INFLUENCE OF FREEZING UPON BEEF THAT HAS BEEN AGED

by

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INTRODUCTION

The frozen food locker industry offers a variety of services to the people in the United States. Although the industry is new, it has grown very rapidly during the last ten years. The services now offered by the industry make available to the public a means of preserving food products in a condition more nearly like the fresh product than other methods of food preservation. The rapid growth and the lack of scientific information related to the freezing of food products have confronted this industry with many problems that can only be solved through research.

In recent years a number of investigations have been conducted with various kinds of meats relative to the influence of freezing temperature, storage temperature, length of the storage period, and the type and nature of packaging upon the quality and condition of the product. Tressler, Birdseye, and Murray (1932) and Hankins and Hiner (1940) have shown that freezing fresh beef does increase the tenderness over that of fresh unfrozen beef. Moran and Smith (1929) found that aging or ripening of beef, that is holding it in cold storage at 34° to 36° F. for a period of time, also increased the tenderness of beef. Little or no work has been done to show the effect of freezing upon tenderness in aged beef.

In order to obtain some information on this particular problem, the study presented here was undertaken during the past year at the Kansas Agricultural Experiment Station. Additional data on cooking losses and press fluid were collected as a matter of routine laboratory procedure.

METHOD OF PROCEDURE

The beef used in this study was obtained from the carcasses of six Hereford steers. Four of the carcasses became available in the fall of 1940 when a group of steers on a paired calcium-phosphorus feeding experiment was slaughtered in the Station laboratory. One steer had been fed on a ration low in phosphorus, while the other three had been fed a ration adequate in all respects. The steers weighed about 700 pounds at the time of slaughter and graded U. S. Medium to U. S. Good on foot.

The other two carcasses became available in the spring of 1941 when a group of fall yearling Hereford steers fed on a standard corn belt ration for a period of 190 days were slaughtered in the Station laboratory. These steers graded U. S. Good on foot and were of higher quality than the other four steers. The six steers were about the same age at the time of slaughter.

Four of the carcasses graded U. S. Good and were aged for 32 days; the other two carcasses graded U. S. Medium and were aged for 42 days. The available facilities made it impossible to accommodate the steaks from more than two carcasses at one time, hence the variation in the aging periods. Following the method of sampling used by Hankins and Hiner (1938), the steaks were cut from the longissimus dorsi muscle between the 13th thoracic and 5th lumbar vertebrae. This cut of beef is commonly known as the short loin.

The short loins were first boned and beginning at the anterior end, eight steaks, each one and a half inches thick, were cut and weighed. The steaks from the left side were numbered 1, 2, 3, etc., and those from the right side 1a, 2a, 3a, etc., as indicated in Figure 1. Steaks 1 to 4 inclusive were designated as coming from the anterior section of the short loin and those numbered from 5 to 8 inclusive from the posterior section.

The temperature assignment eliminated as far as possible the variation between right and left loins and between adjacent steaks. This was accomplished by freezing alternate steaks on each loin and one member of each pair of steaks (Figure 1).

The steaks to be frozen were double wrapped in an approved moisture vapor proof paper and frozen at -10° to -15° F. This temperature was suggested by Hankins and Hiner (1938) to be the most economical and practical temperature to use in tenderizing

No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
C	F	C	F	C	F	C	F

Anterior section Posterior section
Carcass A - Left loin - C=Control steaks
F=Frozen steaks.

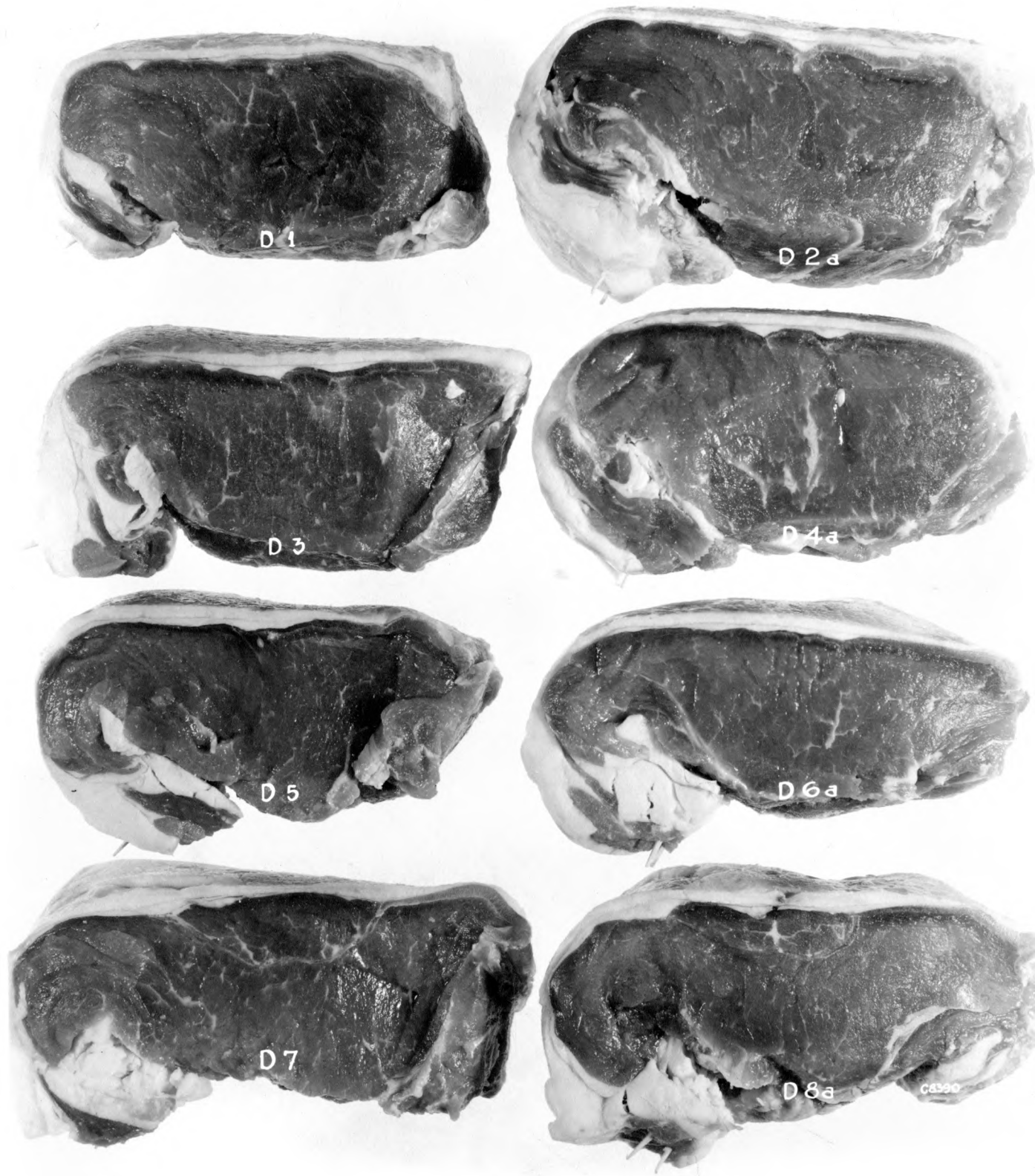
No. 1a	No. 2a	No. 3a	No. 4a	No. 5a	No. 6a	No. 7a	No. 8a
F	C	F	C	F	C	F	C

Anterior section Posterior section
Carcass A - Right loin - C=Control steaks.
F=Frozen steaks.

Fig. 1 Diagram showing method of sampling.

Explanation of Plate I

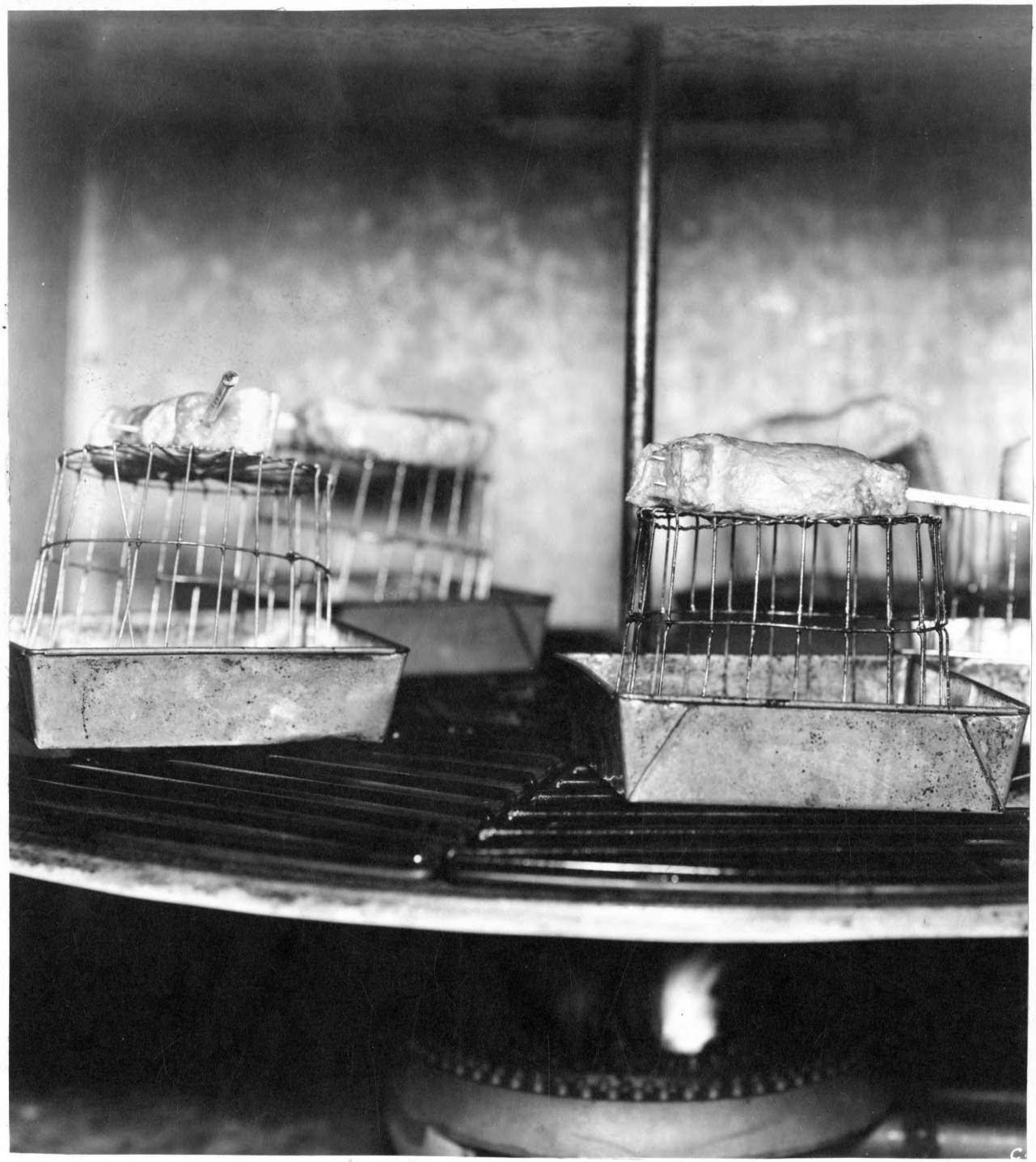
The frozen steaks from carcass D just prior to cooking. These steaks were from an animal grading U. S. Medium.


D 1
D 2a
D 3
D 4a
D 5
D 6a
D 7
D 8a

Explanation of Plate II

Gas oven used in cooking steaks. The steaks are shown on racks with the thermometers in position. The racks rest on a revolving hearth.

Plate II



fresh beef. The frozen steaks from carcass D are shown in Plate I.

The control steaks were cooked and tested for tenderness within 24 hours after cutting. Uniform cooking was accomplished by placing the steaks on a wire rack eight inches in height. The racks in turn were placed on a revolving hearth within a gas heated oven maintained at a constant temperature of 392° F. (Plate II). Turning the steaks was unnecessary because heat could reach the steaks uniformly from all sides. The steaks were removed from the oven and weighed when the internal temperature reached 136° F.

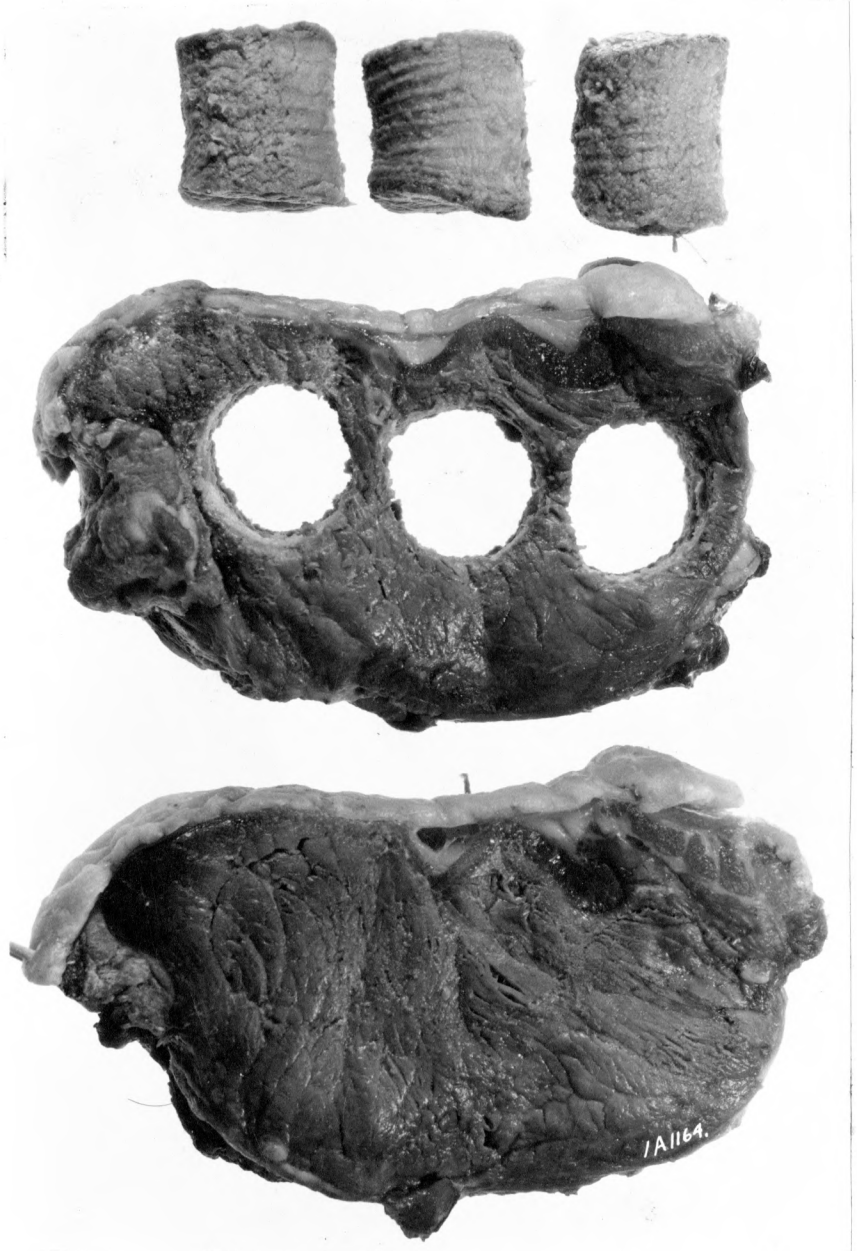
Three cores or samples were removed from each steak and were designated as the lateral, central, and medial cores according to the method used by Bratzler (1932) (Plate III). Tenderness determinations were made on the cores by means of the Warner-Bratzler tenderness shear (Plate IV). This instrument has been demonstrated as a reliable method of measuring tenderness on cooked samples of meat by Mackintosh, Hall, and Vail (1936). Three shearing strength determinations were made at 25, 50, and 75 percent of the distance between the anterior and posterior ends of each core, making a total of nine determinations on each steak.

The frozen steaks were allowed to thaw in a refrigerator maintained between 34° and 38° F. After thawing, these steaks were handled in the same manner as the control steaks.

Explanation of Plate III

The cores used in measuring tenderness. The cores are designated from left to right as lateral, central, and medial cores.

Plate III



Press fluid determinations have been used as a possible method of measuring juiciness of meat by Vail, Hall and Mackintosh (1935).

Following the tenderness determinations on the three cores, the longissimus dorsi muscle was divided into anterior and posterior sections. These composite samples were used as a basis for comparing the press fluid from the frozen and non-frozen steaks. Three press fluid determinations were made from each section of the longissimus dorsi muscle using the Carver Laboratory Press according to the method described by Hall and Vail (1935). The Carver Laboratory Press as used in determining the amount of press fluid is illustrated in Plate V.

DATA

The tenderness data are presented in Tables 1, 2, and 3. The term control is used to designate the steaks which were cooked without treatment other than aging, while the term treated is used to designate those steaks which were frozen prior to cooking and tenderness determinations. The two steers slaughtered in the fall of 1940 and grading U. S. Good were designated as steers A and B, and the tenderness data are presented in Table I. The tenderness data from steers C and D, grading U. S. Medium are presented in Table 2. The two steers slaughtered in the spring and grading U. S. Good were designated as steers E and F. The tenderness data for

Table 1. Tenderness data, steers A and B.

Control steaks												Treated steaks											
	Medial core				Central core				Lateral core			Total		Medial core				Central core				Lateral core			Total
Steak No.	25%	50%	75%	Av.	25%	50%	75%	Av.	25%	50%	75%	av.	Steak No.	25%	50%	75%	Av.	25%	50%	75%	Av.	25%	50%	75%	av.
A-No. 1	14.0	14.0	12.0	13.33	12.5	11.5	10.0	11.33	24.0	20.5	27.0	22.25	15.64	A-No. 2	12.0	11.5	10.5	11.33	10.0	9.5	10.0	9.83	17.0	18.0	23.0*	17.50	12.89
A-No. 3	14.0	13.0	12.0	13.00	10.5	9.0	12.0	10.50	13.2#	13.2#	13.2#	13.19	12.23	A-No. 4	14.0	11.0	11.0	12.00	10.0	12.0	11.0	11.00	15.0	17.0	34.0*	16.00	13.00
A-No. 5	12.5	11.5	12.0	12.00	13.0	11.0	11.5	11.83	20.0	21.0	13.0	11.33	11.72	A-No. 6	10.0	10.0	10.0	10.00	10.0	9.0	8.5	9.17	14.5	13.0	17.0	14.83	11.33
A-No. 7	10.5	9.5	9.0	9.67	11.0	7.5	8.0	8.83	15.0	14.5	20.0	14.75	11.08	A-No. 8	7.5	9.0	8.5	8.33	10.0	8.5	11.0	9.50	10.5	8.5	8.0	9.00	8.94
A-No. 2a	8.5	8.5	9.0	8.67	8.5	8.0	9.5	8.67	15.0	12.0	15.5	14.17	10.50	A-No. 1a	6.5	6.5	8.0	7.00	31.5*	9.5	9.5	9.50	15.5	8.5	8.0	10.33	8.94
A-No. 4a	11.0	11.5	11.5	11.33	11.5	9.5	11.5	10.83	16.5	15.0	15.0	15.50	12.55	A-No. 3a	10.5	10.0	9.5	10.00	11.5	8.5	10.0	10.00	15.5	13.0	12.5	13.67	11.22
A-No. 6a	12.5	11.0	9.0	10.83	10.0	9.5	10.5	10.00	23.5*	17.5	14.5	16.00	12.28	A-No. 5a	9.5	8.5	11.0	9.67	9.5	9.5	13.5	10.83	14.0	12.0	14.5	13.50	11.33
A-No. 8a	12.0	10.5	11.5	11.33	13.0	9.5	11.0	11.17	20.0	18.0	18.5	15.50	12.67	A-No. 7a	10.0	11.0	9.0	10.00	12.0	9.0	11.5	10.83	33.0*	17.5	15.0	16.25	12.36
B-No. 1	14.0	14.0	-	14.00	20.0	11.0	15.0	15.33	19.0	18.0	17.0	18.00	15.78	B-No. 2	14.5	11.5	14.0	13.33	12.0	12.0	12.0	12.00	19.5	18.0	22.0*	18.75	14.67
B-No. 3	17.0	18.0	23.0	19.33	17.0	14.5	15.5	15.67	19.0	23.0	25.0	23.33	19.11	B-No. 4	14.5	15.0	15.0	15.50	11.5	10.5	12.0	11.33	16.0	16.0	20.0	17.33	14.72
B-No. 5	30.0	23.0	21.0	24.67	21.0	17.0	17.0	18.67	21.0	17.0	19.0	19.00	20.78	B-No. 6	21.0	16.0	17.5	14.83	13.0	10.5	13.0	12.17	15.0	14.0	18.0	15.67	14.22
B-No. 7	18.0	15.0	13.5	15.50	10.5	10.0	15.5	12.00	17.0	19.0	22.0	19.33	18.94	B-No. 8	15.5	11.5	11.0	12.67	7.5	7.0	8.5	7.67	12.5	10.5	17.0	13.33	11.22
B-No. 2a	12.5	15.0	13.5	13.67	12.0	12.5	15.0	13.17	12.5#	12.5#	12.5#	12.47	13.30	B-No. 1a	10.5	9.5	12.0	10.67	13.5	12.5	13.5	13.17	14.5	11.0	13.5	13.00	12.28
B-No. 4a	19.0	16.5	15.0	16.83	11.5	11.5	12.0	11.67	19.0	17.0	18.0	18.00	15.50	B-No. 3a	13.5	13.0	14.0	13.50	15.5	10.5	13.5	13.17	23.5*	17.0	17.5	17.25	14.64
B-No. 6a	20.0	15.5	23.0	19.50	16.0	11.0	18.0	15.00	19.0	14.0	15.0	16.00	16.83	B-No. 5a	10.0	11.5	15.0	12.17	18.0	12.0	12.0	14.00	24.0*	15.0	12.5	13.75	13.31
B-No. 8a	23.0	11.5	20.5	18.33	18.0*	9.0	9.0	9.00	19.0	11.0	12.5	14.17	13.73	B-No. 7a	16.0	15.0	20.5	17.17	16.5	11.0	10.5	12.67	24.0*	14.5	14.5	14.50	14.78

Calculated value substituted.
* Large amount connective tissue present.
- Reading not made

Table 2. Tenderness data, steers C and D.

Control steaks												Treated steaks											
	Medial core				Central core				Lateral core			Total		Medial core				Central core				Lateral core			Total
Steak no.	25%	50%	75%	Av.	25%	50%	75%	Av.	25%	50%	75%	Av.	av.	Steak no.	25%	50%	75%	Av.	25%	50%	75%	Av.	25%	50%	75%	Av.	av.
C-No. 1	12.5	12.5	14.5	13.17	13.0	11.0	-	12.00	12.5	11.0	16.0	13.17	12.78	C-No. 2	14.0	17.0	20.5*	15.50	14.0	12.5	21.5	16.00	21.0	24.0*	38.5*	21.00	17.50
C-No. 3	17.0	15.0	17.0	16.33	13.5	12.0	11.5	12.33	13.0	11.5	15.5	13.33	13.99	C-No. 4	19.0	18.0	17.5	18.17	14.5	12.0	11.0	12.50	24.0	23.0	17.5	21.50	17.39
C-No. 5	22.5	22.5	20.0	21.67	14.0	10.0	15.5	12.17	16.0	18.5	19.0	17.83	17.56	C-No. 6	11.0	8.5	9.5	9.67	12.4#	12.4#	12.4#	12.38	15.5	16.0	25.0*	15.75	12.60
C-No. 7	17.0	16.5	13.5	15.67	15.0	11.0	9.5	8.50	17.5	16.0	15.5	16.33	13.50	C-No. 8	15.0	15.5	16.0	15.50	12.0	13.0	12.0	12.33	20.0	20.0	18.0	19.33	15.72
C-No. 2a	12.0	12.0	15.5	13.17	14.5	10.0	12.5	12.33	17.0	15.0	17.0	16.33	13.61	C-No. 1a	10.5	11.0	12.0	11.17	9.5	9.0	8.5	9.00	14.0	16.0	15.0	14.00	11.39
C-No. 4a	13.5	12.5	15.0	13.67	15.5	12.0	15.0	14.17	18.5	18.5	16.0	17.67	15.17	C-No. 3a	15.0	13.0	13.5	13.83	10.5	10.0	12.5	11.00	17.5	14.0	16.0	15.83	13.55
C-No. 6a	11.5	11.0	13.0	11.83	8.0	8.0	9.5	8.50	15.0	11.5	11.5	12.67	11.00	C-No. 5a	16.0	15.0	15.0	15.33	13.0	12.0	13.0	13.67	21.0	18.0	19.5	19.50	16.17
C-No. 8a	8.0	10.0	9.0	9.00	14.0	14.5	11.5	13.33	14.0	13.0	13.0	13.33	11.89	C-No. 7a	16.0	14.5	18.5	16.33	11.5	10.5	13.0	11.67	20.5	15.0	15.5	17.00	15.00
D-No. 2	9.5	11.0	10.5	10.33	11.0	10.0	11.0	10.67	22.0	21.0	22.5	21.83	14.28	D-No. 1	13.5	11.5	14.5	13.17	14.5	12.0	19.5	15.33	19.0	20.0	22.0*	19.50	16.00
D-No. 4	10.5	11.5	15.5	12.50	12.0	15.0	15.0	14.00	20.0	21.5	22.0	21.17	15.89	D-No. 3	13.0	13.5	14.0	13.50	14.5	13.0	10.5	12.67	26.0	20.0	20.5	22.17	16.11
D-No. 6	12.0	10.0	9.0	10.33	9.0	8.0	10.0	9.00	15.0	16.0	24.0*	15.50	11.61	D-No. 5	12.5	14.0	14.5	13.67	14.0	8.0	9.5	10.50	18.0	19.5	19.0	18.83	14.33
D-No. 8	10.5	8.5	10.5	9.83	14.0	14.0	13.0	13.67	14.5	11.0	10.0	11.83	11.78	D-No. 7	10.0	10.0	9.0	9.67	15.0	15.5	14.5	15.00	16.5	17.0	19.0	17.50	14.06
D-No. 1a	10.0	12.0	12.0	11.33	10.0	10.0	10.0	10.00	15.5	16.0	14.5	15.33	12.22	D-No. 2a	14.0	15.0	13.0	14.00	12.0	9.5	11.0	10.83	20.5	20.0	18.5	19.67	14.83
D-No. 3a	14.0	13.0	13.0	13.33	11.5	8.0	10.0	9.83	24.0*	19.0	17.5	18.25	16.53	D-No. 4a	13.0	12.5	11.5	12.33	13.0	11.0	13.5	12.50	24.0	26.0	22.0	24.00	16.28
D-No. 5a	12.5	11.5	11.0	12.67	11.0	11.0	12.0	11.33	17.0	14.5	14.5	15.33	13.11	D-No. 6a	10.5	10.5	13.0	11.33	14.5	9.5	9.0	11.00	23.0*	17.0	19.5	18.25	13.53
D-No. 7a	10.0	12.0	11.0	11.00	11.0	10.0	10.0	10.33	15.0	16.0	15.0	15.33	12.22	D-No. 8a	10.0	9.0	8.5	9.17	20.5*	12.5	11.5	12.00	8.0	13.0	10.0	10.33	10.50

\# Calculated value substituted.
* Large amount connective tissue present.
\- Reading not made.

Table 3. Tenderness data, steers E and F.

Control steaks													Treated steaks											
	Medial core				Central core				Lateral core				Total		Medial core				Central core				Lateral core				Total
Steak no.	25%	50%	75%	Av.	25%	50%	75%	Av.	25%	50%	75%	Av.	av.	Steak no.	25%	50%	75%	Av.	25%	50%	75%	Av.	25%	50%	75%	Av.	av.
E-No. 1	10.5	9.0	7.5	9.00	7.0	6.0	6.0	6.33	12.0	10.0	12.5	11.50	8.94	E-No. 2	14.0	17.0	20.5*	15.50	14.0	12.5	21.5	16.00	21.0	24.0*	38.5*	21.00	17.50
E-No. 3	9.5	9.5	6.5	8.50	6.5	7.0	8.0	7.17	13.0	9.0	11.0	11.00	8.89	E-No. 4	19.0	18.0	17.5	18.17	14.5	12.0	11.0	12.50	24.0	23.0	17.5	21.50	17.39
E-No. 5	7.0	7.0	8.0	7.33	8.5	6.0	8.0	7.50	21.0	12.5	9.0	14.17	9.67	E-No. 6	11.0	8.5	9.5	9.67	12.4#	12.4#	12.4#	12.38	15.5	16.0	25.0*	15.75	12.60
E-No. 7	7.5	6.5	5.0	6.33	8.0	8.0	6.0	7.33	10.5	8.5	8.0	9.00	7.55	E-No. 8	15.0	15.5	16.0	15.50	12.0	13.0	12.0	12.33	20.0	20.0	18.0	19.33	15.72
E-No. 2a	8.0	7.0	8.0	7.67	10.0	6.5	7.0	7.83	21.5	15.0	13.0	14.00	9.83	E-No. 1a	10.5	11.0	12.0	11.17	9.5	9.0	8.5	9.00	14.0	16.0	15.0	14.00	11.39
E-No. 4a	6.5	6.5	6.5	6.50	8.0	7.0	8.0	7.67	11.0	9.0	10.0	10.00	8.06	E-No. 3a	15.0	13.0	13.5	13.83	10.5	10.0	12.5	11.00	17.5	14.0	16.0	15.83	13.55
E-No. 6a	7.5	6.5	7.5	7.17	8,0	5.5	6.0	6.50	11.5	8.5	10.0	10.00	7.89	E-No. 5a	16.0	15.0	15.0	15.33	13.0	12.0	13.0	13.67	21.0	18.0	19.5	19.50	16.17
E-No. 8a	5.5	6.5	8.0	6.67	14.0	14.0	14.0	14.00	7.5	7.0	5.0	6.50	9.06	E-No. 7a	16.0	14.5	18.5	16.33	11.5	10.5	13.0	11.67	20.5	15.0	15.5	17.00	15.00
F-No. 2	10.5	11.0	10.5	10.67	9.5	8.5	9.5	9.17	12.0	9.5	12.5	11.33	10.39	F-No. 1	13.5	11.5	14.5	13.17	14.5	12.0	19.5	15.33	19.0	20.0	22.0*	19.50	16.00
F-No. 4	7.0	7.0	6.5	6.83	6.0	8.5	8.5	6.83	11.0	9.0	10.5	10.17	7.94	F-No. 3	13.0	13.5	14.0	13.50	14.5	13.0	10.5	12.67	26.0	20.0	20.5	22.17	16.11
F-No. 6	8.5	8.0	8.5	8.33	9.0	7.0	8.5	8.17	9.5	8.5	11.5	9.83	8.78	F-No. 5	12.5	14.0	14.5	13.67	14.0	8.0	9.5	10.50	18.0	19.5	19.0	18.83	14.33
F-No. 8	10.0	7.0	9.5	8.83	10.0	8.5	11.0	9.83	8.5	7.0	8.0	7.83	8.83	F-No. 7	10.0	10.0	9.0	9.67	15.0	15.5	14.5	15.00	16.5	17.0	19.0	17.50	14.06
F-No. 1a	11.0	10.0	9.5	9.83	9.0	8.0	9.0	8.33	17.0	9.5	10.5	10.00	8.72	F-No. 2a	14.0	15.0	13.0	14.00	12.0	9.5	11.0	10.83	20.5	20.0	18.5	19.67	14.83
F-No. 3a	8.0	7.0	9.0	8.00	9.0	7.0	9.0	8.33	11.0	9.5	14.0	11.50	9.24	F-No. 4a	13.0	12.5	11.5	12.33	13.0	11.0	13.5	12.50	24.0	26.0	22.0	24.00	16.28
F-No. 5a	9.5	8.0	10.0	9.17	7.5	7.0	7.0	7.17	8.5	10.0	11.0	9.83	8.72	F-No. 6a	10.5	10.5	13.0	11.33	14.5	9.5	9.0	11.00	23.0*	17.0	19.5	18.25	13.53
F-No. 7a	8.5	7.0	7.0	7.50	11.5	7.5	7.5	8.83	18.0	10.0	12.0	13.33	9.89	F-No. 8a	10.0	9.0	8.5	9.17	20.5*	12.5	11.5	12.00	8.0	13.0	10.0	10.33	10.50

the steaks from these steers are presented in Table 3.

The cooking loss was determined by weighing the steaks immediately after cutting and again after cooking. The data on cooking losses are presented in Tables 4 and 5.

The press fluid data involves only the frozen and non-frozen steaks from steers C, D, E and F. The Carver Press was not available when the data was collected on the steaks from steers A and B. Three samples were taken from the anterior and posterior sections of each loin from the C and D steers, while only two samples were taken from steers E and F. These data are presented in Table 6.

The data were analyzed for variance by methods presented by Snedecor (1938).

DISCUSSION

A summary of the statistical analyses of the data for tenderness is presented in Table 7. Snedecor's F test was used to indicate the significant sources of variation. The mean squares in the summary starred once are significant (5% level) and those starred twice are highly significant (1% level).

Apparently freezing does not have a consistent effect upon tenderness in aged beef. This is indicated by the non-significant mean square for treatment and highly significant

Table 4. Cooking loss data.

Control steaks				Treated steaks			
Steak No.	Weight: raw grams	Weight: cooked grams	Per cent loss	Steak No.	Weight: raw grams	Weight: cooked grams	Per cent loss
A-No. 1	300.0	247.0	17.66	A-No. 1a	286.0	239.0	16.43
A-No. 2a	260.0	204.0	21.53	A-No. 2	300.0	246.0	18.00
A-No. 3	274.0	226.0	17.51	A-No. 3a	235.0	191.0	18.72
A-No. 4a	235.0	185.0	21.27	A-No. 4	250.0	209.0	16.38
A-No. 5	250.0	208.0	16.80	A-No. 5a	262.0	225.0	14.12
A-No. 6a	272.0	222.0	18.38	A-No. 6	265.0	222.0	16.22
A-No. 7	290.0	238.0	17.93	A-No. 7a	293.0	246.0	16.04
A-No. 8a	307.0	250.0	18.56	A-No. 8	370.0	296.0	20.00
Average	273.50	222.50	18.70		282.63	284.25	16.99
B-No. 1	265.0	235.0	11.32	B-No. 1a	365.0	303.0	16.98
B-No. 2a	330.0	289.0	12.42	B-No. 2	305.0	252.0	13.99
B-No. 3	305.0	257.0	15.73	B-No. 3a	305.0	245.0	19.67
B-No. 4a	290.0	230.0	20.51	B-No. 4	310.0	258.0	16.62
B-No. 5	275.0	227.0	17.45	B-No. 5a	240.0	204.0	15.00
B-No. 6a	240.0	204.0	14.90	B-No. 6	265.0	218.0	17.73
B-No. 7	265.0	222.0	16.21	B-No. 7a	260.0	210.0	19.23
B-No. 8a	270.0	231.0	14.44	B-No. 8	315.0	266.0	15.55
Average	280.00	236.88	15.37		295.65	144.50	16.85
C-No. 1	235.0	204.0	13.19	C-No. 1a	285.0	215.5	24.73
C-No. 2a	260.0	214.0	17.69	C-No. 2	250.0	211.5	15.40
C-No. 3	270.0	221.0	18.14	C-No. 3a	278.0	214.0	23.02
C-No. 4a	278.0	227.0	18.34	C-No. 4	245.0	195.5	20.20
C-No. 5	255.0	200.0	21.56	C-No. 5a	267.0	234.0	12.35
C-No. 6a	275.0	225.0	18.18	C-No. 6	260.0	242.5	6.73
C-No. 7	280.0	222.0	20.71	C-No. 7a	275.0	237.5	14.00
C-No. 8a	322.0	261.0	18.94	C-No. 8	295.0	204.0	30.84
Average	271.88	221.75	18.28		269.38	219.31	18.41

Table 5. Cooking loss data.

Control steaks				Treated steaks			
Steak No.	Weight: raw grams	Weight: cooked grams	Per cent loss	Steak No.	Weight: raw grams	Weight: cooked grams	Per cent loss
D-No. 1a	318.0	264.0	16.98	D-No. 1	200.0	173.5	13.25
D-No. 2	300.0	245.0	18.33	D-No. 2a	315.0	259.0	17.77
D-No. 3a	315.0	268.0	14.92	D-No. 3	275.0	221.5	19.45
D-No. 4	255.0	213.0	16.47	D-No. 4a	310.0	257.0	17.09
D-No. 5a	290.0	239.0	17.58	D-No. 5	251.0	203.0	19.12
D-No. 6	288.0	243.0	15.62	D-No. 6a	275.0	232.5	15.45
D-No. 7a	295.0	238.0	19.32	D-No. 7	300.0	241.5	19.50
D-No. 8	307.0	256.0	16.61	D-No. 8a	315.0	242.5	23.01
Average	296.00	245.75	16.98		280.12	228.81	18.08
E-No. 1	405.0	337.5	16.67	E-No. 1a	364.0	286.0	21.43
E-No. 2a	423.0	367.0	13.24	E-No. 2	385.0	308.5	19.87
E-No. 3	367.0	307.5	16.22	E-No. 3a	360.0	290.5	19.31
E-No. 4a	409.0	344.5	15.77	E-No. 4	351.0	282.0	19.66
E-No. 5	362.0	307.5	15.06	E-No. 5a	392.0	320.0	18.37
E-No. 6a	390.0	338.0	13.33	E-No. 6	351.0	290.0	17.38
E-No. 7	402.0	342.5	14.80	E-No. 7a	397.0	326.0	17.88
E-No. 8a	366.0	294.5	19.54	E-No. 8	434.0	349.0	19.59
Average	390.50	329.87	15.58		379.25	306.50	19.18
F-No. 1a	370.0	312.5	15.54	F-No. 1	367.0	291.5	20.57
F-No. 2	335.0	275.0	17.91	F-No. 2a	352.0	289.5	17.76
F-No. 3a	379.0	308.5	18.60	F-No. 3	314.0	260.0	17.20
F-No. 4	314.0	264.0	15.92	F-No. 4a	336.0	263.0	21.73
F-No. 5a	345.0	284.5	17.54	F-No. 5	338.0	273.5	19.08
F-No. 6	342.0	287.0	16.08	F-No. 6a	351.0	274.0	21.94
F-No. 7a	323.0	275.0	14.86	F-No. 7	357.0	277.5	22.27
F-No. 8	391.0	312.0	20.20	F-No. 8a	332.0	265.0	20.90
Average	349.88	289.81	17.08		343.75	286.75	20.15

Table 6. Press fluid data.

Control steaks		Treated steaks	
Sample, 50 grams	Volume, cc	Sample, 50 grams	Volume, cc
C-Anterior	13.0	C-Anterior	13.5
C-Anterior	13.5	C-Anterior	15.0
C-Anterior	15.0	C-Anterior	16.0
Average	13.83		14.83
C-Posterior	13.0	C-Posterior	13.0
C-Posterior	13.5	C-Posterior	12.5
C-Posterior	15.0	C-Posterior	12.0
Average	13.83		12.50
D-Anterior	10.0	D-Anterior	15.0
D-Anterior	12.0	D-Anterior	15.5
D-Anterior	12.0	D-Anterior	15.0
Average	11.33		15.17
D-Posterior	11.0	D-Posterior	8.5
D-Posterior	11.0	D-Posterior	9.0
D-Posterior	11.0	D-Posterior	10.0
Average	11.0		9.17
E-Anterior	12.0	E-Anterior	11.0
E-Anterior	12.0	E-Anterior	12.0
Average	12.0		11.50
E-Posterior	10.0	E-Posterior	14.0
E-Posterior	10.0	E-Posterior	14.0
Average	10.0		14.0
F-Anterior	12.0	F-Anterior	12.0
F-Anterior	14.0	F-Anterior	14.0
Average	13.0		13.0
F-Posterior	10.0	F-Posterior	10.0
F-Posterior	11.0	F-Posterior	11.5
Average	10.5		10.75

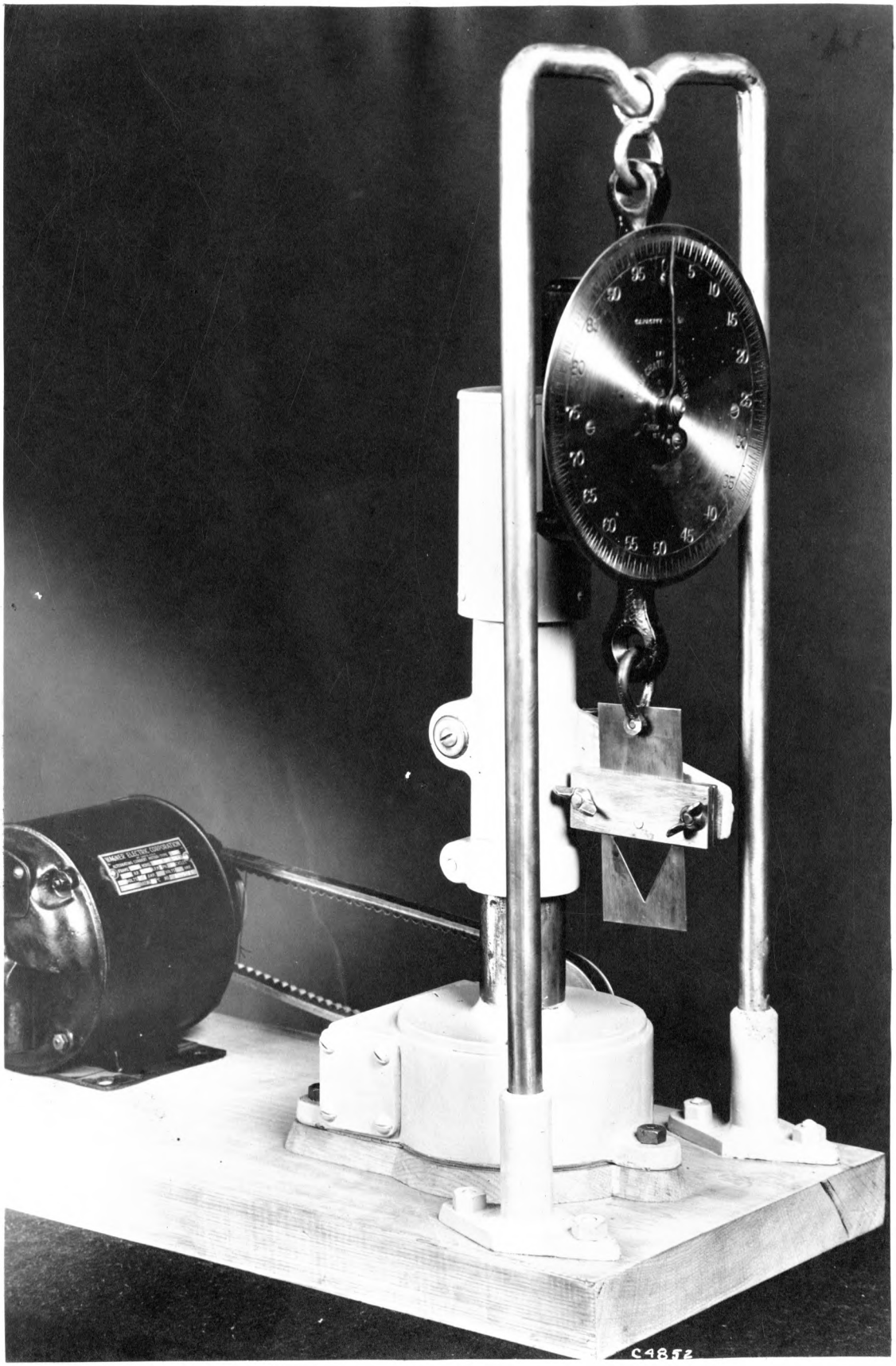
Table 7. Analysis of variance in tenderness of steaks. A=anterior, P=posterior, L=left, R=right, D.F.= degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean squares
Animals	5	1891.533	378.306**
Left versus right	1	46.689	46.698
Anterior vs. posterior	1	43.191	43.191
Between cores	2	796.556	389.278**
Treatment	1	8.436	8.436
Interactions			
Animals - L. vs. R.	5	26.839	5.367
A. vs. P.	5	41.732	8.436
Cores	10	198.046	19.804**
Treatment	5	144.561	28.912**
L. vs. R. - A. vs. P.	1	23.387	23.387*
L. vs. R. - Core	2	.172	.086*
L. vs. R. - Treatment	1	11.226	11.226
A. vs. P. - Core	2	48.406	24.203**
A. vs. P. - Treatment	1	6.519	6.519
Core - Treatment	2	.806	.403
Remainder	243	1152.563	4.743
Total	287	4440.671	

* Significant
** Highly significant

Explanation of Plate IV

The Warner-Bratzler shear used to measure tenderness of steaks.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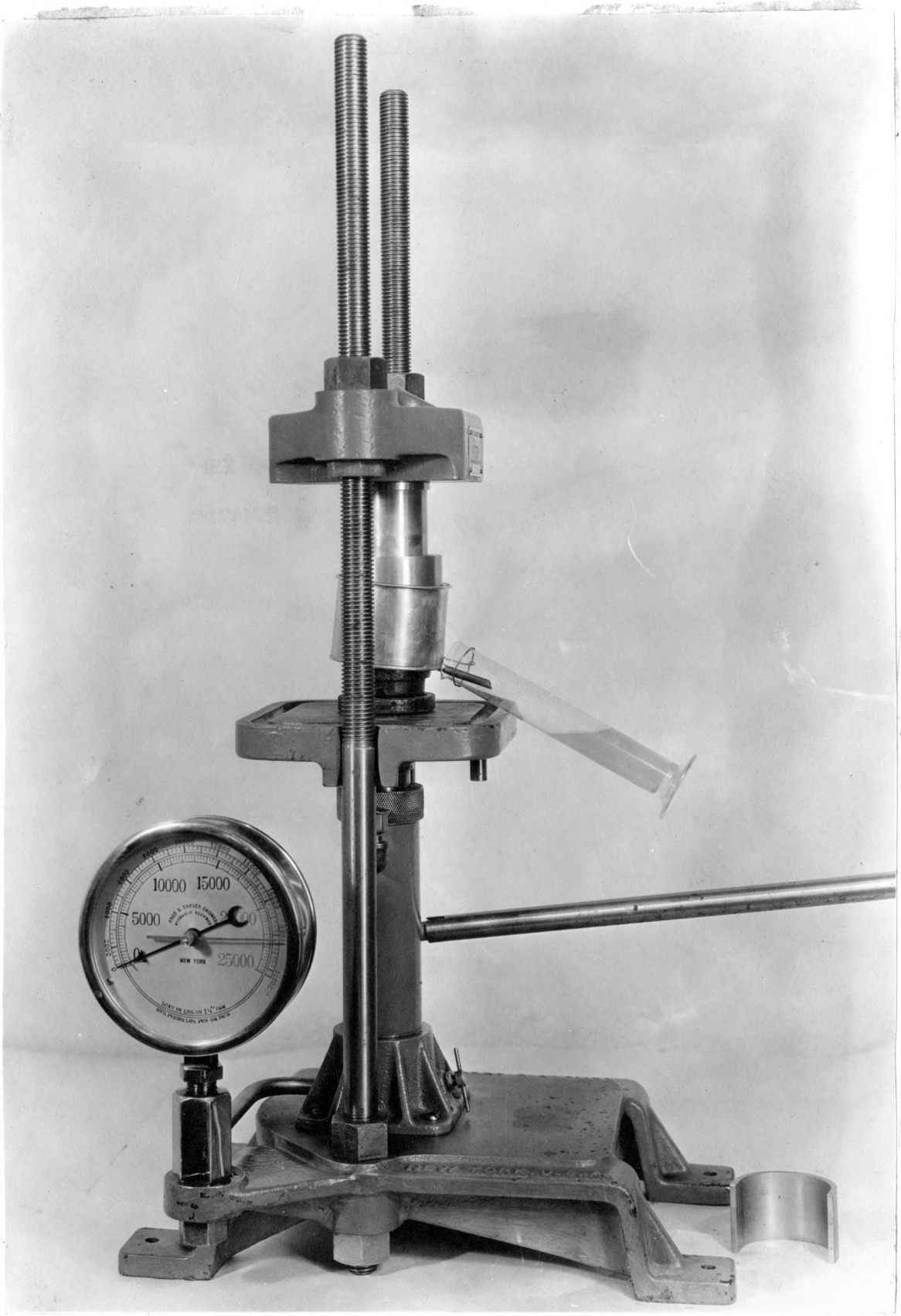
Explanation of Plate V

The Carver Laboratory Press used in the press fluid study between frozen and non-frozen steaks.

Plate V



interaction between animals and treatment. The steaks from the animal fed on a low phosphorus ration and the steaks of one of the animals slaughtered in the spring were significantly tenderized by freezing. The steaks from the animals grading U. S. Medium proved to be less tender after freezing than did the control steaks from the same animals. The tenderness of the steaks from the other two animals was not influenced by freezing; thus an over-all effect of freezing upon the tenderness of aged beef was not significant.

The influence of freezing was similar in the posterior and anterior sections of the loins.

A highly significant variation was found among the six animals. This variation is to be expected as the animals may have varied in breeding, management, individuality, grade, and perhaps other factors, any of which might have an influence upon the results.

The steaks from the animals grading U. S. Medium were less tender than those from the animals grading U. S. Good with the exception of the steaks from the animal fed on a ration low in phosphorus. This finding may indicate to some degree a relationship between grade and tenderness.

The steaks from the steer on a low phosphorus ration were the least tender of those tested in this study. This observation is in agreement with the work of Hoglund (1937) who suggests that the amount of phosphorus in a ration may influence the tenderness of the beef.

The steaks from the animals slaughtered in the spring were more tender than the steaks from the steers slaughtered in the fall. These tenderness readings were among the lowest observations ever recorded at this station. This condition of tenderness can not be explained but may be associated with carcass grade, individual animal differences, or method of management.

The data indicate that the right side was more tender than the left side, which is not in agreement with the concensus of popular opinion. The lack of a significant interaction between animals and the left versus the right side indicates that animals were consistently more tender on the right side. However, there was no apparent difference between the right and left side on the frozen steaks. As yet no satisfactory explanation can be given for this variation. Many more tenderness readings will be necessary before any definite conclusions can be reached on this point.

In general the posterior section of the short loin was found to be more tender than the anterior section. This finding is in agreement with similar work done by Hankins and Hiner (1938).

The greatest variation was found among the cores (Plate III). The medial and central cores were more tender than the lateral core. The lateral core was taken from the smaller portion of the eye or longissimus dorsi muscle which made it

difficult in some cases to obtain a representative core. The variation in tenderness among the cores may be attributed in part to this difficulty in sampling. The difference in tenderness between the medial and central cores was not significant.

The interaction between animals and cores is highly significant indicating that the comparative tenderness among the cores was not the same in all of the animals. In some animals the lateral core readings were almost identical with those of the medial and central cores.

Another interaction proving to be highly significant was that of the cores with the anterior and posterior sections of the loin. The medial and central core readings in the anterior and posterior sections were quite similar, but the lateral core was more tender in the posterior than in the anterior section of the loin. This increased tenderness of the lateral core in the posterior section of the loin may be attributed to the increase in the width of the eye muscle in that section which made it easier to obtain a representative lateral core.

In view of these findings, it would seem advisable to use only two cores from the center of the eye muscle as a source of data in a study of this nature rather than three cores as was used in this work.

The non-frozen and frozen steaks were weighed at the time of cutting and again after cooking. The weight losses, appar-

Table 8. Analysis for variance of cooking losses
D. F. = Degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean squares
Animals	5	45.358	9.071
Treatment	1	69.751	69.751
Interactions Animals - Treatment	5	137.489	27.497
Remainder	84	1415.246	16.848
Total	95	1667.844	

Table 9. Analysis for variance of press fluid.
A=anterior, P=posterior, D. F.=Degrees of freedom.

Source of variation	D. F.	Sum of squares	Mean squares
Animals	3	11.644	3.881
Treatment	1	1.717	1.717
Anterior vs. posterior	1	10.416	10.416
Interactions			
Animals - Treatment	3	2.272	.757
A. vs. P.	3	6.660	2.220
Treatment	1	.785	.785
Remainder	3	14.812	4.937
Total	15	47.310	

ently due to cooking and probably other unknown factors were calculated in percent and analyzed for variance. The summary of this analysis is presented in Table 8.

The treatment variance was not significant, which indicates that freezing had no influence upon cooking losses. The variance among animals relative to the cooking losses was not significant. The interaction between the animals and treatment indicates that the cooking losses in the control and frozen steaks were proportionately the same in each animal.

The analysis of variance of the press fluid data is presented in Table 9 and indicates that freezing had no effect upon the volume of press fluid. The difference in the amount of press fluid was not significant among the animals or between the anterior and posterior sections of the loin.

CONCLUSIONS

1. The results of the study indicate that freezing has no influence upon tenderness in beef that has been aged; however, indications were that this may vary among the animals.

2. Considerable variation in tenderness was found among the animals.

3. The posterior section of the short loin was found to be more tender than the anterior section.

4. The greatest variation exists among the cores taken from the longissimus dorsi muscle. The lateral core was significantly less tender than the medial or central core.

5. The right side was found significantly more tender than the left side, but as yet no satisfactory explanation can be offered for this condition.

6. Freezing has no influence upon cooking losses.

7. The amount of press fluid is not influenced by freezing.

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LITERATURE CITED

Bratzler, L. J.
Physical research on meat with special reference to tenderness. Prog. Rpt. 9 p. 1932.

Hankins, O. G. and Hiner, R. L.
Freezing makes beef tenderer. Food Industries, 12:38-40. 1940.

Hoglund, G. C.
The effect of phosphorus on the quality of meat. Unpublished thesis. Kans. State Col. of Agr. and Appl. Sci. 49 p. 1937.

Mackintosh, D. L., Hall, J. L. and Vail, G. E.
Some observations pertaining to tenderness of meat. Amer. Soc. Anim. Prod. Proc. 1936:285-289.

Moran, T. and Smith, E. C.
Post-mortem changes in animal tissue - The conditioning or ripening of beef. Dept. Sci. and Indus. Res. Food Invest. Bd. Special Rpt. 36. 86 p. 1929.

Snedecor, C. W.
Statistical methods. Ames, Iowa. Collegiate Press, Inc. 378 p. 1938.

Tressler, D. K., Birdseye, Clarence and Murray, W. T.
Tenderness of meat. Indus. and Engin. Chem. 24:242. 1932.

Vail, Gladys E. and Hall, J. L. and Mackintosh, D. L.
Confidential Progress Report, Kansas Agr. Expt. Sta. 12 p. 1935.