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# **Organoleptic, Chemical, Physical And Microscopic Characteristics Of Muscles in Eight Beef Carcasses, Differing in Age of Animal, Carcass Grade and Extent of Cooking**

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**AGRICULTURAL AND HOME ECONOMICS EXPERIMENT STATION  
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## SUMMARY

Studies have been made of the organoleptic and some chemical, physical and microscopic characteristics of cooked and uncooked beef muscles obtained from carcasses of animals differing in age and quality. The beef animals were divided into pairs according to animal age and carcass grade. Group I included animals I and V — age, 18 months; carcass grade, Commercial. Group 2 included animals II and VI — age, 18 months; carcass grade, Choice. Group 3 consisted of animals III and VII — age, 6 months; carcass grade, Commercial. Group 4 included animals IV and VIII — age, 42-48 months; carcass grade, Commercial.

Roasts were obtained from the "tender" cuts (the rib, loin and tenderloin). Braised cuts were obtained from the "less tender" muscles of the round (biceps femoris, semitendinosus and semimembranosus). Cuts from one side of a pair were cooked to an interior temperature of 90° C.; those from the other side of the same animal, to 70° C.

Data were obtained for the following: cooking time and shrink (length, width, depth, volume and weight); the palatability of the cooked cuts (aroma, flavor of lean, tenderness and juiciness); the shear force and press fluid values of the cooked cuts; the pH values, fat content, moisture content and total nitrogen. Histological sections (for microscopic study) both before and after cooking were also taken and analyzed. Collagen nitrogen for cuts from all animals and the elastin nitrogen (for the first four animals only) were determined by the procedure of Lowry *et al.* (14).

1. The data obtained in this investigation failed to provide strong support for the widely held belief that carcass grade, age, degree of fatness, fat and connective tissue content of beef are closely and consistently associated with tenderness, juiciness, flavor and aroma of cooked beef.

2. The temperatures to which the cuts were cooked — 90° C. and 70° C. — brought about the following differences: cuts cooked to 90° C. required longer to cook, had greater cooking weight losses and, in general, were considered less desirable in aroma, flavor of fat and flavor of lean than those cooked to 70° C. The panel scored roasts cooked to 70° C. more tender than those cooked to 90° C., but the shear force values did not indicate this difference in tenderness. Cuts cooked to 90° C. were less juicy, had less press fluid and a lower collagen content than the cuts cooked to 70° C.

3. One of the outstanding findings was the difference between animals constituting a pair (same age

and grade). Cuts from these pairs of carcasses varied in the time for cooking, cooking weight losses, aroma scores, flavor of fat, flavor of lean, tenderness scores, shear force values, juiciness scores, press fluid values, fat content and collagen content of the cuts. This difference in animals within a pair was very striking, for the variation was for many characteristics.

The oldest animals were not the toughest. The age of the animal did not affect the cooking weight losses, the shear force values, juiciness scores and the press fluid values.

4. The analytical method used to determine the collagen-N content of the raw and cooked cuts gave the following results: In the majority of the samples, the collagen-N content was less than 3 percent of the total nitrogen in the raw cuts and less than 1 percent in the cooked cuts. The average amount of the initial collagen-N remaining in the cuts after cooking to an interior temperature of 90° C. was less than 25 percent; after cooking to 70° C., it was less than 40 percent. The correlations (a) between tenderness scores and collagen-N content of the cooked cuts, (b) between shear force and collagen-N content of raw muscle and (c) between shear force and collagen-N content of the cooked muscle were not significant.

5. Although it is widely accepted that the fat content, carcass grade and age of animal are highly correlated with the palatability of beef, the results of detailed analysis of these eight beef carcasses indicate that the tenderness, juiciness, flavor and fat content of cuts vary within wide limits for carcasses of the same age and grade.

6. The results of this study indicate that the factors affecting the organoleptic qualities of beef are complex.

7. In view of the lack of concordance in the values reported in the literature for the different components of meats and the obvious lack of agreement about how they are related to tenderness of meat, it would seem that a much more rigorous study of the factors influencing this quality in meats is needed. It seems proper to suggest that many of the older approaches to this problem ought to be abandoned and new ones developed. Clearly, beliefs long held about the relationship of carcass quality as defined by grade standards with palatability of beef ought to be more seriously investigated. The continued lack of adequate support for such assumptions that have been made in these connections is sufficient reason for doubt and further questioning and research.



# Organoleptic, Chemical, Physical and Microscopic Characteristics of Muscles in Eight Beef Carcasses, Differing in Age of Animal, Carcass Grade and Extent of Cooking <sup>1</sup>

BY BELLE LOWE AND JOSEPH KASTELIC

Carcass grade specifications for slaughter cattle are based upon the assumption that the age of the animal, the amount of fat both within and on muscles and the firmness and texture of muscle and fat are closely correlated with the tenderness, juiciness, aroma and flavor of the cooked beef. Carcass grades for cattle are, therefore, assumed to reflect those beef-cut qualities which are of primary concern to consumers.

Experience has shown that the palatability of beef can be influenced appreciably by the extent to which the carcass or cut has been ripened and by the time, temperature and method of cooking used. It also has been observed that, regardless of the method of cooking, there are considerable differences in tenderness and juiciness among the different cuts of beef obtained from a carcass representing a specific grade category. It thus follows that the differences in the organoleptic characteristics of cooked beef must accrue from inherent differences in the physical and chemical composition of muscle, fat and fibrous connective components of animal tissue and from the effect of cooking upon these and other components of meats. More specifically, it is believed that the organoleptic properties of cooked beef are dependent, not only upon the age of the animal and its nutritional status at time of slaughter, but also upon the quantity and distribution of the fat and fibrous connective tissue in each cut. Likewise it is generally accepted that animals of the same grade, other things being equal, will produce carcasses possessing similar quality attributes.

Considerable attention has been directed toward developing an understanding or an appreciation of the role played by fat and fibrous connective tissue in the tenderness and juiciness of meat. The most widely accepted index of carcass excellence is marbling. The degree of marbling reflects the amount of fat in fine fibrous connective tissue binding muscle cells together. Beef that is well marbled and covered with a layer of firm, smooth fat is, therefore, assumed to be more tender and juicy and to have a better flavor than beef which lacks fat and marbling. Nevertheless, there remains a paucity of information regarding the quanti-

tative interrelationships which appear to exist among the age of the animal, carcass grade, extent of cooking and certain organoleptic and compositional characteristics of the cooked meat.

The objective of this investigation was to evaluate the differences in the palatability and the composition of braised and roasted cuts of meat from steer carcasses varying in age and grade when cooked by standardized procedures.

## PROCEDURE

The selection of the animals was specified in the contract between the sponsor and Iowa State University. Four animals were used during the first year of the work. The specifications required that they were to be of the same sex and breed. Three animals were to be of varying ages, and the carcasses were to grade Commercial. A fourth animal was to be of approximately the same age as one of the other three animals, but its carcass was to grade Choice. Later, the contract was extended to use four more animals as nearly as possible replicates of the first four animals. Practical limitations on cost and availability of extensive laboratory facilities and of trained personnel prohibited studies being conducted on more animals.

The carcasses were graded by an official government beef carcass grader in accordance with grade standards in use prior to Jan. 1, 1951. Table 1 contains information about the pairing of animals according to age and carcass grade, plus other pertinent data about the animals.

All the animals were killed in the Department of Animal Husbandry meat laboratory. The carcasses were stored in a cooler at about 1.7°C. (35°F.) until the aging time (given in table 1) had elapsed. The

TABLE 1. INFORMATION ABOUT THE ANIMALS AND THE PAIRING OF ANIMALS.

	Animal							
	I	V	II	VI	III	VII	IV	VIII
Animal age (months)	18	19	17	18	5-6	6	42-48	42-48
Carcass grade	Hi. Com.	Low Com.	Low Choice	Low Choice	Low Com.	Ave. Com.	Ave. Com.	Low Com.
Carcass age (days)	7	10	10	10	7	7	10	10
Carcass wt. (lbs.)								
Right side	199	219	328	318	102	155	313	393
Left side	202	218	337	320	106	149	310	398

<sup>1</sup>Project 934 of the Iowa Agricultural and Home Economics Experiment Station.



cuts were then removed from the carcass or part of carcass for individual animals. The cuts were frozen at -34.4°C. (-30°F.) and then stored at -23.3°C. (-10°F.) until removed for defrosting and cooking.

The cuts from one side of each animal were roasted or braised to an interior temperature of 70°C. (158°F.); the cuts from the other side of a given pair were cooked to 90°C. (194°F.). Usually the cuts cooked to 90°C. came from the right side, but this was not always the case.

Data were obtained for cooking time and shrink (length, width, depth, volume and weight); the palatability (aroma, flavor of lean, tenderness and juiciness) of the cooked cuts; the shear force and press fluid values of the cooked cuts; the pH values, fat content, moisture content, total nitrogen, collagen nitrogen, elastin nitrogen (for the first four animals only) and from histological sections (for microscopic study) both before and after cooking.

#### THE CUTS

#### THE ROASTS

The "tender" cuts were obtained from the ribs, the loin and the tenderloin. The longissimus dorsi muscle extends through the ribs and loin. It was used for the tests for the rib (LDR) and loin (LDL) cuts. The psoas major (PM) was used for the tenderloin. The rib and loin roasts were not boned, but the psoas major was dissected from the bones. Two roasts were used from each cut of animals II and IV. It was found, however, that although the cuts from these two animals were large, there was barely enough tissue for the different tests; therefore this procedure was not followed for the other large carcasses (animals VI and VIII).

#### THE BRAISED CUTS

The "less tender" cuts, used for braising, were obtained from muscles of the round. The biceps femoris (BF) and the semitendinosus (St) came from the "bottom" round, the semimembranosus (Sm) from the "top" round. The muscles were dissected from the round. The adductor was removed with the semimembranosus. It was also cooked with the semimembranosus but was not used in the tests unless — as occurred with cuts from the calves — there was too little material from the semimembranosus for all the tests. The adductor did protect the semimembranosus on one side during the cooking. The adductor is similar to the semimembranosus in texture and in some areas is difficult to separate from the semimembranosus; *i.e.*, there is no definite dividing line.

TABLE 2. THE NUMBER OF SAMPLES COOKED FROM EACH CUT.

Cuts	Animal							
	I	V	II	VI	III	VII	IV	VIII
Roasts								
LDR	1	1	2	1	1	1	2	1
LDL	1	1	2	1	1	1	2	1
PM	1	1	2	1	1	1	2	1
Braised cuts								
BF	2	2	3	2	2	2	3	2
St	1	1	2	1	1	1	2	1
Sm	2	2	3	2	2	2	3	2

As shown in table 2, more cuts were braised from the muscles of animals II and IV than from the muscles of the other large animals (VI and VIII). Dividing the muscles of the round from animals II and IV into more cuts resulted in small quantities for the samples that were not weighed.

#### SAMPLING

The method of sampling can be shown graphically. Anterior or proximal end

Posterior or distal end

A	B	C	A'	B'	D	E
---	---	---	----	----	---	---

A. Samples for nitrogen (100 grams) and microscopic study from the uncooked cut were obtained at this end of the cut. The sample for sectioning was a small rectangular one.

B. Sample for fat analysis (100 grams second year, 35 grams the first year) from raw cut.

C. Browned outer slice of cooked cut, discarded.

A'. Same sample as A, but from the cooked cut.

B'. Same sample as B, but from the cooked cut.

D. Area from which samples for palatability tests were taken.

E. Samples for shear force and press fluid obtained at this end of the cooked cut.

Samples for pH determinations usually were taken from A and A' areas. But if material was scarce, they were taken from any area that could be used (about 15 grams).

#### WEIGHT, MEASUREMENTS, VOLUME

After the samples for pH, nitrogen, fat determinations and microscopic study were removed from the raw muscle, the cut was weighed. The length, width and depth of the cut also were recorded. Volume measurements were taken by water displacement. A string tied around the cut facilitated handling the cut during this procedure. The temperature of the water used to determine the volume of the uncooked cut was 25° C. (77°F.). Boiling water was used for the volume determinations of the cooked cuts.

#### OBJECTIVE TESTS

Shear data were obtained with the Warner-Bratzler shear apparatus. The 1-inch cylinder used for shearing was removed from the center of the cut. This cylinder varied in length from about 1.25 to 2 inches, depending on the amount of the cut left after the other samples had been removed. Hence, some cylinders were sheared three, some four and others five times.

The press fluid was determined on the Minnesota pressometer.

#### CHEMICAL TESTS AND MICROSCOPIC OBSERVATIONS

Some routines had to be chosen arbitrarily. Since palatability evaluations, shear force values and press fluid tests were made upon the interior of the muscle,



it was decided that the exterior fat and connective tissue (usually about  $\frac{1}{8}$  inch or less) would be trimmed from the cut. Thus, tissues for fat, moisture and nitrogen analysis were from samples similar to those used for other tests.

#### MOISTURE AND FAT

The moisture content was determined by the American Association of Agricultural Chemist's procedure. Moisture content was determined on samples used for fat analyses and for nitrogen analyses.

The fat content of tissues was determined by alcohol-ether extraction of samples dried to constant weight at 80°C., using a modification of the procedure described by Bloor (4).

#### TOTAL NITROGEN, COLLAGEN NITROGEN AND ELASTIN NITROGEN

Total nitrogen was determined by the micro-Kjeldahl method. Collagen and elastin nitrogen were determined by a modification of the Lowry, Gilligan and Katersky (14) method.

The modification of this procedure included (a) grinding the muscle tissue with dry ice after the sample had been ground in a small household food chopper and (b) additional extractions of the autoclave insoluble residue with 0.1 N NaOH. After washing with distilled water, this residue was dissolved in 87 percent formic acid. MicroKjeldahl nitrogen determinations conducted on the autoclave-solubilized fractions and formic acid-solubilized fractions were recorded as collagen and elastin nitrogen, respectively.

#### MICROSCOPIC OBSERVATIONS

A sample was taken for sectioning from each muscle after the carcass had been in the cooler for approximately 24 hours. These samples were taken close to the surface of each muscle. Taking the sample deep in the muscle would have interfered with uniform cooking of the cut. Since the 24-hour samples were taken near the surface, the samples just before and after cooking also were taken near the surface.

Samples were preserved in a 10-percent formalin and physiological salt solution. Longitudinal sections were prepared on a freezing microtome, mounted on slides and stained with Weigert's elastic tissue stain and van Giessen's mixture of acid fuchsin and picric acid. These stains produced blue-green in the elastic tissue and pink to red in the collagenous tissue. The muscle fibers were a yellowish brown. After staining, glycerin jelly was placed over the section, followed by a cover glass. Five to seven sections were obtained from each sample.

#### COOKING

To defrost, cuts were placed in the refrigerator 48 hours before they were to be cooked. Average interior temperature of the cuts at start of cooking was around -2°C. (28°F.) to 0°C. (32°F.).

#### ROASTS

Rib roasts were placed in an open pan, the roast resting on the rib and chine bone ends. Loin roasts and the tenderloin were placed on racks in open pans.

The roasts were cooked until the thermometer (the bulb of which was placed in the center of the muscle) reached the desired temperature, 70° or 90°C. The oven temperature was 150°C. (approximately 300°F.).

#### BRAISED CUTS

Each cut was browned 12 minutes. For browning, 20 grams of bland lard (Swift's) were placed in the bottom of the Dutch oven. The Dutch oven was heated over a gas burner until a temperature of 175°C. (approximately 350°F.) was reached as shown by a griddle thermometer. Some cuts had six surfaces for browning, some had only four. After browning, a rack was placed under the meat. A hole was made in the meat for the thermometer, which was inserted so that the bulb was in the center of the thick portion of the muscle. There was a hole (1 inch in diameter) in the lid through which the stem of the right angle thermometer was inserted.

The Dutch oven and contents were then placed in the oven. The oven was maintained at 150°C. Interior temperature of the finished braised cuts was 70° or 90°C. No water was added for braising. A great deal of liquid came from the meat during cooking and all of it did not evaporate.

#### PALATABILITY EVALUATIONS

Interior slices were used for scoring. These slices were cut across the fibers on a slicing machine set to cut  $\frac{1}{4}$ -inch slices. Each slice was about  $\frac{3}{16}$  inch in thickness.

Four scorers judged the palatability of the cuts throughout the study.

The following qualities were scored on the basis of 10 points: aroma, flavor of fat (cuts from animal III had little visible fat, and some cuts from the round had little fat), flavor of lean, tenderness and juiciness. Each scorer counted the number of chews required to masticate a sample of a given size to an end point determined by each scorer as an aid in determining tenderness. The scores for fat are given, but they were not analyzed statistically.

## RESULTS

### COOKING AND PALATABILITY DATA

#### THE WEIGHT OF THE CUTS

The weight of each cut varied with the weight of the animal and the muscle from which it was obtained. The rib roasts were heavier than the loin roasts, and the loin roasts were heavier than the roasts from the tenderloin. Cuts from the semitendinosus weighed the least of the braised cuts. The average, maximum and minimum weights for the roasts and braised cuts are shown in table 3.

TABLE 3. AVERAGE, MAXIMUM AND MINIMUM WEIGHTS IN GRAMS FOR ROASTS AND BRAISED CUTS.

Cuts	Average wt.	Maximum wt.	Minimum wt.
Roasts	2,338	5,052	893
Braised cuts	1,688	3,675	463



COOKING TIME

As would be expected, the cooking time, tables 4 and 5, varied with the size of the cut, the interior temperature to which the cut was cooked and the method of cooking.

TABLE 4. THE AVERAGE COOKING TIME IN MINUTES FOR ROASTS AND BRAISED CUTS FROM EACH ANIMAL.

Animal Grade	Age (mos.)	Roasts cooked to:		Braised cuts cooked to:	
		90°C.	70°C.	90°C.	70°C.
I-- Comm.	18	240	148	138	113
V-- Comm.	19	292	178	182	154
II-- Choice	17	356	220	162	111
VI-- Choice	18	368	264	197	167
III-- Comm.	5-6	258	188	112	76
VII-- Comm.	6	247	158	128	109
IV-- Comm.	42-48	311	196	163	126
VIII-- Comm.	42-48	337	228	237	190

TABLE 5. THE AVERAGE COOKING TIME IN MINUTES FOR CUTS FROM EACH MUSCLE USED IN THE STUDY.

Interior temperature	LDR	LDL	PM	BF	St	Sm
Cooked to 90° C. ----	359	286	259	157	119	187
Cooked to 70° C. ----	257	178	148	124	99	154

Cuts cooked to an interior temperature of 90°C. required a longer time than those cooked to 70°C. The cooking time varied for cuts from animals constituting a pair. A longer time was required for roasts than for braised cuts. Roasts were cooked uncovered so that they were surrounded by air, which conducts heat more slowly than steam. The braised cuts were covered so that they were surrounded by steam after the juice from the meat reached a temperature high enough to form steam.

COOKING WEIGHT LOSSES

The cooking weight losses varied among muscles, among animals, between grades and between animals constituting a pair. The cut cooked to an interior temperature of 90°C. always had a greater weight loss than the one cooked to 70°C. (tables 6 and 7).

TABLE 6. AVERAGE TOTAL COOKING WEIGHT LOSSES FOR EACH ANIMAL, IN PERCENT.

Animal Grade	Age (mos.)	Roasts cooked to:		Braised cuts cooked to:	
		90°C.	70°C.	90°C.	70°C.
I-- Comm.	18	33.9	17.3	34.6	26.7
V-- Comm.	19	32.9	15.7	33.6	24.9
II-- Choice	17	34.0	17.6	32.6	25.2
VI-- Choice	18	34.8	20.6	33.8	22.5
III-- Comm.	5-6	24.6	17.3	32.3	20.3
VII-- Comm.	6	30.3	16.3	33.5	25.4
IV-- Comm.	42-48	36.6	21.3	37.8	30.1
VIII-- Comm.	42-48	34.9	23.0	36.4	28.8

TABLE 7. AVERAGE TOTAL COOKING WEIGHT LOSSES FOR EACH MUSCLE USED IN THE STUDY, IN PERCENT.

Interior temperature	LDR	LDL	PM	BF	St	Sm
Cooked to 90° C. ----	31.5	29.8	38.7	32.8	31.0	37.5
Cooked to 70° C. ----	19.0	16.3	21.5	24.4	20.5	27.5

VOLUME CHANGES

Average changes in volume and in length of each muscle cooked to interior temperatures of 90° and 70° C. are shown in tables 8 and 9. Cuts cooked to an interior temperature of 90°C. had a greater shrinkage in volume than those cooked to 70°C. (table 8). The semimembranosus muscle was outstanding for its shrinkage in volume during cooking — about twice that of the other muscles.

TABLE 8. AVERAGE DECREASE IN VOLUME DURING COOKING IN CUTS FROM EACH CARCASS, IN PERCENT.

Animal	Roasts Cooked to:		Braised cuts Cooked to:	
	90° C.	70° C.	90° C.	70° C.
I	18.5	4.6	22.7	18.6
II	11.1	2.6	16.9	9.6
III	10.2	4.5	20.4	11.6
IV	14.8	6.9	22.9	16.0
V	11.5	3.4	16.8	9.7
VI	14.1	1.8	16.2	6.3
VII	5.9	4.1	13.4	4.0
VIII	10.7	7.8	23.1	17.0
Av.	12.1	4.5	19.1	11.6

TABLE 9. AVERAGE SHRINKAGE IN VOLUME AND IN LENGTH OF EACH MUSCLE DURING COOKING, IN PERCENT.

	LDR	LDL	PM	BF	St	Sm
Shrinkage in volume						
Cooked to 90° C. ---	13.4	9.5	14.6	16.4	12.4	24.9
Cooked to 70° C. ---	4.9	5.4	4.8	9.9	5.1	16.1
Shrinkage in length						
Cooked to 90° C. ---	22.9	22.2	29.1	19.2	23.4	21.5
Cooked to 70° C. ---	24.7	20.8	21.4	17.2	22.9	18.7

CHANGES IN MEASUREMENTS DURING COOKING

In addition to losing weight and volume during cooking, the cuts shrank along the length of the fiber (tables 10 and 11). The cuts also shrank in a second dimension, which could be called depth, and gained in a third dimension, width (table 11). The gain in the third dimension may become a loss if the cut is cooked long enough.

TABLE 10. AVERAGE PERCENTAGE OF SHRINK IN LENGTH DURING COOKING OF CUTS FOR DIFFERENT ANIMALS.

Animal	Roasts Cooked to:		Braised cuts Cooked to:	
	90° C.	70° C.	90° C.	70° C.
I	19.8	24.6	21.7	22.5
II	22.2	15.7	22.1	14.6
III	27.2	24.0	27.5	25.8
IV	29.6	27.4	21.2	20.4
V	26.7	20.5	19.7	18.6
VI	13.8	14.6	14.2	10.4
VII	23.8	22.1	19.4	19.3
VIII	29.0	30.4	20.9	20.8
Av.	24.6	22.4	20.8	19.1

TABLE 11. AVERAGE PERCENTAGE CHANGES IN MEASUREMENTS OF CUTS DURING COOKING.

Measurement	Roasts Cooked to:		Braised cuts Cooked to:	
	90° C.	70° C.	90° C.	70° C.
Shrinkage in length	24.6	22.4	20.8	19.1
Shrinkage in depth	7.8	10.8	12.4	16.6
Gain in width	5.8	10.7	11.4	22.6

Muscle shrinks with the ends tending to curl during cooking, so that accurate measurements are difficult to make. Raw muscle, owing to its lack of rigidity, also is difficult to measure. The error in measurement probably is large, but relative change in measurements can be shown.

Although meat shrinks in length during cooking, it is not known whether this shrinkage is due primarily to connective tissue, to muscle fiber, or to both. It has been reported that connective tissue containing principally collagen shrinks more in length when heated than connective tissues containing principally elastin (24). The braised cuts, which usually contain more collagen than the roasts, did not shrink as much as the roasts. Thus it appears that fibers, as well as connective tissue, may shrink during cooking. The



cuts from animal VI shrank less in length than those from the other animals.

PALATABILITY

Scores for aroma, flavor of lean and flavor of fat.

The aroma and flavor-of-lean scores are given in tables 12 and 13.

TABLE 12. AVERAGE SCORES FOR AROMA, FLAVOR OF LEAN AND FLAVOR OF FAT FOR EACH ANIMAL (HIGHEST POSSIBLE SCORE IS 10).

Cuts	Animal, grade and age (mos.)								
	I	V	II	VI	III	VII	IV	VIII	
	Commercial 18		Choice 18		Commercial 6		Commercial 42-48		
<i>Aroma scores</i>									
<i>Roasts</i>									
Cooked to 90° C.	----	8.2	6.7	8.6	7.2	7.4	7.1	7.6	6.6
Cooked to 70° C.	----	8.3	7.8	9.6	8.1	7.8	7.3	8.3	7.5
<i>Braised cuts</i>									
Cooked to 90° C.	----	7.9	7.4	8.8	7.0	7.7	6.8	7.2	6.9
Cooked to 70° C.	----	8.0	7.5	9.2	7.2	7.6	7.1	7.4	7.4
<i>Scores for flavor of lean</i>									
<i>Roasts</i>									
Cooked to 90° C.	----	7.6	5.3	8.4	6.1	6.9	5.7	6.2	5.8
Cooked to 70° C.	----	8.2	7.2	9.9	8.3	7.3	6.6	7.4	7.3
<i>Braised cuts</i>									
Cooked to 90° C.	----	7.2	5.7	8.2	6.0	7.0	5.6	6.0	5.5
Cooked to 70° C.	----	7.6	6.9	9.3	7.0	7.4	6.3	6.5	6.6
<i>Scores for flavor of fat</i>									
<i>Roasts</i>									
Cooked to 90° C.	----	7.5	6.0	8.6	6.0	--	6.1	7.2	5.6
Cooked to 70° C.	----	7.1	7.5	9.7	7.6	--	6.4	7.7	7.1
<i>Braised cuts</i>									
Cooked to 90° C.	----	7.2	6.6	8.4	6.7	--	6.8	6.5	6.1
Cooked to 70° C.	----	7.4	6.4	8.7	7.1	--	6.8	6.5	7.1

TABLE 13. THE AVERAGE SCORES FOR AROMA, FLAVOR OF LEAN AND FLAVOR OF FAT FOR EACH MUSCLE USED IN THE STUDY.

	Muscle						
	LDR	LDL	PM	BF	St	Sm	
<i>Aroma</i>							
Cooked to 90° C.	-----	7.6	7.6	7.1	7.6	7.7	7.2
Cooked to 70° C.	-----	8.0	8.0	8.3	7.7	7.7	7.6
<i>Flavor of lean</i>							
Cooked to 90° C.	-----	6.5	6.6	6.3	6.3	6.9	6.1
Cooked to 70° C.	-----	7.6	7.6	8.2	7.3	7.4	6.9
<i>Flavor of fat</i>							
Cooked to 90° C.	-----	7.1	7.1	6.5	6.7	7.1	7.1
Cooked to 70° C.	-----	7.8	7.3	7.8	7.1	7.5	6.7

It is known that meat from different animals may vary in flavor. This was shown in the present study. Cuts from animal II (Choice grade) generally rated higher in flavor of lean, aroma and flavor of fat than did cuts from most of the other animals. Cuts from animal I (Commercial grade) ranked next in order. In spite of the excellent flavor of the cuts from animal I, cuts from this animal were not tender. The average aroma and flavor scores from animal VI (Choice grade) are about the same as those for animal IV (3.5-4 years old). The cuts from animal VII received the lowest average aroma and flavor scores.

The cuts from the Choice-grade carcasses received higher average flavor scores, 7.7, than did those from the Commercial-grade carcasses, 6.7. These results should not be emphasized too much, since there were cuts from only two Choice-grade carcasses to compare with cuts from six Commercial-grade carcasses. The results, however, follow the same trend as in an earlier study. Lowe *et al.* (13), using four roasts from each of 10 Choice-grade carcasses found the flavor scores "of lean" from Choice- and Good-grade carcasses to average about the same, 5.9 and 5.8, respectively, whereas the Commercial cuts averaged 5.3. (In Lowe's study, the highest possible score was 7.0).

One of the objectives of this study was to determine the relationship between the age of the animal

and the palatability of the cooked cuts. The average flavor scores for the Commercial-grade carcasses are: the 6-month age group, 6.6; the 18-month age group, 7.0; and the 42- to 48-month age group, 6.5. This may be logical, as the cuts from the calves may have lacked flavor, whereas the cuts from the older animals may have been stronger than desired by the scoring panel. There was, however, variation in the cuts from animals constituting a pair. Except for the data for the Choice-grade carcasses, the aroma scores also varied with the age of the animal, but not in the same order as the flavor scores.

There was no visible fat to score for the cuts from animal III. Many of the other cuts, particularly those from the round, had very little visible fat.

*Tenderness.* The average tenderness scores and shear force values for the cuts from each animal and for each muscle are shown in tables 14 and 15.

TABLE 14. AVERAGE TENDERNESS SCORES AND SHEAR FORCE VALUES (IN POUNDS) FOR THE CUTS FROM EACH ANIMAL (HIGHEST POSSIBLE TENDERNESS SCORE, 10).

Cuts	Animal, grade and age (mos.)								
	I	V	II	VI	III	VII	IV	VIII	
	Commercial 18		Choice 18		Commercial 6		Commercial 42-48		
<i>Tenderness scores</i>									
<i>Roasts</i>									
Cooked to 90° C.	----	5.6	6.0	8.4	8.3	7.9	7.1	7.3	7.5
Cooked to 70° C.	----	6.6	6.7	9.1	8.4	8.3	7.2	7.9	7.7
<i>Braised cuts</i>									
Cooked to 90° C.	----	5.6	6.9	7.3	7.9	8.0	6.7	6.2	6.4
Cooked to 70° C.	----	5.4	7.6	7.4	7.6	7.5	7.9	6.5	6.7
<i>Shear force values</i>									
<i>Roasts</i>									
Cooked to 90° C.	--	15.1	30.1	14.0	14.4	18.4	26.3	15.3	19.7
Cooked to 70° C.	--	20.8	22.6	14.4	13.5	22.2	23.6	17.8	23.5
<i>Braised cuts</i>									
Cooked to 90° C.	--	24.0	20.2	15.2	14.0	20.1	21.4	19.1	22.0
Cooked to 70° C.	--	27.5	17.6	19.2	15.2	17.6	25.4	23.6	23.6

TABLE 15. AVERAGE TENDERNESS SCORES AND SHEAR FORCE VALUES (IN POUNDS) FOR EACH MUSCLE USED IN THE STUDY.

	Muscle						
	LDR	LDL	PM	BF	St	Sm	
<i>Tenderness scores</i>							
Cooked to 90° C.	-----	6.8	6.7	8.4	7.0	7.3	6.5
Cooked to 70° C.	-----	7.4	6.9	8.9	7.3	7.6	6.5
<i>Shear force</i>							
Cooked to 90° C.	-----	24.1	20.2	13.3	15.5	21.0	22.2
Cooked to 70° C.	-----	22.1	23.4	13.9	18.3	22.3	22.4

It is commonly known that different muscles from a given animal vary in tenderness and that the tenderness of a muscle from one animal may differ from the same muscle in another animal. The length of the cooking process may also affect the tenderness of a given cut. In this study, the roasts cooked to 70°C. had higher tenderness scores than those cooked to 90°C. The majority of the braised cuts cooked to 70°C. had higher tenderness scores than those cooked to 90°C.

The tenderness scores for the cuts from the two Choice-grade carcasses averaged 8.1, whereas those from the six Commercial-grade carcasses averaged 7.3. Note that the scores for cuts from individual animals varied considerably. Cuts from animal I had the lowest tenderness scores. Cuts from one of the calves, animal III, had scores nearly as high as those from the Choice-grade carcasses. The cuts from the Choice-grade carcasses required the least number



of pounds for shearing. In general, there was good correlation between the tenderness scores and shear force values. This was shown by the regression analysis on the data for tenderness scores and shear force values which gave an *r* value of 0.581, significant at the 1-percent level.

It has been suggested that the rate of cooking may affect the comparative tenderness of cooked cuts. Cover (7) cooked one cut of a pair of several different types of roasts at an oven temperature of 125°C., the other at 225°C. Most cuts were more tender when cooked at the lower temperature, but, for other cuts, the temperature of the oven made little difference. Cover states, "Any apparent relationship between tenderness and oven temperature observed in these tests seems to be much better explained on the basis of difference in time required for cooking. . . ." It should be added that the differences in time of cooking paired cuts in this study were far shorter than in Cover's study.

This discussion should not be construed to mean that beef cooked to a higher interior temperature is tougher than that cooked to a lower one in all instances. Bard and Tischer (2) have shown that the tenderness of canned beef is a direct function of the processing temperature within the range 107-124°C. Aldrich and Lowe (1) have reported that cooking one cut of a pair to a higher interior temperature than 90°C. produced beef more tender (but less desirable in flavor and less juicy) than cuts cooked to 90°C.

Considerable variation in tenderness of muscles in animals of similar grade has been observed by others. This is suggested by the results of an earlier study (13) at Iowa State University. Cuts (leg roasts, boned shoulder roasts, cutlets from the leg and the loin and stews) were cooked from 18 U.S. Choice veal carcasses. All the cuts from animals 1, 4, 13 and 15 consistently had the lowest tenderness scores, whereas cuts from animals 3, 6 and 14 consistently had the highest tenderness scores.

Other factors, discussed in subsequent sections, which may be associated with tenderness of the cuts in this study, are the fat content and the collagen-N content of the muscles and the diameter of the muscle fibers.

**Juiciness.** The average juiciness scores and press fluid values for the cooked cuts from each animal and for individual muscles are summarized in tables 16 and 17.

The amount of press fluid obtained varied with the temperature to which the cut was cooked. The cuts cooked to 90°C. were much drier than those cooked to 70°C.

When the foregoing data were assembled and subjected to analysis of variance, it was observed that there was a large number of significant differences between muscles, temperature of cooking, individual animals and grade with respect to cooking time, cooking weight losses, organoleptic ratings, shear force and press fluid. One can only conclude from these findings that age of animals and carcass grade cannot be consistently associated with a given organoleptic rating, whether it be for aroma, flavor of lean, tenderness or juiciness, and that different muscles taken from the

TABLE 16. THE AVERAGE JUICINESS SCORES AND PRESS FLUID VALUES (IN PERCENT) FOR ROASTS AND BRAISED CUTS FROM EACH ANIMAL.

Cuts	Animal, grade and age (mos.)							
	I		V		III		VII	
	Commercial 18		Choice 18		Commercial 6		Commercial 42-48	
<i>Juiciness scores</i>								
<i>Roasts</i>								
Cooked to 90° C.	5.3	4.3	4.6	4.3	5.6	4.3	3.8	3.8
Cooked to 70° C.	7.6	6.9	8.2	7.6	6.5	6.3	7.0	6.6
<i>Braised cuts</i>								
Cooked to 90° C.	4.7	3.5	4.9	3.6	4.2	3.8	3.9	3.5
Cooked to 70° C.	6.6	5.7	7.1	6.1	6.1	5.6	5.7	5.4
<i>Press fluid values</i>								
<i>Roasts</i>								
Cooked to 90° C.	28.4	26.9	29.8	30.8	32.2	30.3	27.9	26.1
Cooked to 70° C.	46.7	43.2	43.5	40.5	37.7	39.8	44.0	39.8
<i>Braised cuts</i>								
Cooked to 90° C.	24.8	27.0	31.7	32.9	32.1	28.6	32.0	28.2
Cooked to 70° C.	33.8	36.4	38.2	38.1	40.7	33.5	40.9	32.0

TABLE 17. AVERAGE JUICINESS SCORES AND PRESS FLUID VALUES (IN PERCENT) FOR EACH MUSCLE USED IN THE STUDY.

	LDR	LDL	PM	BF	St	Sm
<i>Juiciness scores</i>						
Cooked to 90° C.	4.3	4.6	4.6	4.1	4.4	3.6
Cooked to 70° C.	6.8	6.8	7.5	6.5	7.0	5.2
<i>Press fluid values</i>						
Cooked to 90° C.	28.5	30.2	38.4	30.6	32.9	28.2
Cooked to 70° C.	41.7	41.1	42.8	37.5	39.4	34.9

same carcass regardless of grade were often scored differently.

Although correlations were computed for a few combinations of factors, the results would not be meaningful in the absence of adequate knowledge about how such factors are related to each other. For example, correlation between juiciness and press fluid could not be expected to be a simple cause-result relationship in view of the lack of harmony among data from juiciness scores and press fluid values for individual animals and muscles presented in tables 16 and 17. The additional difficulty is that the present study, because of technical limitations, did not allow the use of large numbers of animals of similar age and carcass grade. For these reasons, the results of the analysis of variance and correlations among or between the various factors are not presented.

#### ANALYSES FOR PH, MOISTURE, FAT, TOTAL NITROGEN, COLLAGEN NITROGEN AND ELASTIN NITROGEN

##### PH

Muscles from the neck were used to determine the pH of part of the carcass soon after slaughter. The muscles were selected because they were accessible, and their removal did not affect the rest of the carcass. The pH of these muscles, within an hour or less after the animal was killed, varied from 6.2 to 7.0 and averaged 6.5 for the eight animals. The remaining neck muscles were refrigerated, and the pH was determined at 24-hour intervals for periods of 5 to 7 days. At the end of these periods the pH of the neck muscles varied from 5.6 to 6.0 and averaged 5.7.

The pH of the cuts used in the study was determined on the raw sample just before cooking and also on the cooked cuts. The results of these determinations are given in table 18. The cooked cut was always more alkaline than the raw meat. The pH values could not be related to differences in palatability scores.



TABLE 18. AVERAGE pH VALUES OF RAW AND COOKED CUTS; pH OF RAW CUTS DETERMINED AT TIME OF PREPARATION FOR COOKING.

Cuts	pH		pH	
	Cooked		Cooked	
	Raw to 90° C.	Raw to 70° C.	Raw to 90° C.	Raw to 70° C.
Roasts	5.4	5.9	5.6	5.9
Braised cuts	5.5	5.8	5.6	5.9
Av.	5.5	5.9	5.6	5.8

MOISTURE

Moisture determinations were made upon two sets of samples: (a) those used for fat determinations and (b) those used for total nitrogen, collagen and elastin nitrogen. The results for these two sets of analyses were similar, hence only one set of figures is reported. The average moisture content from the samples used in the fat analysis is given in table 19.

The moisture content of the raw samples is similar to that published in the literature. The muscles from the two Choice-grade carcasses (II and VI) had the lowest average water content and the highest fat content. The muscles from the calves (III and VII) had the highest average moisture content, and animal III had the lowest fat content.

TABLE 19. THE AVERAGE MOISTURE CONTENT OF THE RAW AND COOKED CUTS, IN PERCENT.

Animal	Cooked to 90° C.		Cooked to 70° C.	
	Roasts	Braised	Roasts	Braised
	Raw Cooked a/	Raw Cooked a/	Raw Cooked a/	Raw Cooked a/
I	74.0	59.6	75.4	60.7
V	74.7	62.2	74.5	61.2
II	71.2	61.4	71.0	58.2
VI	70.2	55.9	71.7	57.0
III	76.1	66.4	75.4	64.4
VII	74.6	62.4	75.4	61.4
IV	74.4	59.3	73.6	60.2
VIII	73.2	59.7	73.3	59.8

a/ Samples were removed before cooking to the indicated temperatures.

The longissimus dorsi of the rib and loin portions was cooked without removing the top fat covering or the rib and chine bones. Theoretically, the psoas major might have lost the most moisture because it was not protected by bone and fat tissue during cooking.

The cuts cooked to an interior temperature of 90°C. had a lower water content than those cooked to an interior temperature of 70°C., as was expected.

FAT

The fat content of the cuts and muscles before and after cooking is shown in tables 20 and 21.

The average fat content of the cuts from the different animals varied considerably, table 20. As may be expected, the cuts from the two Choice-grade carcasses had the highest average fat content. Cuts from one calf, animal III, and from animal V had the least fat.

The psoas major muscle consistently had the highest fat content of all the muscles for seven of the animals, table 21. But, for animal VI, the fat content of the longissimus dorsi (both rib and loin) was as high as for the psoas.

The "tender" muscles used for roasts had a higher fat content than the "less tender" muscles from the round used for braising.

The wide variation in the fat content of muscles

TABLE 20. THE AVERAGE FAT CONTENT a/ OF THE MUSCLES FROM EACH ANIMAL, IN PERCENT.

Animal	Cooked to 90° C.		Cooked to 70° C.	
	Roasts	Braised	Roasts	Braised
	Raw Cooked b/	Raw Cooked b/	Raw Cooked b/	Raw Cooked b/
I	12.9	17.3	10.8	12.9
V	10.5	11.8	9.1	9.2
II	19.7	25.5	19.8	17.6
VI	27.1	29.3	17.9	22.2
III	7.4	7.1	5.3	5.1
VII	14.0	16.0	9.8	10.7
IV	15.0	18.9	12.0	12.9
VIII	16.5	20.2	13.0	12.3

a/ Dry weight basis

b/ Samples were removed before cooking to the indicated temperatures

TABLE 21. AVERAGE FAT CONTENT a/ OF THE MUSCLES USED IN THE STUDY, IN PERCENT.

Raw b/	LDR	LDL	PM	BF	St	Sm
	Cooked to 90° C.	13.7	14.1	18.3	13.6	13.5
Cooked to 70° C.	14.4	13.5	19.5	12.5	12.7	10.6
Cooked						
Cooked to 90° C.	15.8	17.1	22.0	15.0	12.9	10.7
Cooked to 70° C.	14.4	15.9	20.2	13.3	13.9	10.5

a/ Dry weight basis

b/ Samples removed before cooking

from the two animals constituting a pair (same age and grade) is evident, table 20.

The data in this study indicate that some relationship exists between the tenderness of the muscle and its fat content. This is shown graphically in fig. 1. Some animals and some muscles, however, did not con-

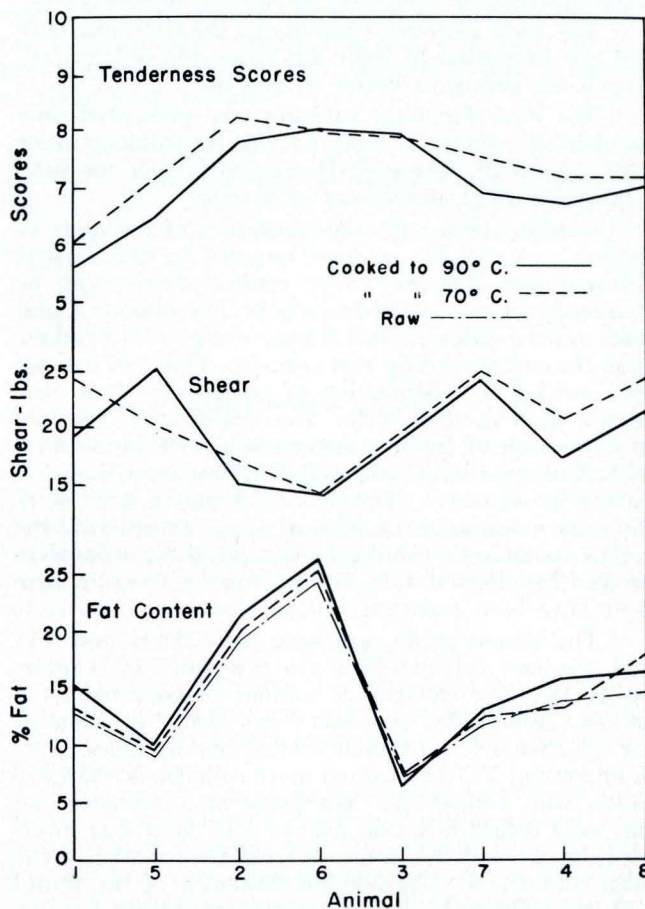


Fig. 1. Tenderness scores, shear force values and fat content of cuts from each animal. Higher scores and lower shear force values indicate greater tenderness.



form with the general pattern. The cuts from animal III (a calf) had a low fat content, yet were tender. The data for animal VI (Choice grade) conformed with the general pattern better than cuts from animal III (Commercial grade). The cuts from animal VI had the highest fat content, but scored lower in tenderness than cuts from animal II, which was also Choice grade.

The psoas muscle was always tender. Although it had the highest fat content of any muscle used in the study, its tenderness (from scatter diagrams) did not appear to be associated with its fat content. The tenderness of the semitendinosus likewise did not appear to be associated with the amount of fat the muscle contained.

There was no significant difference between the fat content of the muscles cooked to an interior temperature of 90°C. and those cooked to 70°C. or between the fat content of raw and cooked samples. This indicates that little or no fat was lost from the interior of the cuts during cooking.

#### TOTAL NITROGEN, COLLAGEN AND ELASTIN NITROGEN

Data for the total nitrogen, collagen and elastin nitrogen were obtained for the individual muscles taken from the beef carcasses to determine their relationship to tenderness and for comparison with the histological observations on sections of muscle tissue.

The total nitrogen contents of the different muscles are presented in table 22; those for collagen nitrogen are shown in tables 23 and 24.

The data for total nitrogen are presented only incidentally, since the computations for collagen nitrogen and elastin nitrogen data are based on the total nitrogen content of each cut or muscle.

Determinations in this laboratory of collagen nitrogen (collagen-N) in beef muscles by the Lowry, Gilligan and Katersky (14) method were made by Prudent (19) in an earlier study. She observed that some cooked samples had higher collagen-N contents than the corresponding raw samples. This was not logical and led to modification of the Lowry *et al.* procedure used in this study. The modification resulted in extraction of larger amounts of alkali-soluble proteins and gave lower collagen-N values than those reported by Prudent. The muscles Prudent used were the same as those in the present study, except that the biceps femoris was omitted. The physical, organoleptic and histological data for the muscles used by Prudent have been reported (10).

The Choice-grade carcasses (animals II and VI) had the least collagen-N in the raw cuts. It is interesting that the collagen-N content of cuts from the calves (animals III and VII) was about the same as for the 18-month-old Commercial-grade carcasses. Cuts from animal VIII contained more collagen-N than did those from animal IV. The psoas major muscle had the least collagen-N, the longissimus dorsi was intermediate, whereas the muscles from the round had the most collagen-N. The semimembranosus of the round had less collagen-N than the biceps or semitendinosus.

The collagen-N content was considerably less after cooking than before cooking. The cuts cooked to an interior temperature of 90°C. retained from about 11

TABLE 22. PERCENTAGE OF TOTAL NITROGEN (DRY WEIGHT BASIS) OF THE MUSCLES USED.

	LDR	LDL	PM	BF	St	Sm
<i>Raw a/</i>						
Cooked to 90° C. ---	12.7	13.6	12.0	12.6	13.6	13.2
Cooked to 70° C. ---	12.8	13.1	12.1	12.6	13.2	13.3
<i>Cooked</i>						
Cooked to 90° C. ---	12.0	12.8	11.3	12.6	13.3	13.5
Cooked to 70° C. ---	12.0	12.1	11.2	12.1	11.5	13.0

a/ Samples were removed before cooking

TABLE 23. AVERAGE COLLAGEN-N CONTENT IN PERCENT OF TOTAL NITROGEN OF RAW AND COOKED CUTS OF ANIMALS USED IN THE STUDY.<sup>a</sup>

Animal	Cooked to 90° C.				Cooked to 70° C.			
	Roasts		Braised		Roasts		Braised	
	Raw b/	Cooked b/	Raw b/	Cooked b/	Raw b/	Cooked b/	Raw b/	Cooked b/
I ---	1.49	0.27	2.80	0.44	1.54	0.37	2.73	0.84
V ---	0.95	0.20	2.94	0.31	1.52	0.43	2.77	0.85
II ---	0.90	0.21	1.53	0.33	0.90	0.29	2.06	0.30
VI ---	0.91	0.08	1.46	0.33	0.71	0.60	1.20	0.56
III ---	1.83	0.23	2.34	0.24	1.64	0.25	2.25	0.41
VII ---	1.59	0.45	3.01	0.31	1.50	0.39	2.70	1.19
IV ---	1.05	0.06	2.04	0.22	1.20	0.38	2.22	0.61
VIII ---	1.70	0.31	3.61	0.28	1.26	0.56	3.14	0.79

a/ Dry weight basis

b/ Samples were removed before cooking to the indicated temperatures

TABLE 24. AVERAGE PERCENTAGE OF COLLAGEN-N CONTENT AS PERCENT OF TOTAL NITROGEN FOR MUSCLES COOKED TO AN INTERIOR TEMPERATURE OF 90° C. AND 70° C. AND THESE SAME CUTS BEFORE COOKING. ALSO OF INITIAL COLLAGEN IN THE MUSCLE AFTER COOKING.

	LDR	LDL	PM	BF	St	Sm
<i>Before cooking</i>						
Cooked to 90° C. ---	1.41	1.55	0.94	2.66	2.76	1.98
Cooked to 70° C. ---	1.36	1.53	0.95	2.76	2.56	1.83
<i>Cooked</i>						
Cooked to 90° C. ---	0.33	0.19	0.22	0.31	0.31	0.31
Cooked to 70° C. ---	0.52	0.39	0.32	0.65	0.91	0.52
<i>Percent initial collagen after cooking</i>						
Cooked to 90° C. ---	23.7	11.9	23.4	11.6	11.2	15.6
Cooked to 70° C. ---	38.2	12.0	33.7	23.6	35.5	28.4

to 24 percent of their initial collagen-N; those cooked to 70°C., from about 12 to 38 percent (see table 24). Griswold (8) has reported that the average loss of collagen-N for 15 methods of cooking beef cuts from the round was 61 percent. She also found that collagen-N loss, in general, increased as the interior temperature to which the cut was cooked was elevated.

The collagen-N content was determined on 152 cuts before and after cooking. In the majority of these samples the collagen-N was less than 3 percent in the raw cuts and less than 1 percent in cooked cuts. This collagen-N (figs. 2 and 3) is a very small proportion of the total nitrogen. It should be recalled that the epimysium or muscle sheath was trimmed from the samples so that all the chemical determinations were made on the interior of the muscle.

The data for collagen-N in the raw and cooked muscles as they relate to differences among muscles, cuts, animals, grade and temperature of cooking were subjected to an analysis of variance. These results are presented in table 25.

Differences in the content of collagen-N between muscles, cuts, animals or pairs of animals were all significant. The differences in content of collagen-N of cooked muscles within cuts and of cooked muscles between carcass grades were not significant. These findings reflect the variations in beef observed in other connections and confirm the fact that the properties of raw or cooked beef considered in this study are not related in any clear-cut, simple way to carcass grade, age of animal or location of muscles in the carcass.



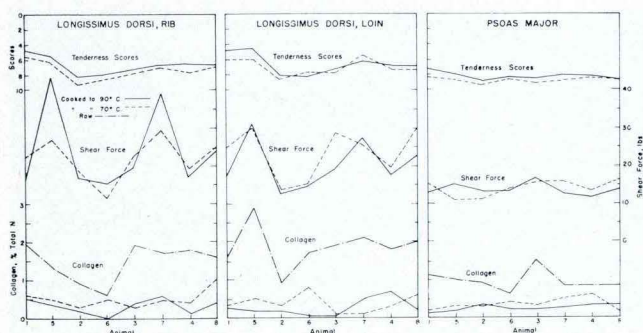


Fig. 2. The tenderness scores, shear force values and collagen content of the muscles cooked as roasts.

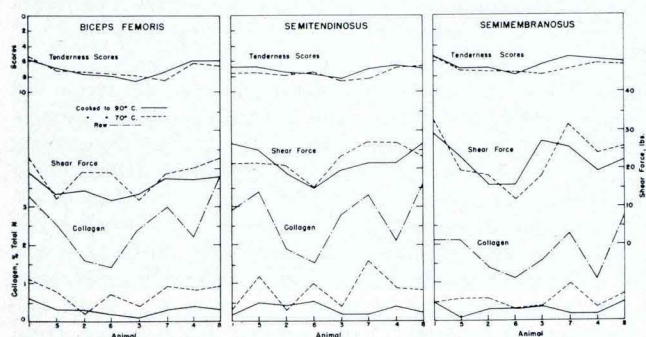


Fig. 3. The tenderness scores, shear force values and collagen content of muscles cooked as braised cuts.

Nevertheless, it was considered advisable to determine the extent to which collagen-N was related to tenderness scores and shear force values. The following sample correlations were determined: (a) tenderness scores for the cooked raw cuts and collagen-N content of the corresponding raw cuts, (b) tenderness scores and collagen-N content of the cooked muscle, (c) shear force and collagen-N content of raw muscle and (d) shear force and collagen-N content of the cooked muscle. The correlation computed for tenderness scores for cooked cuts and the collagen-N content of the corresponding raw cut was the only consistent relationship found;  $r = -0.37$ ,  $P = 0.05$ .

The graphical presentation of the content of collagen-N in raw and cooked muscles taken from carcasses of individual animals and the shear force values and tenderness scores, as shown in figs. 2 and 3, indi-

TABLE 25. THE RESULTS OF ANALYSIS OF VARIANCE, SIGNIFICANCE OF F VALUES, UNDER ANALYSIS OF COLLAGEN-N CONTENT OF RAW MEAT: "CUTS" REFERS TO ROASTS VS. BRAISED CUTS; "TEMPERATURE" FOR UNCOOKED CUTS REFERS TO CUTS FROM RIGHT AND LEFT SIDE; UNDER ANALYSIS OF COOKED CUTS "TEMPERATURE" REFERS TO TEMPERATURE TO WHICH CUT WAS COOKED. THE INTERACTIONS WERE NONSIGNIFICANT.

	Collagen-N content	
	Raw	Cooked
Muscles	**	**
Cuts	**	**
Muscles within cuts	**	**
Temperature	-	**
Animals	**	*
Grades	**	-
Within pairs	**	**

\*\* significant,  $P = 0.01$ ; \* significant,  $P = 0.05$ ; and - nonsignificant

cate that there is considerable variation in the relationship of one factor with another from one carcass to another.

Since the data for collagen-N appeared to be inversely associated with the fat content of raw cuts, the simple correlation was computed for this relationship. The correlation coefficient obtained was  $-0.52$ ;  $P = 0.01$ . Thus it can be seen that collagen-N and fat content of meat are associated with tenderness. The relationship which exists between tenderness of a cut and its fat content, graphically presented in fig. 1, while not impressive, is also consistent with this observation. The variation which is apparent in the data for the fat and collagen-N content, for shear force values and for tenderness scores, however, is such that one must accept with reservation the value of chemical and physical procedures used in these studies as a basis for predicting the quality attributes of cooked meats such as tenderness or juiciness. Basically, the problem posed by these findings is that the relationships found among the various factors considered appear to be qualitative rather than quantitative in nature.

A number of cuts were used in the elastin-N study, but elastin data failed to provide much additional information about meat tenderness.

The elastin-N content of the cuts for animals I, II, III and IV is shown in table 26. The data for the elastin-N content of the raw and the cooked cuts do not indicate that cooking had any consistent or appreciable effect on elastin-N. Elastin-N was found in all the muscles studied.

TABLE 26. ELASTIN-N IN PERCENT OF TOTAL NITROGEN FOR THE SAMPLES FROM THE RAW CUTS AND THE SAME CUTS AFTER COOKING.

	LDR	LDL	PM	BF	St	Srn
<i>Raw</i>						
Cooked to 90° C.	0.14	0.12	0.13	0.17	1.48	0.12
Cooked to 70° C.	0.16	0.15	0.13	0.17	0.37	0.13
<i>Cooked</i>						
Cooked to 90° C.	0.10	0.09	0.10	0.24	1.76	0.16
Cooked to 70° C.	0.10	0.10	0.09	0.18	1.76	0.16

#### MICROSCOPIC STUDY

This study was initiated for two purposes: (a) to determine whether histological findings could be related to the chemical and physical changes brought about in meat by cooking and (b) to determine whether the histological approach provided a basis for evaluating differences in tenderness of muscles and cuts before and after cooking.

#### MUSCLE FIBERS

Longitudinal sections were prepared on a freezing microtome. The sections were composed mostly of muscle fibers, but also had connective, fatty and vascular tissue.

The muscle fibers were straight or waved, although a combination of both in the same section was usually found. The fibers in the sections from the 24-hour samples (rsw) had the most waves, the 7- to 10-day-aged uncooked samples were intermediate, and the fibers from the cooked samples had the least waves.

*The muscles.* The appearance of the sections from the longissimus dorsi of the rib and loin were, in gen-



eral, similar to each other. The longitudinal striae were distinct and persisted after the carcass was aged 7 to 10 days, but not to the extent that they did in the biceps and semimembranosus muscles. The longissimus dorsi also had a large proportion of wavy fibers. The extent of the collagenous bundles of the interstitial tissue was intermediate in frequency and size between those of the psoas and the muscles of the round.

The psoas major muscle was the easiest to identify by microscopic study. It lacked longitudinal striae even in the 24-hour-aged fibers. Its cross striae were wide, bold and distinct, fig. 4. The muscle fibers tended to be in large V- or U-shaped waves. The diameter of the muscle fibers was by far the smallest of the five muscles used in the study. Of any of the muscles, the psoas major had the least amount of granular material in the cooked samples and the least amount of collagenous bundles of the interstitial tissues (and those present were small in size). Also, the presence of fatty tissue was not obvious, although its fat content was the highest of the muscles.

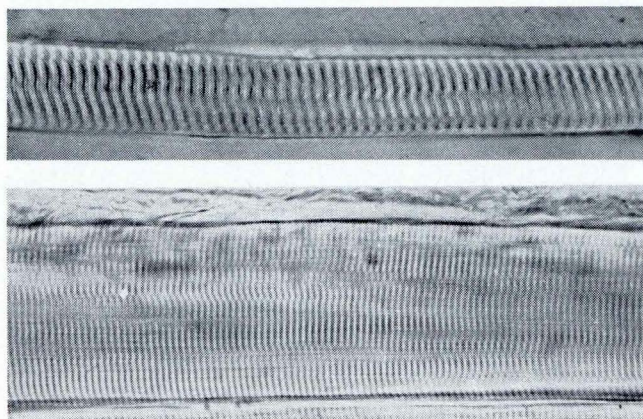


Fig. 4. *Upper*: Fiber from the psoas muscle of animal II, cooked to 70° C. *Lower*: Fiber from the uncooked semitendinosus muscle of animal I. (Magnification x 450).

The semitendinosus was the next easiest to identify. It was characterized by having few longitudinal striations, except in sections from the 24-hour-aged samples. The cross striations were narrow, fine and distinct, fig. 4. Large amounts of elastin were found in the connective tissue as indicated by the staining method employed.

The biceps femoris and semimembranosus were characterized by distinct longitudinal and cross striations in most sections. In general, waved fibers were less characteristic of these two muscles than of the longissimus dorsi. The collagenous bundles of the interstitial tissues of the muscles of the cuts from the round were more obvious than those present in the longissimus dorsi or psoas.

Fat cells and fatty tissues were found most frequently in sections from the Choice-grade carcasses, least frequently in tissues from animal III.

*Fiber diameter.* The relative size of the fiber diameter was estimated as follows: Using a 10x eyepiece

TABLE 27. THE AVERAGE NUMBER OF FIBERS IN THE MICROSCOPIC FIELD FOR DIFFERENT MUSCLES FROM EACH ANIMAL.

Muscle	No. of fibers	Animal	No. of fibers
LDR	7.0	I	6.9
LDL	7.5	V	7.8
PM	10.8	II	8.3
BF	7.7	VI	8.3
St	7.4	III	9.5
Sm	7.7	VII	9.5
		IV	7.5
		VIII	7.2

and a 43x objective, an area was located in the microscopic field of the section in which the fibers lay side by side. The number of fibers in a full microscopic field was counted. For most sections this was repeated from four to six times in different areas of the sections. The results were averaged for a given cut. Obviously, by this method the larger the number of fibers in the field, the smaller the fiber diameter, table 27.

It is known that muscles from young animals have fibers of smaller diameter than those from old animals. In this study, the diameter of the muscle fibers varied more from animal to animal than from muscle to muscle. As expected, the fiber diameter of muscles from the calves was the smallest. Next in order was the diameter of fibers from the Choice-grade carcasses. The diameter of fibers from animal I was the largest. Cuts from animal I received the lowest tenderness scores of any of the animals. With the exception of animal I, the largest fibers came from the two oldest animals.

Brady (6) reported significant differences in fiber diameter of muscles from cows and steers, among 2-hour-aged, 10-day-aged and cooked fibers, but none among the muscles used in his study; namely the adductor, longissimus dorsi, semitendinosus and triceps. He concluded that "... the number of fibers in a bundle is a measure of texture. . . Texture is an indication of tenderness, the 'finer' the texture the more tender the meat."

#### CONNECTIVE TISSUE

The microscopic study of collagen in muscle in this project was interesting from two standpoints: (a) the organization of the collagenous tissue and (b) the effect of cooking upon it. Connective tissue is found in cartilage, tendons, ligaments, around fat cells and in muscles. There were varying proportions of collagen and elastin in the tissues from the muscles used as indicated by the response to differential stains. The density of the collagenous tissues also varied. The microscopic study of the stained sections indicated bundles of denser connective tissue within the muscle, figs. 5 and 6. These bundles differed in appearance from the tissue around the fat cells and blood vessels. They were small, varied in shape and interspersed throughout the muscles—less frequently in tender muscles, such as the psoas major, and more frequently in the less tender muscles. Sometimes there was one (or, at most, a few bundles) in a given area; sometimes there were many collagenous bundles concentrated in an area as shown at the top of fig. 6. The collagenous fibers in these bundles were parallel and wavy with fine interlacing fibers of elastin. A detailed description of these tissues was not available in the books on microscopic anatomy which were consulted.





Fig. 5. *Upper*: Granular material between fibers. From biceps femoris of animal I, cooked to 70° C. *Lower*: Collagenous bundles in raw biceps femoris from animal VIII. At top organized bundles of collagenous fibers of the interstitial tissues; in middle, less dense connective tissues; and, at bottom, ends of muscle fibers. The less dense connective tissue probably was changed to granular material by cooking to 70° C. or higher. (Magnification x 100).

Drs. Foust and Getty of the Department of Veterinary Anatomy, Iowa State University, stated the following terminology applies to these tissues: "intercolated tendonous portions or collagenous bundles of the interstitial tissues."

When heated, these small collagenous bundles behaved in the same way as connective tissue of tendons and of other areas reported by Winegarden *et al.* (24). Heating to 70°C. or higher left the fibers in bundles, but they were no longer wavy; they appeared fused together and had shrunk in length (fig. 6).

Before cooking, all the collagenous fibers stained pink or red with van Giessen's stain. After cooking, the tissue around the fat cells and the granular material did not stain. The fibers of the collagenous bundles stained pink or red after cooking, but upon standing, the red stain gradually faded with storage and faded faster if exposed to light.

The less dense tissue appears to be changed, or partially so, to a granular substance during cooking (figs. 5 and 6).

Studies have been reported which show that the extent of conversion to gelatin depends upon several factors (5). Among these factors are the temperature to which the collagen is heated and the time held at a given temperature. Thus it would be expected, if the source of the granular material is an integral

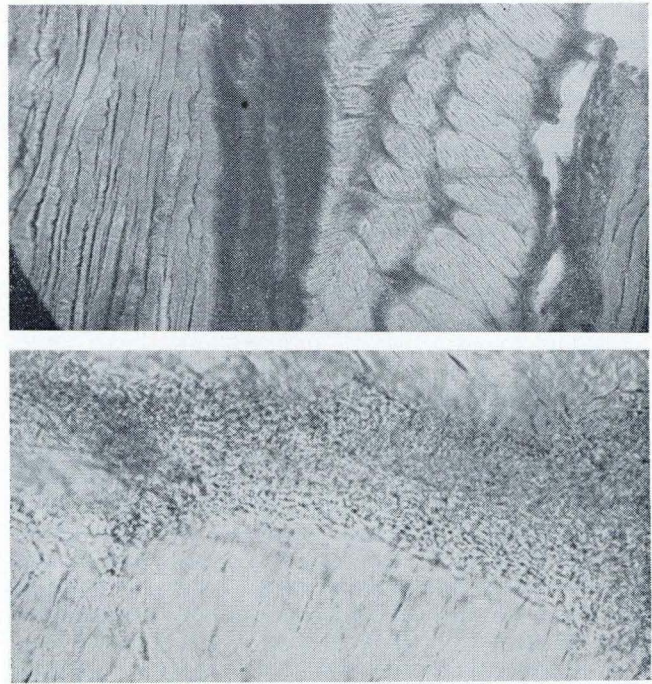


Fig. 6. *Upper*: Many collagenous bundles of the interstitial tissues are shown among granular material (dark areas in the center). From biceps femoris of animal I, cooked to 90° C. (Magnification x 54). *Lower*: A small amount of the granular material appears at the top, the collagen bundle at bottom. The fibers in this bundle appear to be fused together. This is a higher magnification of one bundle shown above. From semitendinosus muscle of animal VII, cooked to 90° C. (Magnification x 450).

portion of the collagen moiety, that cuts cooked to an interior temperature of 90°C. would have more granular substance than cuts cooked to 70°C. This was found to be true in a majority of the cases.

From the results of the study by Winegarden *et al.* (24) it was assumed that little change occurred in the connective tissue below 65°C. To test this assumption, Paul's (17) sections, which were still on file in the laboratory, were observed. The cuts had been cooked to an interior temperature of 63°C. and then removed from the oven. The microscopic sections from the cooked cuts showed no evidence of granular material.

Sections from another study (10) made it possible to compare the amount of granular material obtained when cuts were heated to the same interior temperature, 70°C., but at different rates (i.e., in different mediums). Harrison's (10) cuts were cooked in fat, which conducts heat more rapidly than air. Only about half the slides of cooked cuts of Harrison's study showed the presence of granular material.

The average time in minutes for the interior temperature of the roasts used in this study to rise from 65°C. to 90°C. was: LDR, 132.6; LDL, 114.0; and PM, 139.8. Note that the psoas, which weighed the least, required the longest amount of time.

The comparative amounts of collagen and elastin



were estimated by microscopic examination of the stained sections. The scoring system of Ramsbottom, Strandine and Koonz (21) was used. The correlation between the amount of collagen-N as determined by the Lowry *et al.* (14) procedure and collagen estimated from microscopic sections was determined. This correlation was 0.80, significant at the 1-percent level, when the data for all raw samples later cooked to either 90°C. or 70°C. were combined.

## DISCUSSION

### TECHNIQUES

The organoleptic characteristics and the chemical and physical attributes of cuts taken from carcasses of beef cattle of different ages were the subjects of this investigation. For purposes of comparison, two carcasses grading low-Choice from relatively young animals and six carcasses grading Commercial from animals ranging in age from 6 months to 48 months were selected for these studies. In an attempt to eliminate as many variables as possible, standardized procedures were used in cooking selected paired muscles representing each individual carcass. Animals were paired on the basis of age and grade to determine the degree of variation one might encounter in the results of studies done on carcasses of animals of similar age, breed and grade.

The results of the chemical, physical, cooking, taste panel evaluations and microscopic studies have been summarized and presented in this report. Some results are as would be expected. For example, greater losses in weight during cooking would be expected in meat cooked very well done than in a similar cut cooked medium done. Some results, particularly those with animals constituting a pair showed lack of uniformity. This will be discussed later. It should be emphasized, however, that the relationships observed between certain chemical and physical measurements of tenderness, juiciness, flavor and aroma of cooked beef appear to be quite complex.

### BIOLOGICAL CONSIDERATIONS

Variations in biological materials cannot be eliminated, even when standardized techniques are used, for these materials are not homogeneous. Hence many tests are necessary to increase the validity of the results. But there is an economical limit to the number of animals that can be purchased as well as a time limit to the completion of tests.

Many factors affect the palatability ratings (flavor, tenderness and juiciness) and the physical tests (shear force and press fluid) of beef muscles. The result of growth in a meat animal is essentially a change in the proportions of the body and the composition of its tissues, muscle, fat and bone. Hereditary factors affect growth in a number of ways. Some animals grow faster, mature faster and fatten more easily than others. The changes in the tissues which occur in animals during growth will be variable by virtue of the fact that one will seldom encounter hereditary, nutritional and environmental complexes which are similar for a given group of animals.

The problem of muscle characteristics becomes more complicated with the age of the animal and the pre- and post-mortem treatment of the carcass. The animal may be starved or fed before killing. During holding of the carcass or cuts many changes occur which collectively are called aging or ripening. Aging is slower at refrigerator temperature. The carcasses of young animals age more rapidly than those of older ones. There also will be aging variations in carcasses from animals of the same age, breed and grade. Cooking also affects the palatability ratings and physical test results, the extent depending on the duration and method of cooking. Some other factors that may affect the tenderness of muscles to a greater or lesser extent are freezing, mechanical alteration, size of fibers and size of the bundles of muscle fibers. The tenderness of the muscles from a given animal vary widely. This has been shown by earlier studies in this laboratory (10, 17) and particularly by Ramsbottom *et al.* (21) who tested 25 of the principal muscles from beef carcasses. The present study indicates that the intramuscular fat and connective tissue content may vary for the different muscles of a given animal and for the same muscle from different animals. When so many factors affect tenderness of the muscle, and each factor to unequal degrees, it is easily understood that variation in palatability characteristics may occur in animals of the same age, breed and carcass grade.

### BEEF GRADES

Beef carcass grade standards, as specified by the United States Department of Agriculture, are based largely on subjective specifications which divide beef carcasses into groups. There are no clearcut objective measurements which would provide a basis for classifying carcasses into groups which would clearly define quality as the consumer understands it. In one previous study (13) the organoleptic scores indicated that cuts from Commercial-grade animals were less desirable than those from Good and Choice grades. The data in the present study, however, indicate that it cannot always be assumed that the age of the animal, the fat in and between masses of muscle tissue, the color, texture and firmness of the visible fat and lean are correlated closely with and indicative of tenderness, juiciness, aroma and flavor of beef.

Another aspect of the problem is how to cook the cut. If the meat is to be cooked properly, the consumer needs to know whether the cut is tender enough to roast or broil or whether it should be cooked by moist heat.

The present pricing system for the different grades of beef carcasses is based on the assumption that the higher the grade the better the over-all quality of meat. The current paucity of data which would relate the organoleptic characteristics of beef with grade specification leaves much to be desired.

The authors are aware that dividing the carcasses into grade is the best and easiest method in use at the present time to indicate the desirability of the meat. The inconsistencies shown in this and other studies between grades and organoleptic characteristics indi-



cate that improvement in the grading system or the development of new tests would be desirable.

The conclusion to be drawn from these studies is that, although it has been generally accepted that fat content, grade of the carcass and age of the animal are highly correlated with the palatability of beef, the results of detailed analysis of the several relationships which appear to exist between the characteristics of a beef carcass and the tenderness, flavor, juiciness and fat content of the cooked cuts vary within wide limits.

#### AGE OF THE ANIMAL AND TEXTURE OF THE MUSCLE

In a previous study (10) in this laboratory, the cuts from an 8-year-old cow (carcass grade, Cutter) were decidedly less tender than cuts from three steers (two carcass grade, Good; and one carcass grade, Commercial) of approximately 14-16 months of age. These results are in accord with the commonly accepted premise that meat from older animals is tougher than meat from younger animals. This premise appears to be valid in many cases, but exceptions may occur. Much depends upon the difference in age span, the condition of the animal and other factors. In the present study, the toughest cuts, as shown by tenderness scores, came from animal I of intermediate age. The microscopic study revealed that the diameter of the fibers in muscles from animal I was larger than the diameters of the fibers from the other seven animals. This may account for the otherwise unexplained results.

Brady (6) has reported that the texture of muscle fibers is related to tenderness — muscles of coarse grain being tougher than those of fine grain. Strandine *et al.* (22) have also reported, after a chemical and histological study of 50 beef and 12 chicken muscles, that the size of the fasciculi (bundles of fibers) and amount of connective tissue affect the tenderness of muscles — tenderness being associated with muscles having indistinct fasciculi.

#### TENDERNESS AND FAT CONTENT OF MUSCLES

It is widely accepted that finish and marbling have a direct influence on degree of tenderness, despite the fact that the amount of fat *per se* is not invariably associated with tenderness of beef. One of the interesting results of this study was the difference in fat content of the cuts from the two animals constituting a pair. These animals had been selected for their similarity by a person experienced in this type of work. The carcasses of a given pair did resemble each other in certain characteristics, but differed in others. For example, one calf (animal III) had little visible fat, whereas the other calf had some visible fat. The fat content of the interior of the cuts (the epimysium was removed), however, differed considerably for each animal of a pair. A regression (for dependency of all tenderness scores upon the fat content of the muscles) gave an *r* value 0.46 which was significant at the 1-percent level. If the *r* value had been larger, the results would have been more impressive. The highest average tenderness scores were 8.1, 8.0 and 7.9. Two of these scores were for

cuts from animals II and VI (the two Choice-grade carcasses) whose muscles had a fat content of 20.6 percent and 25.6 percent, respectively. The lowest score was for cuts from animal III (a calf of Commercial grade) whose muscles had a fat content of 6.4 percent. Cuts from some of the animals grading Commercial were as acceptable to members of the panel as were the cuts from the Choice-grade carcasses, as shown in tables 12 and 14.

At least three groups of workers have reported that animals with more finish produced more tender beef than less well finished ones (3, 11, 18). On the other hand, Hankins and Ellis (9) found no significant correlation between the fat content and tenderness of the longissimus dorsi muscle.

Another aspect that needs further investigation is the change of the fat content of the muscle during cooking. An examination of the data for the fat content of the interior portions of the cuts used in this study shows no marked difference between the raw and cooked muscles. Hood *et al.* (12) found the fat content to be lower in the cooked than in the raw cuts.

The question of translocation of both fat and granular substance in muscle during cooking is of interest. Wang *et al.* (23) have reported that, from broiling 1.5-inch steaks from the longissimus dorsi and semitendinosus muscles at about 205° C. to an interior temperature of 65° C., a "fair amount of fat was released by diffusion from the fat cells in perimysia of all sizes. The released fat gave no evidence whatever of existence in a continuous liquid state, but showed a progressive dispersion along the path of degraded (hydrolyzed) collagen with the resulting fat droplets thoroughly intermingled with the latter. Intact collagen and endomysial spaces were free of this fat. The size of the droplets was found to decrease from the dispersion center toward the periphery of the field, finally passing below the limits of microscopic resolution. The phenomenon has been interpreted as a process of emulsification in which degraded collagen may function as a dispersing agent the accompanying cooking providing, among other things, the necessary agitation."

#### CONNECTIVE TISSUE CONTENT AND TENDERNESS OF BEEF MUSCLES

It has been widely accepted that the tenderness of muscle is related to its initial content of connective tissue. The collagen-N and elastin-N data in this study, although admittedly not necessarily indicative of the true connective tissue of beef, failed to offer strong support for this belief. The *r* values for correlations of (a) tenderness scores and collagen-N content of cooked muscles, (b) shear force and collagen-N of raw muscles and (c) shear force values and collagen-N content of cooked muscles were all non-significant. Only the tenderness scores and collagen-N of raw muscles showed a barely significant relationship. Stronger relationships between tenderness and collagen-N content of the muscles might have been obtained if the beef had been cooked rare so that little degradation of the collagen would have occurred. Mitchell *et al.* (16) found no relationship between



the connective tissue content of the cut and the carcass grade. None of their cuts were cooked. Strandine *et al.* (22), after a chemical and histological study of 50 of the principal beef muscles and 12 of the principal chicken muscles, concluded that tenderness is associated with muscles having indistinct fasciculi. The larger amount of connective tissue of the less tender muscles divided the fibers into larger fasciculi.

Prudent (19) was not able to demonstrate that aging beef cuts from 1 to 30 days brought about significant change in the collagen-N content as determined by the Lowry *et al.* (14) procedure. The cuts aged 10, 20 and 30 days were more tender, as determined by subjective and objective evaluations, than other portions of these same muscles aged 1, 2 or 5 days. The changes in aging of beef cuts in Prudent's investigation did not appear to be related to changes in the collagen content. It is also possible, however, that none of the present methods for determining collagen-N is sensitive enough to determine slight changes in collagen content.

It is known that some of the collagen was degraded to gelatin during cooking, for the juices coming from the meat produced a jelly when refrigerated. Hence the extent of cooking (i.e., rare or well done) must have some influence upon the tenderness. The connective tissue may be altered only slightly or not at all in cuts cooked rare. Likewise, the muscle fiber proteins may be only slightly coagulated. But, when cuts are cooked well done or very well done, the extent of cooking on tenderizing the beef depends upon a balance between the extent of softening the connective tissue and the extent of toughening or hardening the muscle fiber proteins. This problem was studied by Ramsbottom, Strandine and Koonz (21). They compared the tenderness of 25 beef muscles, both before and after cooking. Their samples were cooked in lard at 121° C. to an interior temperature of 76.7° C. (170° F.), hence the rate of heating was rapid. They found that the tenderness of a majority of the muscles was decreased during cooking. This they attributed to the hardening of the muscle fiber proteins by coagulation. Their graphs indicate less variation in shear force values after cooking than before cooking. They found in preliminary experiments that oven-cooked meat was consistently more tender with less variation in tenderness among muscles than when the samples were cooked in lard.

In general, the data obtained in this study for the shear force values and tenderness scores were correlated. But, there were some exceptions. Although shear force did not differentiate between cuts cooked

to an interior temperature of 70° C. and 90° C., the scores did. If the average shear force data were studied (figs. 2 and 3), it would be found that the shear force values for the longissimus dorsi rib cuts from animals V and VII are not in harmony with other shear force values for cuts from these animals. The collagen-N content of the raw and cooked cuts and the shear values for these cuts from the carcass of one of the 6-month-old animals (VII) and the muscles of one of the much older animals (VIII) do not provide any consistent basis on which to explain the lack of concordance in the relationship between shear force values or collagen-N content with tenderness scores.

The collagen-N data in this study indicate that considerable collagen-N within the muscle was degraded by cooking to 70° or 90° C. Winegarden *et al.* (24) have shown that connective tissue from tendons, the ligamentum nuchae and the aponeurotic sheet (a large triangular sheet of connective tissue of the flank with the apex at the tuber coxae) became more tender (as shown by shear force) when heated above 65° C.

The microscopic studies indicate that the granular substance in the sections of cooked muscle may represent a fraction of the connective tissue complex. A detailed discussion of the current concepts of the composition and character of various types of connective tissue have been published by several workers (20). The current view is that the connective tissue of muscle is composed of fibrillar tissue (collagen and elastin fibers) and an amorphous matrix (ground substance) which serves to hold the fibrillar tissue in place. Ground substance appears to be solubilized by both alkali extraction and autoclaving, Miller and Kastelic (15). In view of this problem, it is not known precisely what fractions of connective tissue are represented by data obtained using the Lowry *et al.* procedure. The interpretations of the results of measures of tenderness in relation to the "collagen" and "elastin" content of beef muscle as obtained by the Lowry *et al.* procedure must, therefore, be considered in the light of the foregoing discussion.

The photomicrographs of the degraded collagen emulsion described by Wang *et al.* resemble the granular substance observed in the present study, but the emulsion is not as extensive as the granular substance. This might be expected, as the beef used by Wang *et al.* was not cooked as well done as the beef used in this study. Whether the granular substance of this study is related to the degraded collagen and fat translocation in the Wang *et al.* study remains to be determined.



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