FURTHER OBSERVATIONS ON THE QUALITY OF FROZEN MEAT

by

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INTRODUCTION

Recognizing the fact that it is possible to preserve food in a condition which is similar to the fresh product, many people are turning to the use of frozen food lockers. Within the last few years this method of food preservation has developed rapidly and today there are over 4,000 of these plants operating in the United States. The importance of preserving food, now that the Nation is at war, has undoubtedly greatly increased the number of plants. With such rapid growth and development came many unanswered problems which could only be answered by research workers.

Some of these problems were related to the proper type of wrapping or packaging; the best quality or grade of food for freezing; the most desirable freezing temperatures and length of storage time for the product; in the case of vegetables, the best varieties to use; and also what effect freezing had on the condition and quality of the product.

Meat is one of the highly perishable foods and the frozen food locker furnishes a means for preserving it for a limited time. Not only does freezing help to preserve meat but also to make it more tender as was shown by Hankins and Hiner (1940) in their research on fresh beef. Beef that has been aged or ripened at 34° F. to 36° F. for a period of time became more tender according to Moran and Smith (1929), but Bray (1941) found that freezing aged or ripened beef did not increase its tenderness. However, under normal conditions,

the beef would be stored for some time in this frozen condition. Little or no work has been done to show the effect of a prolonged period in which the meat remains frozen to see if any change takes place in the tenderness of the aged beef.

The present investigation was made to determine whether or not the freezing or storing for a period of time in the frozen condition had any effect upon tenderness of aged beef. Additional data were obtained upon the amount of press fluid, the cooking losses and the total nitrogen content of the meat and of the press fluid.

MATERIALS AND METHODS

The beef used in this study was obtained from the carcasses of three Hereford steers. These steers were purchased when about six months old and placed on a ration of corn and silage supplemented with urea, cottonseed oil, and a mineral mixture. They remained on this ration for eleven months and were then slaughtered the last week of October, 1941. The steers weighed about 975 pounds at the time of slaughter and graded from U. S. Good to U. S. Choice on foot.

Two of the carcasses graded U. S. Good and the other graded U. S. Choice. All three were aged for a period of 40 days at a temperature of 36° F. to 38° F. At the end of this period the loins were sampled by a method similar to the one used by Hankins and Hiner (1940). The steaks were

cut from the longissimus dorsi muscle between the 13th thoracic and the 5th lumbar vertebrae, commonly known as the short loin of beef.

The short loins were first boned and nine steaks, each one and one fourth inches thick, were cut and weighed. The steaks from the right side were numbered 1R, 2R, 3R, etc., and those from the left side were numbered 1L, 2L, 3L, etc., beginning at the anterior end as indicated in Fig. 1. Steaks 1, 2, and 3 were designated as coming from the anterior section; steaks 4, 5, and 6 from the mid section; and 7, 8, and 9 from the posterior section of the loin.

The temperature assignment eliminated as far as possible the variation between right and left loins and between adjacent steaks thus systematizing the sampling. This should not have been done according to Snedecor (1940) as it did not follow true randomized sampling and thus reduces the significance of results shown in the analysis of variance.

The "fresh" steaks were aged and then cooked within 24 hours after they were cut; during the intervening time they were held in a refrigerated temperature of 34° F. The cooking was done in a gas oven heated to a constant temperature of 392° F. The oven was equipped with a revolving hearth which insured an even temperature to all the steaks during the cooking. The steaks themselves were placed on wire racks eight inches in height above the drip pans which were placed on the revolving hearth. The wire racks made it unnecessary to

Carcass A - Right loin

1	2	3	4	5	6	7	8	9
FR	FZ	FS	FR	FZ	FS	FR	FZ	FS

Anterior section Mid section Posterior section

Carcass A - Left loin

1	2	3	4	5	6	7	8	9
FZ	FS	FR	FZ	FS	FR	FZ	FS	FR

Anterior section Mid section Posterior section

Carcass B - Right loin

1	2	3	4	5	6	7	8	9
FZ	FS	FR	FZ	FS	FR	FZ	FS	FR

Anterior section Mid section Posterior section

Carcass B - Left loin

1	2	3	4	5	6	7	8	9
FS	FR	FZ	FS	FR	FZ	FS	FR	FZ

Anterior section Mid section Posterior section

Carcass C - Right loin

1	2	3	4	5	6	7	8	9
FS	FR	FZ	FS	FR	FZ	FS	FR	FZ

Anterior section Mid section Posterior section

Carcass C - Left loin

1	2	3	4	5	6	7	8	9
FR	FZ	FS	FR	FZ	FS	FR	FZ	FS

Anterior section Mid section Posterior section

FR=Fresh steaks FZ=Frozen steaks FS=Stored steaks

Fig. 1 Diagram showing method of sampling.

turn the steaks as the heat reached each side uniformly. The steaks were left in the oven until they reached an internal temperature of 145° F. and were then removed for weighing (Plate I).

The term "frozen" was used to designate those steaks which were aged and then frozen for a 24 hour period. The "frozen" steaks were first double wrapped in an approved moisture-vapor-proof paper and frozen at -10° F. to -15° F., as suggested by Bray (1941), and also recommended by Hankins and Hiner (1940) as being the most economical temperature for freezing beef to tenderize it.

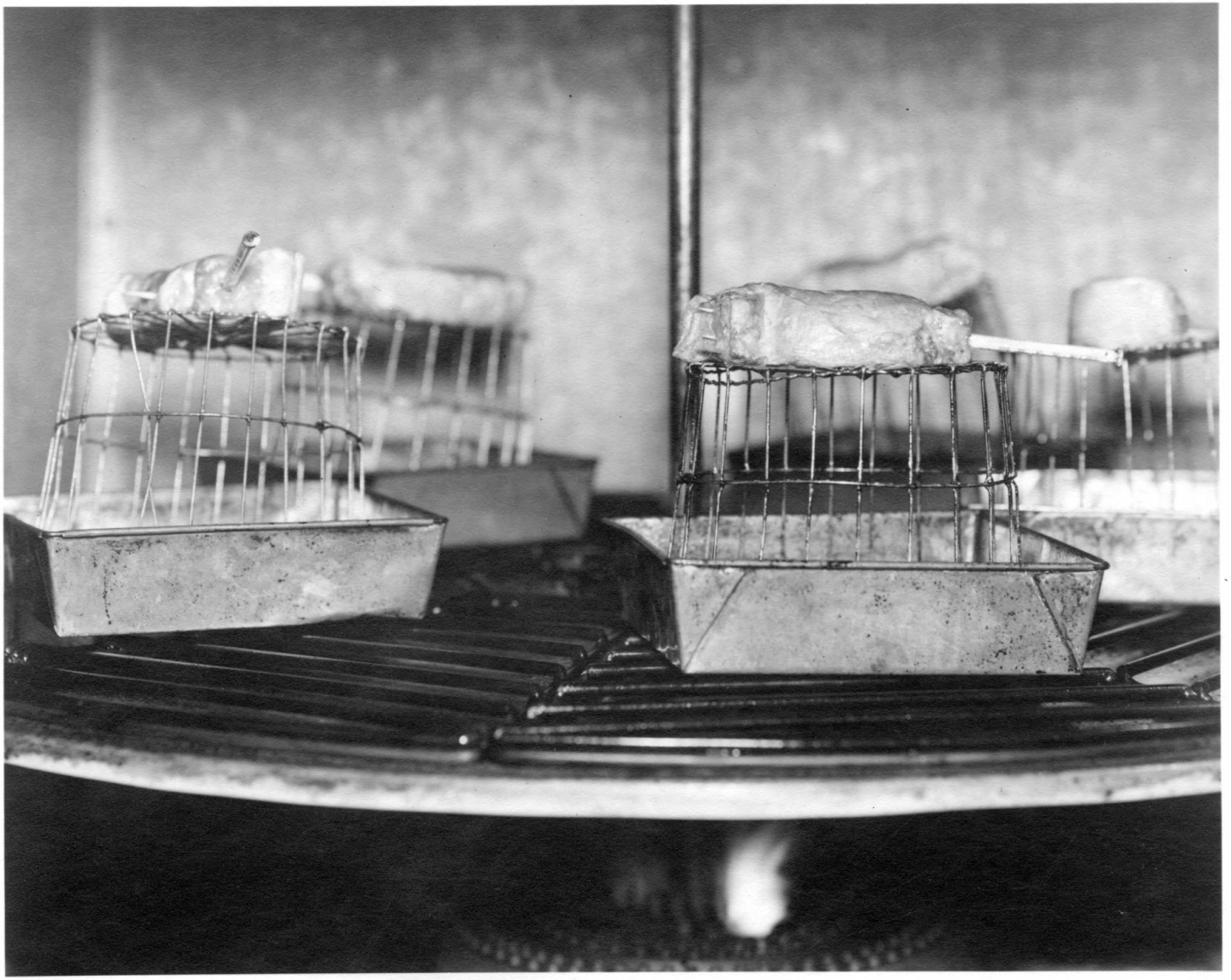
The "frozen stored" steaks were wrapped and frozen the same as the "frozen" steaks except they were held at the freezing temperature of -10° F. to -15° F. for 90 days. Before cooking the "frozen" and the "frozen stored" steaks were allowed to thaw for 24 hours in a refrigerator maintained between 34° F. and 36° F. These steaks, after thawing were handled in the same manner as the control steaks.

From each steak three cores were removed by pushing a one inch borer through from the anterior to the posterior side of the steak. The cores were designated as lateral, central, and medial according to the method used by Bratzler (1932) (Plate II). Each core was then tested for tenderness in the Warner-Bratzler mechanical tenderness shear (Plate III) and results recorded. The three determinations being made

EXPLANATION OF PLATE I

Gas oven equipped with a revolving hearth used to cook the steaks. The pans with wire racks are shown with the steaks and thermometers in place.

PLATE I



EXPLANATION OF PLATE II

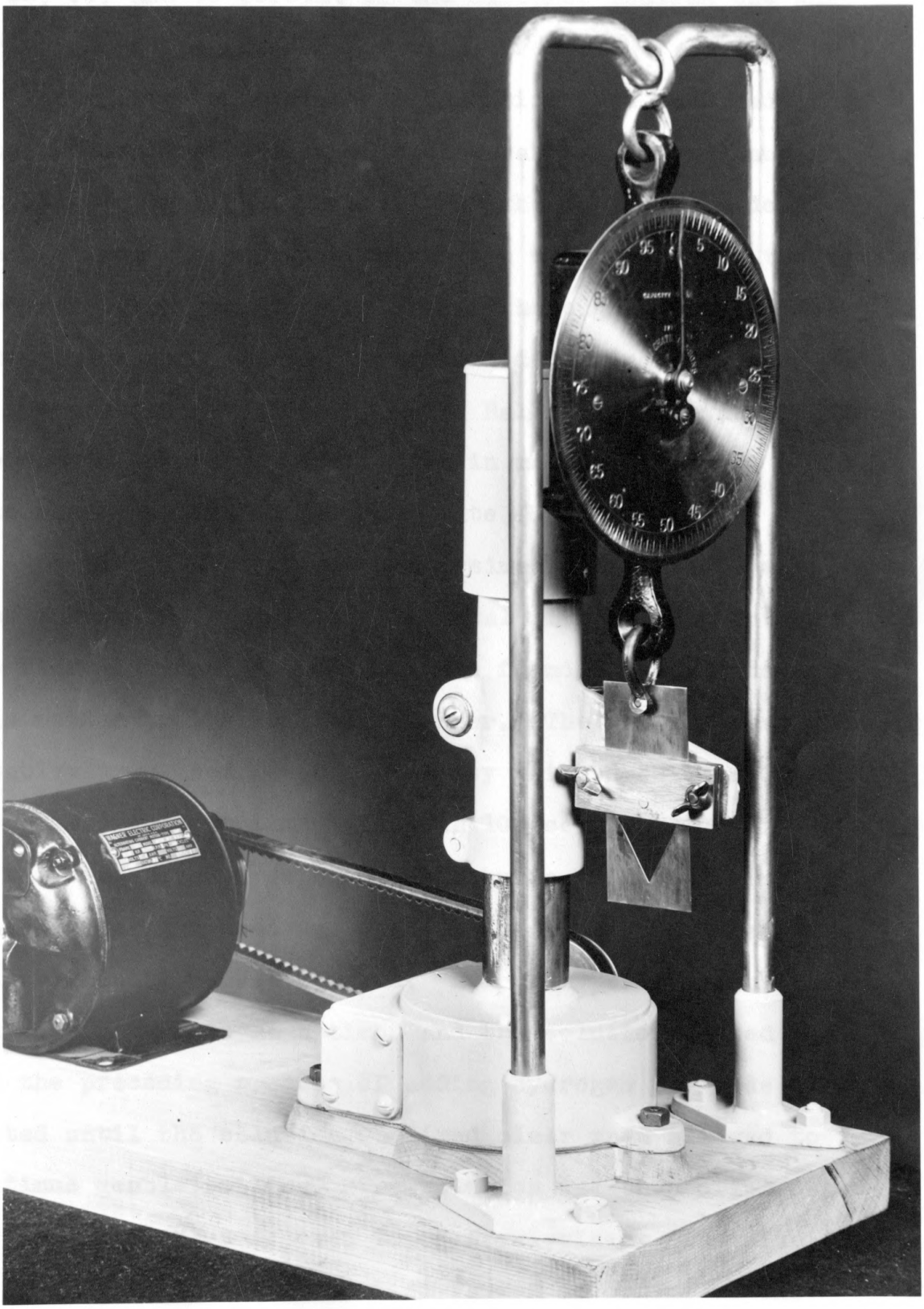
Steak with the cores removed from the longissimus dorsi muscle. The cores are designated from left to right as lateral, central, and medial and are ready to be tested for tenderness.

PLATE II

EXPLANATION OF PLATE III

Warner-Bratzler Mechanical tenderness shear used to measure the tenderness of the cores from the steaks.

PLATE III



at 25, 50, and 75 percent of the distance between the anterior and posterior ends of each core.

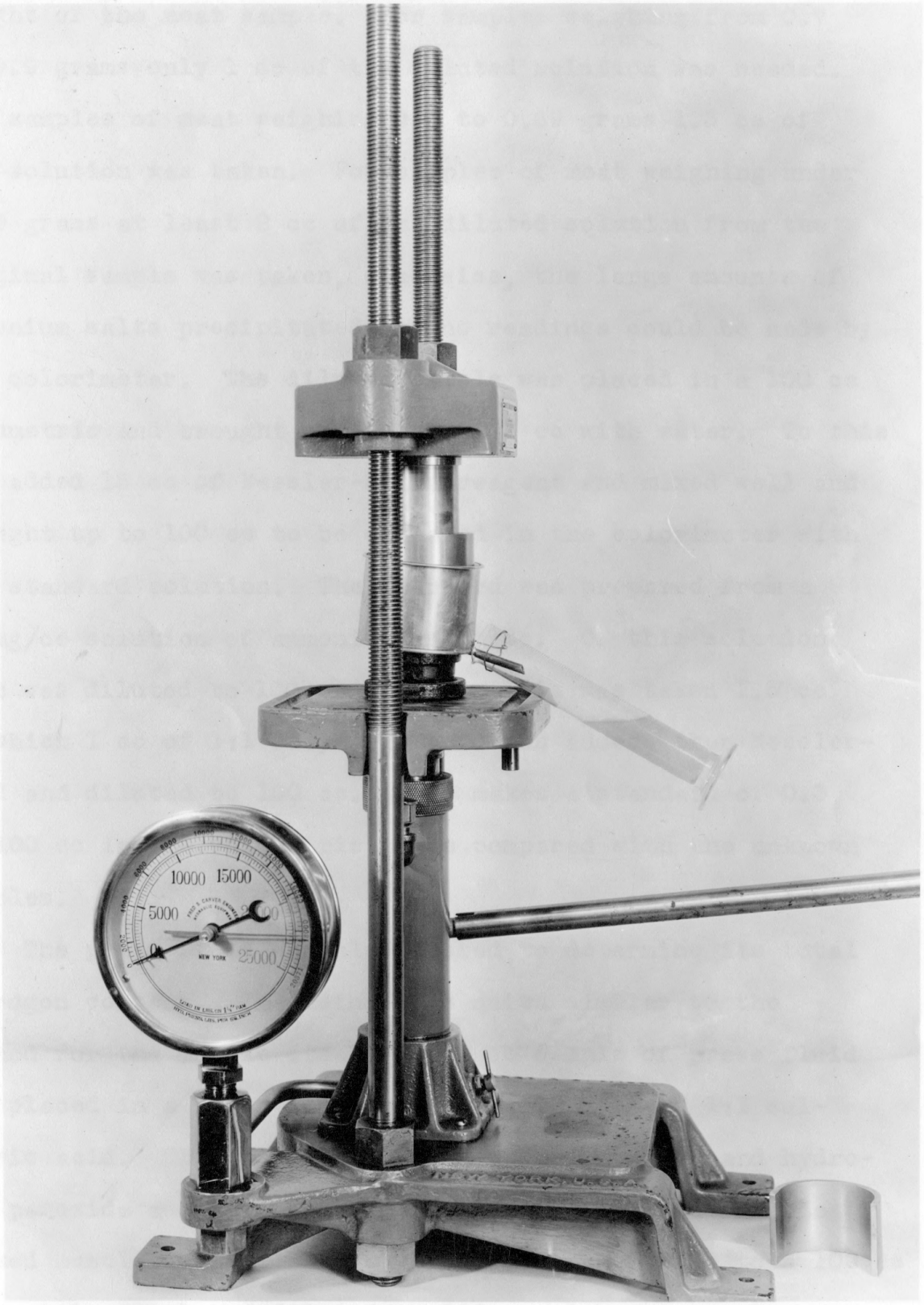
After the tenderness determinations had been made the longissimus dorsi muscle of each steak was removed and all fat scraped from the surface. All the longissimus dorsi muscles from the steaks of each loin which received the same treatment were ground together and thoroughly mixed. Each mixture was sampled and press fluid determinations were made by the process described by Vail, Hall, and Mackintosh (1935). The Carver Laboratory Press used in making the press fluid determinations is pictured in Plate IV.

Samples of the ground longissimus dorsi muscle were also taken for determining the total nitrogen content by the Micro-Kjeldahl method. It was found necessary to modify this method in the following manner. The samples were quantitatively weighed, being sure they weighed between 0.2 and 0.9 grams, and put immediately in 100 cc Pyrex ignition tubes. To this was added 1 cc of 1:1 sulphuric acid. This was then heated under the hood until white fumes began to come off and the liquid became charred. Hydrogen peroxide was added, six to eight drops at a time, and the solution heated again and the preceding process of adding hydrogen peroxide repeated until the solution remained clear when allowed to continue gentle boiling. The solution was then diluted to 100 cc and samples removed to be Nesslerized. The size of these samples to be Nesslerized varied according to the

EXPLANATION OF PLATE IV

Carver Laboratory Press used to express the press fluid to determine the amount of press fluid and to obtain a sample for testing for total nitrogen.

PLATE IV



weight of the meat sample. For samples weighing from 0.7 to 0.9 grams only 1 cc of the diluted solution was needed. For samples of meat weighing 0.5 to 0.69 grams 1.5 cc of the solution was taken. For samples of meat weighing under 0.49 grams at least 2 cc of the diluted solution from the original sample was taken, otherwise, the large amounts of ammonium salts precipitated and no readings could be made by the colorimeter. The diluted sample was placed in a 100 cc volumetric and brought up to about 75 cc with water. To this was added 15 cc of Nessler-Folin reagent and mixed well and brought up to 100 cc to be compared in the colorimeter with the standard solution. The standard was prepared from a 10 mg/cc solution of ammonium sulphate. Of this solution 2 cc was diluted to 100 cc and from this was taken 1.5 cc to which 1 cc of 1:1 sulphuric acid was added, then Nesslerized and diluted to 100 cc. This makes a standard of 0.3 mg/100 cc in the volumetric to be compared with the unknown samples.

The press fluid was also tested to determine its total nitrogen content. The method was quite similar to the method for the muscle itself. A 1 cc sample of press fluid was placed in a Pyrex ignition tube with 1 cc of 1:1 sulphuric acid. This was then heated under the hood and hydrogen peroxide added in the same manner as was used for the cooked muscle. The clear solution was transferred to a 100 cc volumetric flask and diluted to 100 cc with water. From

this dilution a 2 cc sample was taken and diluted with water to about 75 cc. To this dilution 15 cc of Nessler-Folin reagent was added and mixed well and brought up to 100 cc to be compared with the standard. The standard used was prepared in the same manner as the one used with the cooked muscle sample.

REVIEW OF LITERATURE

Tenderness is generally recognized as one of the most important characteristics of meat. In recent years a number of studies have been made to determine the effect of freezing on the tenderness of beef. Hankins and Hiner (1940) found that freezing makes beef tender. Their study was made to discover what effect different freezing temperatures had on fresh beef steaks. The four temperatures used in freezing the steaks were 34° F., the control temperature which was above the freezing point; +20° F., -10° F., and -40° F. The control steaks were definitely less tender than any of the steaks which were frozen and the steaks frozen at -10° F. and -40° F. were more tender than those frozen at +20° F. There was no real difference found between the two lowest temperatures, therefore, -10° F. would seem the more economical and practical for this particular purpose.

According to Tressler, Birdseye, and Murray (1932) quick freezing of meat and the subsequent storage of the

frozen product effects a marked tendering of the beef. The tendering of quick frozen meat continues during cold storage.

To determine the tenderness of meat it was necessary to use a testing machine which is nationally recognized. Bratzler (1932) worked on the problem of developing a mechanical shear which would have but a small amount of variability in its results. Several shearing blades were made and tested on a homogeneous material by using the Henry L. Scott Combination Tensil Strength Tester, Model D, owned by the School of Home Economics. He concluded that the opening in this shearing blade be made by circumscribing an equilateral triangle about a one inch circle. Later, a machine, known as the Warner-Bratzler Mechanical Shear (Plate III), was developed using this blade and is now recognized by authorities as a standard method for determining the tenderness of meat.

After the development of the Warner-Bratzler Mechanical Shear for testing tenderness, Mackintosh, Hall, and Vail (1936) experimented with beef from cattle of the same age and compared the mechanical shear results and the results of a palatability committee. The palatability committee being composed of a group of judges who sampled the roast beef and checked their opinion as to tenderness on a standard report form (Plate V). In their studies the term "shear" is used to indicate the breaking strength of a cylinder of meat one inch in diameter, as registered on the dynamometer of the Warner-Bratzler Mechanical Shear. They

EXPLANATION OF PLATE V

Meat cooking record used by the palatability committee in determining the tenderness of beef.

PLATE V

MEAT COOKING RECORD

Grading Chart for Cooked Meat

Cooking Laboratory No._____ Sample No. _____ Kind _____ Date _____

FACTOR	PHASE	7	6	5	4	3	2	1	REMARKS
Aroma	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.	
	Desirability	very des.	des.	m. des.	s. des.	neutral	undes.	undes.	
Texture (Grain)	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.	

Color of Lean

1. Light red
2. Dark pink
3. Light pink
4. Pinkish brown
5. Light brown
6. Dark brown

Color of Fat

1. White
2. Creamy white
3. Grayish cream
4. Grayish white
5. Yellowish brown
6. Yellow
7. Amber

Key to Abbreviations

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

_____

Signature of Judge

discovered there was a very high correlation between shear and the palatability committee results on beef from fed yearling steers. There was also a significant correlation between shear, collagen nitrogen and the score of the palatability committee on beef from cattle of varying ages. According to their results the Warner-Bratzler Mechanical Shear seems, at present, to be the most accurate method of measuring tenderness of meat. In concluding their study they stated the "shear" on the cooked sample may be substituted for the palatability committee test where tenderness only is to be measured, provided beef from cattle of a like age are being compared.

A highly significant correlation was found between the palatability committee scores for tenderness and the tensil strength values of roast meat as determined by the shear machine as a result of work done by Shrewsbury, Home, Braun, Jordan, Milligan, Vestal, and Weitkamp (1942). However, they found no definite effect on tenderness of roasts and chops that could be related to freezing or storage. Also freezing and storage after freezing had no marked effect upon the cooking losses of the roasts and chops used in their study.

Another important characteristic of meat is its juiciness. Juiciness in meat, as defined by Child and Baldelli (1934) is due to its readily expressible liquid. In their work they used the "pressometer" for determining

the percentage of press fluid and ratio of press fluid to dry matter. The term "press fluid" is used in preference to "juice" as juiciness in meat is graded by individual reactions when meat is eaten. Child and Fogarty (1935) also found that the ratio of press fluid to dry matter is higher at an internal roasting temperature of 58° C. than at 75° C., in fact, almost 11 percent more press fluid was expressed from the muscle heated at the lower temperature.

To determine the amount of press fluid expressible from raw beef muscle, Hall (1934) devised a method of procedure which has since proved very satisfactory. The difficulty caused by extrusion of the tissue was prevented by mixing 100 grams of the finely ground tissue with three grams of dry filter paper, and dividing the mixture into 16 layers between sheets of filter paper in the cylinder of the Carver Laboratory Press. The pressure was increased gradually until it reached 4,000 pounds per square inch the first half hour and then held at this pressure for another hour. The volume of press fluid varied from 33 to 50 cc per 100 grams of muscle tissue.

Only slight modifications were found necessary by Vail, Hall, and Mackintosh (1935) in adapting the procedure of expressing press fluid from raw beef muscle to expressing the press fluid from the cooked sample of beef. No filter paper was necessary and a press period of 15 minutes, during which the pressure was gradually increased up to 4,000 pounds

per square inch the first five minutes and held at this pressure the remaining ten minutes, was sufficient to express the press fluid. The relationships between the amount of juiciness appeared to be negative; that is, the smaller the amount of expressible fluid the juicier the reaction of the palate.

Jeffery (1942) found that the method of thawing frozen meat had little effect upon shear, press fluid, moisture content, and percentage cooking loss. However, meat thawed at refrigerator temperature had the most press fluid and the lowest percentage total loss.

DATA

The tenderness data are presented in Tables 1, 2, and 3. The term "fresh" is used to designate the steaks which were cooked without treatment other than aging. Tenderness data from these "fresh" steaks are presented in Table 1. The term "frozen" is used to designate those steaks which were aged and then frozen for a 24 hour period and the data from these steaks are presented in Table 2. The term "frozen stored" refers to those steaks which were aged, frozen, and stored for 90 days and their tenderness data may be found in Table 3.

The press fluid data are for separate loins from each steer. Only one sample was used for each determination due to the limited time in which the work could be done. The

Table 1. Tenderness data on fresh beef in pounds.

Steak number	Medial	Central	Lateral	Steak number	Medial	Central	Lateral
AR1	10.75	13.25	13.50	AR4	12.00	13.00	18.50
	11.50	11.25	13.00		11.25	13.75	17.50
	13.00	11.75	12.50		13.00	12.50	19.25
Total	35.25	36.25	39.00	Total	36.25	39.25	55.25
Av.	11.75	12.08	13.00	Av.	12.08	13.08	18.42
AR7	6.75	11.50	12.50	AL3	11.25	12.50	17.00
	8.75	10.00	15.50		11.00	12.50	18.00
	9.50	11.00	15.50		11.25	12.75	19.00
Total	25.00	32.50	43.50	Total	33.50	37.75	54.00
Av.	8.33	10.83	14.50	Av.	11.17	12.58	18.00
AL6	10.00	9.00	13.00	AL9	8.75	11.50	13.50
	10.00	7.25	13.00		8.00	9.50	15.00
	9.00	7.50	14.50		7.25	7.50	12.00
Total	29.00	23.75	40.50	Total	24.00	28.50	40.50
Av.	9.67	7.92	13.50	Av.	8.00	9.50	13.50
BR3	9.00	13.00	13.25	BR6	10.25	10.75	18.00
	9.25	10.00	17.50		8.50	12.50	18.50
	11.50	9.25	10.50		6.50	12.75	12.50
Total	29.75	32.25	41.25	Total	25.25	36.00	49.00
Av.	9.92	10.75	13.75	Av.	8.42	12.00	16.33
BR9	8.75	10.50#	9.75	BL2	14.00	15.50	16.50
	7.50	10.50#	11.00		14.50	15.50	16.25
	6.75	10.50#	12.25		13.50	15.50	15.50
Total	23.00	31.50	33.00	Total	42.00	46.50	48.25
Av.	7.67	10.50	11.00	Av.	14.00	15.50	16.08

Calculated value substituted

Table 1. (concl.).

Steak number	Medial	Central	Lateral	Steak number	Medial	Central	Lateral
BL5	9.75	10.75	12.75	BL8	9.50	9.00	12.00
	8.50	10.00	15.00		7.00	9.25	10.75
	8.25	9.00	14.00		5.50	9.00#	10.00
Total	26.50	29.75	41.75	Total	22.00	27.25	32.75
Av.	8.83	9.92	13.92	Av.	7.33	9.13	10.92
CR2	13.00	8.25	11.50	CR5	9.50	12.00	17.50
	14.50	8.50	13.75		9.50	11.75	16.50
	11.00	10.50	14.00		10.75	11.25	14.25
Total	38.50	27.25	39.25	Total	29.75	35.00	48.25
Av.	12.83	9.08	13.08	Av.	9.92	11.67	16.08
CR8	8.75	8.50	13.50	CL1	7.75	8.50	16.00
	11.25	8.75	17.75		7.25#	7.75	14.00
	8.75	8.50	15.50#		6.75	10.00	15.00
Total	28.75	25.75	46.75	Total	21.75	26.25	45.00
Av.	9.58	8.58	15.63	Av.	7.25	8.75	15.00
CL4	8.00	8.50	11.50	CL7	8.25	10.00	14.25
	9.50	8.25	11.75		7.75	10.50	12.50
	9.50	9.50	10.50		8.50	11.75	12.00
Total	27.00	27.25	33.75	Total	24.50	32.25	38.75
Av.	9.00	9.08	11.25	Av.	8.17	10.75	12.92

Calculated value substituted

Table 2. Tenderness data on frozen beef in pounds.

Steak number	Medial	Central	Lateral	Steak number	Medial	Central	Lateral
AR2	8.25	12.50	15.50	AR5	8.50	11.25	13.50
	10.00	10.00	14.75		8.25	10.50	13.50
	12.00	11.25	16.25		8.50	11.00	11.00
Total	30.25	33.75	46.50	Total	25.25	32.75	38.00
Av.	10.08	11.25	15.50	Av.	8.42	10.92	12.67
AR8	8.00	9.50	11.75	AL1	9.50	8.50	16.50
	7.50	6.00	10.25		12.00	11.00	15.50
	8.50	7.00	11.50		10.75#	9.75	13.00
Total	24.00	22.50	33.50	Total	32.25	29.25	45.00
Av.	8.00	7.50	11.17	Av.	10.75	9.75	15.00
AL4	10.00	8.50	15.50	AL7	7.50	12.50	12.50
	9.50	8.50	15.50		7.50	10.50	13.75
	10.25	8.25	15.50		7.75	11.00	13.00
Total	29.75	25.25	46.50	Total	22.75	34.00	39.25
Av.	9.92	8.42	15.50	Av.	7.58	11.33	13.08
BR1	12.00	11.75	20.00	BR4	7.75	11.75	16.25
	11.75	11.25	18.00		7.75	10.00	15.00
	10.50	11.25	18.00		9.00	12.25	13.50
Total	34.25	34.25	56.00	Total	24.50	34.00	44.75
Av.	11.42	11.42	18.67	Av.	8.17	11.33	14.92
BR7	8.00	11.50	12.75	BL3	7.50	10.00	14.50
	7.00	10.75	12.00		10.00	10.50	18.00
	9.75	11.50	15.00		11.50	12.00	14.50
Total	24.75	33.75	39.75	Total	29.00	32.50	47.00
Av.	8.25	11.25	13.25	Av.	9.67	10.83	15.67

Calculated value substituted

Table 2. (concl.).

Steak number	Medial	Central	Lateral	Steak number	Medial	Central	Lateral
BL6	7.00	11.00	14.00	BL9	5.00	9.00	7.00
	7.00	10.25	14.75		6.00	5.50	7.25
	7.25	9.75	14.00#		6.00	5.50	7.00
Total	21.25	31.00	42.75	Total	17.00	20.00	21.25
Av.	7.08	10.33	14.38	Av.	5.67	6.67	7.08
CR3	11.50	11.50	13.00	CR6	10.00	11.00	12.50
	9.75	9.00	13.75		10.25	12.50	14.00
	10.25	9.75	11.50		12.50	14.00	13.25#
Total	31.50	30.25	38.25	Total	32.75	37.50	39.75
Av.	10.50	10.08	12.75	Av.	10.92	12.50	13.25
CR9	7.25	10.00	13.50	CL2	9.00	10.00	13.75
	7.25	8.75	13.75		11.25	9.00	13.75
	7.75	11.50	14.50		10.50	10.25	15.00
Total	22.25	30.25	41.75	Total	30.75	29.25	42.50
Av.	7.42	10.08	13.92	Av.	10.25	9.75	14.17
CL5	10.25	8.50	18.00	CL8	10.00	9.75	13.50
	10.00	8.00	11.00		10.50	10.00	10.75
	10.25	10.00	11.50		8.50	10.00	12.00
Total	30.50	26.50	40.50	Total	29.00	29.75	36.25
Av.	10.17	8.83	13.50	Av.	9.67	9.92	12.08

Calculated value substituted

Table 3. Tenderness data on frozen stored beef in pounds.

Steak number	Medial	Central	Lateral	Steak number	Medial	Central	Lateral
AR3	16.00	12.50	20.50	AR6	8.25	10.25	16.50
	15.00	20.75	20.50#		8.50	9.25	15.25
	10.00	16.50#	20.50#		10.50	14.25	19.50
Total	41.00	49.75	61.50	Total	27.25	33.75	51.25
Av.	13.67	16.62	20.50	Av.	9.08	11.25	17.08
AR9	9.00	9.75	13.50	AL2	9.75	8.50	18.00
	9.25	7.25	10.50		12.00	12.25	20.75
	10.50	8.75	11.25		10.50	18.50	15.00
Total	28.75	25.75	35.25	Total	32.25	39.25	53.75
Av.	9.58	8.58	11.75	Av.	10.75	13.08	17.92
AL5	10.00	7.50	12.00	AL8	7.00	8.75	14.50
	9.25	9.25	13.75		7.50	7.50	11.25
	10.50	10.25	17.00		9.50	11.00	14.25
Total	29.75	27.00	42.75	Total	24.00	27.25	40.00
Av.	9.92	9.00	14.25	Av.	8.00	9.08	13.33
BR2	9.75	10.00	16.25	BR5	9.00	12.00	18.00
	8.75	10.25	16.00		8.75	16.75	14.75
	10.50	11.00	19.50		7.50	13.75	15.00
Total	29.00	31.25	51.75	Total	25.25	42.50	47.75
Av.	9.67	10.42	17.25	Av.	8.42	14.17	15.92
BR8	9.00	13.75	17.00	BL1	8.25	7.00	15.25
	8.75	10.25	20.75		10.00	7.00	17.00
	9.50	12.75	17.25		11.00	9.00	12.25
Total	27.25	36.75	55.00	Total	29.25	23.00	44.50
Av.	9.08	12.25	18.33	Av.	9.75	7.67	14.83

Calculated value substituted

Table 3. (concl.).

Steak number	Medial	Central	Lateral	Steak number	Medial	Central	Lateral
BL4	7.50	10.00	15.75	BL7	6.50	8.25	10.75
	10.50	13.50	14.00		7.50	7.25	11.25
	11.00	13.75	15.75		9.00	9.75	14.50
Total	29.00	37.25	45.50	Total	23.00	25.25	36.50
Av.	9.67	12.42	15.17	Av.	7.67	8.40	12.17
CR1	10.00	14.00	13.00	CR4	10.00	10.00	11.75
	8.50	11.50	11.25		9.00	10.00	12.50
	10.50	11.25	11.75		10.00	10.25	13.50
Total	29.00	36.75	36.00	Total	29.00	30.25	37.75
Av.	9.67	12.25	12.00	Av.	9.67	10.08	12.58
CR7	7.50	10.00	11.50	CL3	9.50	11.50	13.00
	7.75	9.00	10.50		10.50	10.75	13.50
	10.75	8.50	10.25		13.50	9.50	15.75
Total	26.00	27.50	32.25	Total	33.50	31.75	42.25
Av.	8.67	9.17	10.75	Av.	11.17	10.58	14.08
CL6	6.00	7.50	13.00	CL9	9.25	10.50	15.00
	9.25	8.25	13.50		7.00	12.50	13.00
	10.00	8.50	14.00		6.50	10.25	11.25
Total	25.25	24.25	41.00	Total	22.75	33.25	39.25
Av.	8.42	8.08	13.67	Av.	7.58	11.08	13.08

press fluid data are presented in Table 4. Table 4 also contains the data for the amount of total nitrogen in the press fluid from the steaks. The total nitrogen in the cooked steak meat is given in Table 5.

The data for the cooking loss are presented in Tables 6, 7, and 8 and was determined by weighing the steaks immediately before cooking and again after cooking. The total loss is also given in these tables. This is the loss in weight from the time the steaks were cut until after they were cooked.

The statistical analysis of the data are presented in Tables 9, 10, 11, 12, 13, and 14.

DISCUSSION

All data collected in this study were treated statistically. Snedecor's statistical analysis of variance was used to determine the significance of the results. The mean squares, in the analysis of variance tables, which are starred once are significant, or the possibility of getting such results are likely to happen only about five times in one hundred trials. Those starred twice are highly significant and the possibility of getting such results as these are not over one time in one hundred such trials.

Bray (1941) found a highly significant difference between animals used in his experiment. This animal difference was undoubtedly due to the rations fed the steers,

Table 4. Steak press fluid data.

Loin number	Fresh steaks: cc press fluid in 50 grams sample	Fresh steaks: Total nitrogen in mgms in 1 cc	Frozen steaks: cc press fluid in 50 grams sample	Frozen steaks: Total nitrogen in mgms in 1 cc	Stored steaks: cc press fluid in 50 grams sample	Stored steaks: Total nitrogen in mgms in 1 cc
AR	5.00	6.55	3.50	8.38	7.75	7.58
AL	4.50	6.43	2.75	8.01	9.00	10.46
BR	5.00	6.83	3.75	8.30	12.00	8.38
BL	5.75	6.16	2.75	7.62	13.50	8.39
CR	5.00	6.42	2.75	7.47	11.75	7.65
CL	5.50	6.35	2.75	7.00	9.25	6.53

Table 5. Total nitrogen in cooked steak meat.

Loin number	Fresh steaks: Weight of sample in grams	Fresh steaks: Total nitrogen in mgms per g	Frozen steaks: Weight of sample in grams	Frozen steaks: Total nitrogen in mgms per g	Stored steaks: Weight of sample in grams	Stored steaks: Total nitrogen in mgms per g
AR	0.6185	38.78	0.4363	32.75	0.5270	29.96
	0.3445	35.55	0.4746	34.54	0.5733	30.01
AL	0.6579	32.97	0.3448	35.27	0.5307	22.47
	0.5514	31.55	0.7335	30.60	0.5973	34.30
BR	0.5332	32.50	0.7318	30.23	0.4925	39.81
	0.5351	33.33	0.5550	37.74	0.5770	31.53
BL	0.4685	35.46	0.6844	29.14	0.5878	36.28
	0.4371	32.78	0.4382	32.36	0.5322	30.93
CR	0.3127	28.97	0.5355	33.20	0.6352	32.93
	0.7322	30.46	0.8170	31.25	0.6734	34.21
CL	0.5595	31.36	0.4101	27.69	0.4441	25.68
	0.4754	34.11	0.8205	32.93	0.6092	30.23

Table 6. Steak weight data on fresh beef.

Steak number	Cut weight grams	Before cooking grams	After cooking grams	Cooking loss grams	Total loss grams
AR1	344	341.5	266.0	75.5	78.0
AR4	340	337.0	276.5	70.5	73.5
AR7	392	386.5	321.5	65.0	70.5
AL3	329	326.5	278.0	48.5	51.0
AL6	361	358.5	296.0	62.5	65.0
AL9	407	402.0	337.5	64.5	69.5
BR3	328	323.5	271.0	52.5	57.0
BR6	342	338.0	268.5	69.5	73.5
BR9	390	385.0	306.0	79.0	84.0
BL2	279	276.0	230.5	45.5	48.5
BL5	322	317.5	260.5	57.0	61.5
BL8	375	369.5	302.0	67.5	73.0
CR2	287	283.0	240.5	42.5	46.5
CR5	268	264.5	225.5	39.0	42.5
CR8	318	313.0	264.0	49.0	54.0
CL1	291	290.0	241.5	48.5	49.5
CL4	370	365.0	307.5	57.5	72.5
CL7	350	348.0	274.0	74.0	76.0

Table 7. Steak weight data on frozen beef.

Steak number	Cut weight grams	Before cooking grams	After cooking grams	Cooking loss grams	Total loss grams
AR2	359	356.5	288.0	66.5	69.0
AR5	387	383.5	307.0	76.5	80.0
AR8	365	361.0	292.0	69.0	73.0
AL1	317	316.0	264.0	52.0	53.0
AL4	336	335.0	280.0	55.0	56.0
AL7	339	335.5	282.0	53.5	57.0
BR1	339	334.0	256.0	78.0	83.0
BR4	331	328.0	277.0	51.0	54.0
BR7	339	333.0	269.0	64.0	70.0
BL3	293	289.0	241.5	47.5	51.5
BL6	321	320.5	254.5	66.0	66.5
BL9	380	374.0	295.0	79.0	85.0
CR3	289	287.0	235.5	51.5	53.5
CR6	295	292.0	247.0	45.0	48.0
CR9	322	318.0	251.0	67.0	71.0
CL2	350	345.0	273.0	72.0	77.0
CL5	370	364.0	284.5	79.5	85.5
CL8	360	251.5	264.0	87.5	96.0

Table 8. Steak weight data on stored beef.

Steak number	Cut weight grams	Before cooking grams	After cooking grams	Cooking loss grams	Total loss grams
AR3	379	373.0	314.0	59.0	65.0
AR6	373	368.0	304.0	64.0	69.0
AR9	391	386.5	319.0	67.5	72.0
AL2	319	319.0	270.0	48.5	48.5
AL5	345	341.0	281.5	59.5	63.5
AL8	386	379.5	321.5	58.0	64.5
BR2	351	345.5	287.5	58.0	63.5
BR5	356	350.5	297.5	53.0	58.5
BR8	320	317.0	252.5	64.5	67.5
BL1	298	296.5	244.0	52.5	54.0
BL4	310	307.0	254.5	52.5	55.5
BL7	322	319.0	255.5	63.5	66.5
CR1	355	354.0	292.0	62.0	63.0
CR4	293	290.5	243.5	47.0	49.5
CR7	330	324.0	262.5	61.5	67.5
CL3	350	345.0	281.5	63.5	68.5
CL6	350	346.5	264.5	82.0	85.5
CL9	390	384.5	300.5	84.0	89.5

Table 9. Analysis of variance in tenderness of steaks. A=animals, T=treatments, L=loins, P=position, C=cores, D.F.=degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean square
Animals	2	62.9152	31.4576
Treatments	2	42.1714	21.0857
Loins	1	80.2627	80.2627**
Position	2	434.7748	217.3874**
Cores	2	2,056.6174	1,028.3087**
A. vs P.	4	104.4600	26.1150**
Other interactions	148	1,041.4151	7.0366
Samples within A, T, L, P, and C.	324	2,222.6809	6.8601
Total	485	6,045.2975	

** Highly significant

Table 10. Analysis of variance in total nitrogen of steaks. D.F.=degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean square
Loins	11	101.07	9.19
Treatment	2	15.83	7.92
Discrepance	22	289.16	13.14
Total	35	406.06	

Table 11. Analysis of variance in total nitrogen of press fluid. D.F.=degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean square
Loins	5	4.88	.98
Treatment	2	8.89	4.45*
Discrepance	10	6.24	.62
Total	17	20.01	

* Significant

Table 12. Analysis of variance in press fluid. D.F.=degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean square
Loins	5	10	2.0*
Treatment	2	63	31.5
Discrepance	10	133	13.3
Total	17	206	

* Significant

Table 13. Analysis of variance of cooking losses. A=animals, T=treatment, L=loins, P=position, D.F.=degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean square
Animals	2	7.2	3.6*
Treatments	2	244.4	122.2
Loins	1	21.4	21.4
Position	2	1,088.2	544.1
A. vs. T.	4	894.1	223.5
L. vs. P.	2	959.2	479.6*
Remainder	40	4,841.8	121.0
Total	53	7,156.3	

* Significant

Table 14. Analysis of variance of total weight losses. A=animals, T=treatment, L=loins, P=position, D.F.=degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean square
Animals	2	15.5	7.7*
Treatments	2	200.8	100.4
Loins	1	21.1	21.1
Position	2	1,466.0	733.0
A. vs. T.	4	1,030.2	257.5
L. vs. P.	2	653.0	326.5
Remainder	40	4,827.4	120.7
Total	53	8,214.0	

* Significant

the various grades of carcasses used, and the breeding of the animals themselves.

No difference was found between the steers used in this experiment, probably because they were more nearly of the same grade and carried a higher degree of finish. The steaks from the steer grading U. S. Good were less tender than the steaks from the U. S. Choice steers, but differences were not statistically significant. Grade may be closely related to tenderness because Bray (1941) also found that steaks from U. S. Good steers were more tender than the steaks from U. S. Medium grade steers.

Apparently the storage period of 90 days does not have a tendering effect on aged beef as no significant difference was found to exist. Also no significant difference was found between "fresh" and "frozen" aged beef which agrees with the work done by Bray (1941). The "frozen" steaks in most cases were more tender than either the "fresh" or "frozen stored" steaks but not enough to be statistically significant. The "frozen stored" steaks were of about the same tenderness as the fresh steaks.

The analysis of variance in Table 9 gives a significant difference in tenderness between the right and left loins. The data indicate that the left loin is more tender than the right. This does not agree with Bray (1941) but does agree with popular opinion. However, this difference was not consistent between the steaks from the three steers under

separate treatments in that the right loin of steer A was more tender than the left loin when the steaks had been frozen before cooking. The right loin of steer B was more tender than the left when the steaks were cooked while fresh. Also the right loin of steer C was more tender than the left when the steaks had been stored for 90 days before cooking. No definite conclusion can be made from such variable differences, so the difference between loins must be due to some factor which has not as yet been satisfactorily proven significant.

Hankins and Hiner (1940) found that the posterior end of the short loin was more tender than the anterior end. In this study there was a highly significant difference between the anterior and posterior end of the short loin, the posterior end being more tender than the anterior end.

Considerable variation was found between the three cores taken from each steak. The medial and central cores were more tender than the lateral core. This finding is also in agreement with similar work done by Bray (1941). A possible reason for the lateral core being less tender than the other two is that it was more difficult to obtain a sample due to the small size of that part of the longissimus dorsi muscle. Therefore, this sample may have contained some of the connective tissue surrounding the muscle.

The interaction between animals and position of the steak on the loin was highly significant indicating that the comparative tenderness of the steaks, in relation to their position on the loin, was not the same for all of the animals. In several cases the steaks from the anterior position on the loin were more tender than the steaks from the mid position and also in some animals the mid section was more tender than the posterior section.

The analysis of variance in total nitrogen of steaks given in Table 10 shows no significant difference between any of the treatments, or loins from the various carcasses. In view of these findings it would not seem necessary to take total nitrogen determinations on cooked beef steaks treated in a similar manner as these.

A slightly significant variation of the total nitrogen of the steak press fluid was found to be due to the treatment. Table 11 gives this variation. Too much importance should not be placed on this difference because of the small number of samples. This may also be said of the variance in amount of press fluid expressible from different loins. Table 12 shows that the variation between loins is slightly significant. This may be related in some way to the highly significant variation between loins themselves.

An analysis of variance of cooking losses is presented in Table 13. The steaks were weighed just before cooking and again immediately after cooking. The difference between

steaks from the three carcasses were found to be slightly significant. This significance shows that such a close relation between the amount of cooking losses of the three carcasses is not likely to happen more than five times in one hundred such cooking tests.

A slightly significant difference was found to exist in the interaction between loins and positions indicating that the comparative cooking loss among the positions was not the same for all loins. In some instances the posterior end of the loin had the greatest amount of loss while in others the anterior section or the mid section had the greatest loss. This significance did not hold true when the total loss in weight was analyzed for variance in Table 14. However the same significant difference was found to exist among the animals.

SUMMARY

1. The results of this study indicate that freezing and storing in the frozen condition had no influence upon the tenderness of beef that had been aged.

2. In all cases the Warner-Bratzler shear indicated that steaks from the U. S. Choice carcasses were more tender than steaks from the U. S. Good carcass but these differences were not statistically significant.

3. The analysis of variance shows that the left loin was significantly more tender than the right. However, this difference was not consistent when the individual steaks from the three steers were considered.

4. The posterior section of the short loin was more tender than the mid section which in turn was more tender than the anterior section.

5. Considerable variation was found to exist between the three cores from the longissimus dorsi muscle. In the majority of the cases the lateral core was the least tender of the three.

6. The method of treatment resulted in a slightly significant variation of the total nitrogen of the press fluid.

7. A significant variation in the difference in the amount of press fluid from separate loins was found.

8. No difference was found to exist between the cooking losses of the "fresh", "frozen", or "frozen stored" steaks, but there was a significantly close relation among the steaks from the three carcasses because of the non-random selection of the animals used.

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