores of the judges were conflicting in many cases. The committee agreed that the scores do not show as wide a range in desirability as actually existed between the roasts tested at 60 days and those tested at 217 days. At the 217-day period testing, a fresh pork roast was cooked for comparison, and the storage roasts scored considerably lower than the fresh roast. The storage roasts in general scored correspondingly lower this period (217 days) than they had at previous periods. The committee agreed that the desirability of the meat decreased as the storage period lengthened. It was also agreed that, under conditions of this study, storage of

Table 6. Average scores of palatability committee on quality of juice and desirability of meat.[5]

Period (days)	Quality of juice	Desirability of Meat		
		Aroma	Flavor of Fat	Flavor of Lean
Lot 1				
60	4.7	4.4	3.4	3.6
90	5.1	5.3	4.0	5.1
120	4.3	4.7	3.3	5.5
150	4.4	4.6	4.0	4.6
180	4.0	4.3	4.0	3.5
217	3.6	4.7	3.4	4.5
Lot 2				
60	5.0	5.6	3.2	4.8
90	4.6	4.2	2.8	4.0
120	3.7	4.0	3.8	4.7
150	4.4	4.6	4.6	5.2
180	3.5	3.5	2.5	3.2
217	4.0	4.5	3.0	4.0
Lot 3				
60	5.4	5.0	5.2	4.8
90	5.0	5.0	5.4	4.8
120	4.8	4.8	4.5	5.7
150	4.5	4.2	4.4	4.0
180	5.0	4.7	4.5	5.2
217	4.0	3.7	3.3	3.5
Lot 4				
60	5.4	4.8	4.7	5.4
90	5.5	5.3	5.3	5.8
120	3.8	4.0	3.5	4.5
150	4.6	4.2	4.0	5.4
180	5.3	5.0	4.5	5.3
217	3.7	4.3	2.7	4.1

[5]A score of 7 would indicate maximum desirability.

Table 6 (cont.)

Period (days)	Quality of Juice	Desirability of Meat		
		Aroma	Flavor of Fat	Flavor of Lean
Lot 5				
60	5.0	6.0	6.2	5.2
90	4.3	4.8	4.0	4.8
120	5.0	5.2	4.8	5.6
150	5.0	4.0	4.4	5.6
180	5.0	5.5	4.5	5.5
217	3.7	4.9	3.4	4.1
Lot 6				
60	5.2	5.0	6.2	5.8
90	4.6	5.0	5.0	5.8
120	5.4	5.6	5.0	5.8
150	4.8	4.6	4.4	5.2
180	4.7	4.3	4.5	4.3
217	3.7	4.5	4.3	4.4
Lot 7				
60	5.6	5.6	4.0	4.6
90	5.1	5.1	4.5	5.5
120	4.1	4.8	4.3	5.3
150	4.8	5.8	4.6	5.0
180	4.3	4.7	3.2	4.7
217	3.7	4.4	3.6	4.5
Lot 8				
60	5.2	5.6	5.0	5.2
90	4.7	5.0	4.7	5.5
120	4.0	5.7	4.0	5.7
150	5.0	5.4	6.0	6.0
180	4.8	5.5	4.8	5.2
217	3.6	5.2	4.5	5.0
Lot 12				
60	5.6	5.6	5.4	6.0
90	5.1	5.3	5.3	5.8
120	5.0	5.4	5.2	6.0
150	4.4	4.8	5.0	5.6
180	4.8	5.2	5.5	4.5
217	4.2	4.5	3.5	4.5

fresh pork roasts should not exceed 150 days.

In the paired judging of the roasts and sausage samples there were many disagreements. Table 7 gives the number of judges preferring each member of each pair. At the first four cooking periods, most of the judges preferred the roasts from Lot 2 to those from Lot 1, but this preference was not shown at the 180 and 217 day periods. In the other pairs, no lot was consistently preferred to the lot paired with it. Likewise in the paired sausage judging, the only consistent preference shown by the committee was for Lot 11 over Lot 10. The judges agreed that all the sausage samples had a stale flavor after 120 days of storage.

The peroxide values given in Table 8 show in general a consistent increase with the length of storage, thus indicating increasing degrees of rancidity in the samples. Lot 12 had a decidedly lower peroxide value than any of the other lots. The acid numbers do not show a consistent change.

Table 9 gives the shearing resistance of the cooked roasts. The pounds of resistance at the first three periods and the second three periods are averaged in each lot for comparison. With the exception of one lot, the

Table 7. Results of paired judging tests.

Lots paired	Degree of preference	Number of judges preferring each lot					
		60 days	90 days	120 days	150 days	180 days	217 days
Lot 1	Decided		1		1	3	1
	Slight	1	1	1		1	2
	None	1		1	1		2
Lot 2	Slight		2	1	1		2
	Decided	3	2	3	2		1
Lot 3	Decided			1	1	2	
	Slight	2	4	2	3	2	2
	None	1					
Lot 4	Slight	1	1	1	1		3
	Decided	1	1	2			3
Lot 2	DECIDED	1	1				1
	Slight	1		2	3	1	3
	None	1	1	2			
Lot 7	Slight	2	2	1	1		3
	Decided		2	1	1	3	1
Lot 2	Decided	2		1		1	
	Slight			1	2	1	5
	None	1		1	1		
Lot 8	Slight		4	1	1	1	
	Decided	2	2	2	1	1	4

Table 7 (cont.)

Lots paired	Degree of preference	Number of judges preferring each lot					
		60 days	90 days	120 days	150 days	180 days	217 days
Lot 9	Decided	1		2	2	1	
	Slight	1	1	1		3	3
	None	2	2				
	Slight		2	1	3		2
Lot 10	Decided	1	1	1			1
Lot 9	Decided					1	
	Slight	1	1	2	3	1	3
	None	3	4	2	1		1
	Slight		1	1		2	
Lot 11	Decided	1			1		2
Lot 10	DECIDED						
	Slight		2		1	2	1
	None		1				1
	Slight		2	1	1		4
Lot 11	Decided		1	4	3	2	

Table 8. Peroxide numbers and acid numbers on roasts over successive storage periods.

Lot	Time in Storage											
	90 days		120 days		150 days		180 days		217 days	
	Peroxide number	Acid number	Peroxide number	Acid number	Peroxide number	Acid number	Peroxide number	Acid number	Peroxide number	Acid number
1	4.5	1.8	7.3	1.8	8.0	1.9	9.0	2.1	10.5	2.0
2	...	...	6.2	2.2	8.4	2.0	9.2	2.1	9.8	2.4
3	1.5	2.4	4.5	2.5	5.6	2.6	3.2	1.8	5.1	2.3
4	6.3	2.1	7.0	2.0	9.5	2.0	4.6	1.8	7.0	2.4
5	1.5	1.6	4.1	1.8	9.3	1.9	2.9	1.6	5.1	1.8
6	2.7	1.6	4.5	1.9	6.0	2.0	11.9	1.9	10.2	2.2
7	2.3	1.8	5.2	2.2	5.1	2.4	10.4	2.8	13.9	2.1
8	1.6	1.5	2.6	1.5	2.1	1.9	4.2	1.6	...	...
12	.4	2.3	.4	1.4	.8	2.0	.9	1.9	1.0	1.6

resistance is highest for the second three cooking periods.

The results of the press fluid determinations are presented in Table 10. The amount of juice and fat expelled from cooked roasts of the same lot varied greatly over the successive periods.

Table 9. Tenderness measurements.

Lot	Shearing resistance in pounds							
	60 days	90 days	120 days	Av. 1st 3 periods	150 days	180 days	217 days	Av. 2nd 3 periods
1	10.1	11.5	12.1	11.2	9.9	10.8	8.6	9.8
2	13.8	12.0	13.9	13.2	10.7	12.1	10.6	11.1
3	14.7	12.9	15.5	14.4	11.1	15.1	12.8	13.0
4	11.9	12.4	14.0	12.8	11.2	11.6	13.5	12.1
5	15.6	15.7	20.8	17.4	12.4	14.7	17.4	14.8
6	19.3	17.3	17.5	18.0	14.3	14.4	16.8	15.2
7	16.2	17.0	20.2	17.8	16.2	13.7	12.9	14.3
8	17.0	16.5	13.6	15.7	12.3	14.3	14.3	13.6
12	13.6	13.5	14.4	13.8	14.4	18.1	12.4	15.0

Table 10. Press fluid measurements.

Lot	Cubic centimeters of press fluid pressed from 50 grams of cooked meat											
	60 days		90 days		120 days		150 days		180 days		217 days	
	cc. juice	cc. fat	cc. juice	cc. fat	cc. juice	cc. fat	cc. juice	cc. fat	cc. juice	cc. fat	cc. juice	cc. fat
1	11.0	3.5	12.5	2.0			9.0	3.5	14.0	2.5	7.0	3.0
2	7.0	1.5	11.0	1.0	5.0	2.0	6.5	.5	16.0	1.0	8.5	1.0
3	11.1	4.6	12.0	3.5	5.2	5.0	11.5	4.0	14.0	1.5	10.9	2.6
4	9.0	4.2	12.5	2.5	5.7	3.0	9.5	3.0	14.2	2.1	10.6	1.7
5	8.5	4.0	13.3	2.2	6.3	2.5	5.5	2.8	12.5	1.7	11.2	.8
6	11.8	3.2	7.0	3.0	5.5	2.0	12.0	3.5	10.0	1.0	4.7	1.8
7	10.6	6.4	15.0	2.5	6.0	5.0	7.0	5.0	12.5	3.5	9.0	5.5
8	6.0	5.5	11.0	5.0	9.0	5.0	6.5	4.0	12.0	2.0	9.0	2.0
12	14.0	4.0	11.0	2.5	11.0	3.0	9.0	3.0	12.0	1.0	7.0	3.0

DISCUSSION

As indicated the packages of sausage gained in weight. The ground character of the meat and the high humidity of the locker room may have been factors in the absorption of moisture. The roasts rolled in oat flour very likely lost less weight than the lots which were not so treated because of the greater protection from moisture loss given by the flour adhering to the lean surfaces. The double wrapped group lost less weight than the single wrapped lots due to the additional covering which reduced the amount of moisture vapor leaving the package. The area of the exposed lean surface may have had an influence on the amount of moisture lost during the first periods of storage.

A slight odor was noticeable in the locker room during this study. It was not particularly undesirable. This odor was noticeable on the wrappers and meat at the time of their removal from storage and has been referred to under OBSERVATIONS as a refrigerator or cooler odor. The odor was not apparent in the cooked meat.

Since frozen products upon removal from the freezer locker "sweat" or become covered quickly with condensed

moisture from the air, little could be told as to how soft the wrappers were after storage. However they all were in good condition upon removal.

The abundant covering of fat over the roasts together with the dry surface which developed over the lean area during the first 60 days may have prevented dripping during thawing.

The wide variation in cooking time per pound is hard to explain. Vail[6] stated that some differences were due to variations in the size and shape of the roasts and suggested that the temperature of the meat at the time cooking started may have had an influence. Small roasts require more time per pound than large roasts, other things being the same.

Since the judges' scores on flavor are opinions, and since tastes seem to vary widely, there was always considerable disagreement over the grading of individual samples. Samples which were decidedly rancid to one judge were sometimes quite desirable to others. As can be seen in Table 7, disagreement between judges was fre-

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[6]Correspondence with the author.

quent in the paired judging. When the fresh roast was used as a standard for scoring roasts at the 217-day period, more satisfactory scoring resulted. Apparently this partially eliminated the tendency for the judges to just compare the meat that was before them at the time rather than to compare it also with meat judged 30, 60, or 90 days previous.

Although the peroxide values in general became greater as the storage period lengthened, there were some exceptions as shown in Table 8. Lots 3, 4, and 5 dropped at 180 days to a Peroxide Number below their 150 day value. It does not seem feasible that they became less rancid. The drop could be due to variation in the rate of rancidity between roasts removed from the same lot. The degree of rancidity development may vary in different areas of the fat of an individual roast and the sample removed for chemical tests might not have been representative.

The Acid Numbers indicate that there was little change in the acidity of the fat. Apparently the rancidity that developed was due more to oxidation than to hydrolysis of the glycerides and the liberation of free fatty acids.

With the exception of one lot, the pounds of shearing resistance averaged less the second three cooking periods than the first three cooking periods. This indicates that freezer locker storage may cause meat to become more tender. However the data here presented on tenderness is too limited to be considered as more than exploratory.

SUMMARY AND CONCLUSIONS

1. Pork loin roasts and sausage samples were studied during seven months of freezer locker storage. The meat was divided into 12 lots. Each lot represented a different method of storing meat. Several types of meat wrappers were compared and some lots were treated with plain oat flour to determine its effectiveness as an antioxidant or rancidity inhibitor. The meat was weighed at 30 day periods to observe weight changes. At the close of 60 days of storage one sample was removed from each lot for cooking, palatability, and chemical tests. This process was repeated each 30 days thereafter through seven months. The palatability was measured by a group of judges. The chemical tests used for determining the development of rancidity were the Peroxide Number and

the Acid Number. The tenderness of the cooked roasts was measured by means of the Warner-Bratzler Mechanical Shear. Press fluid determinations were made on the cooked meat using the Carver Laboratory Press.

2. White butcher paper, freezer paper, vegetable parchment paper, and brown waxed paper allowed very nearly the same amount of shrinkage and degree of freezer burn. Roasts double wrapped with freezer paper and roasts rolled in oat flour before packaging with freezer paper lost less weight than lots not so treated.

3. Palatability scores did not indicate the superiority of any wrapper or method of treatment studied.

4. Vegetable parchment paper sized with oat flour did not retard rancidity development as measured by the Peroxide Number and Acid Number. Roasts rolled in oat flour before packaging had much lower Peroxide Numbers and browned more in cooking than untreated roasts. Sausage containing two per cent oat flour was not found by the palatability committee to be superior to untreated sausage. No influence was noted from dusting the packaged meat with oat flour.

5. All the lots of sausage had a gray color after 60 days of storage. Sausage packaged in double waxed

cardboard containers was not found superior to sausage packaged in freezer paper.

6. The palatability committee agreed that the meat became less desirable as the storage period lengthened and that under the conditions of this study, fresh pork roasts should not be stored longer than 150 days and sausage longer than 120 days.

7. Fresh meat should be used as a standard while making palatability tests on stored meat.

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APPENDIX

Form 1. Grading chart for cooked meat.

Factor	Phase	7	6	5	4	3	2	1
Aroma	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.
	Desirability	very des.	des.	m. des.	des.	neutral	undes.	undes.
Texture	Intensity	very fine	fine	m. fine	s. coarse	coarse	very coarse	ext. coarse
Flavor of fat	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.
	Desirability	very des.	des.	m. des.	s. des.	neutral	s. undes.	undes.
Flavor of lean	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.
	Desirability	very des.	des.	m. des.	s. des.	neutral	s. undes.	undes.
Tenderness	Intensity	very tender	tender	m. tender	s. tough	tough	very tough	ext. tough
Juiciness	Quantity of juice	very juicy	juicy	m. juicy	s. dry	dry	very dry	ext. dry
	Quality of juice	very rich	rich	m. rich	s. rich	per.	s. per.	imper.

Key to Abbreviations

pro. - pronounced
m. - moderately
s. - slightly
des. - desirable
undes. - undesirable
ext. - extremely
imper. - imperceptible
per. - perceptible

(Signature of Judge)

Form 2. Score card for paired palatability tests.

Date _____

Kind of Meat _____ Cut of Meat _____

Sample No.		1		2		3		4	
Roast		A	B	A	B	A	B	A	B
More desirable flavor									
Difference	None								
	Slight								
	Decided								

Signature of Judge _____