COMPARATIVE STUDY OF CONSECUTIVE CUTS AND MATCHED CUTS OF THE SEMITENDINOSUS AND SEMIMEMBRANOSUS MUSCLES OF THE ROUND OF BEEF

By

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AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
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The purpose of this study was to determine whether or not adjoining one-inch steaks of the semitendinosus and semimembranosus muscles of the round of beef are comparable to permit their use in experimental meat research.

Consecutive and matched one-inch steaks of the semitendinosus and semimembranosus muscles of the round of beef were analyzed for homogeneity. Muscles from six choice grade beef were used. Nine steaks were cut from the center of each muscle. Four steaks were analyzed raw and four were cooked by braising before analysis. The results were analyzed for differences with the Student Fisher "t" test. The cooked steaks were tested for total cooking losses, shear force values, press fluid, moisture, fat and nitrogen. The tests made on the uncooked steaks were pH, moisture, fat, nitrogen, collagen and elastin by weight difference, and collagen by hydroxyproline determination.

In the semitendinosus muscle the greatest variations were found in consecutive steaks number one through four in the anterior end of the muscle on both sides of the animals. Especially significant were the differences in moisture and fat content in both the raw and cooked steaks in this area. The collagen content by both weight difference and hydroxyproline was slightly different on the left side. The center steaks of the semitendinosus muscle showed homogeneity in all tests. The steaks from the posterior end of this muscle varied slightly in pH and elastin content.

The greatest variations in the semimembranosus muscle were also in consecutive steaks one through four in the anterior end while the steaks in the center and at the posterior end of the muscle were homogeneous in all tests performed on them.

The matched steaks were homogeneous with a few exceptions. These exceptions were in the steaks at either end of the muscle as in the consecutive steaks.

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INTRODUCTION

Matched cuts are used exclusively for comparisons in meat research. Since these are both expensive and difficult to obtain, meat studies are almost non-existent in the small college foods laboratory.

Isolated references to homogeneity of certain long muscles were found. Satorius and Child (36) obtained two comparable roasts from the longissimus dorsi muscle of pork and beef for studying physical properties. Howe (16) stated long muscles of the round of beef were usually more uniform than short muscles. Strandine, Koonz and Ramsbottom (39) concluded histological sections taken anywhere in a muscle, except at the extreme ends, were rather uniform and presented a regular pattern or arrangement of muscle bundles and connective tissue. Child and Fogarty (6) determined the semitendinosus or "eye" muscle from the round of beef was homogeneous. Two comparable roasts, each weighing one and one-half pounds, were obtained from each muscle.

The purpose of the current study was to determine whether or not adjoining one-inch steaks of the semitendinosus and semimembranosus muscles of the round of beef are similar in comparison to the matched steaks.

REVIEW OF LITERATURE

Description of Muscle Tissue

Muscle tissues are classified as: (a) Cross-striated voluntary or skeletal muscle, (b) Cross-striated involuntary or cardiac muscle, and (c) Non-cross striated involuntary or smooth muscle. Skeletal muscle constitutes the whole of the muscular apparatus attached to the bones. A single muscle consists of two or more tissues working together as a unit--a functional and a supporting portion. The functional portion is the muscular tissue and the supporting portion is the connective tissue.

A muscle has many divisions, the ultimate histological unit being the fiber which is an elongated cell. These fibers are arranged parallel to each other and grouped into bundles called fasciculi. Each fasciculus is surrounded by a connective tissue (perimysium), a framework which carries the larger blood vessels. Within the fasciculus is found a finer fabric of connective tissue (endomysium), which gives support to the individual muscle fibers. These fasciculi in turn are grouped into coarser bundles which collectively make up a muscle. The muscle is in turn enveloped in a firm connective tissue layer called the epimysium (5), (23).

In cross section, muscle fibers are round or oval. They vary in diameter and length. Except for those fibers attached to a tendon, which are blunt, they tend to taper to a point. A freshly separated muscle fiber appears slightly yellow and striated in both longitudinal

and transverse directions. These striations are due to the arrangement and the optical properties of the myofibrils which are numerous very thin fibrils located in the sarcoplasm of each muscle fiber. These thin fibrils lie parallel to one another and run the entire length of the fiber, thus accounting for the longitudinal striation. The myofibrils are not homogeneous but consist of alternate dark and light disc-like sections which coincide in adjacent myofibrils and give the fiber its transverse striation. Each muscle fiber contains numerous nuclei generally located just beneath the sarcolema, a thin structureless membrane completely investing the fiber. The sarcoplasm contains a substance which consists of myosin and myogen, nucleo-proteins, liposomes, salts and pigment closely related to hemoglobin, known as myoglobin. There are also metabolic intermediaries such as lactic acid and creatin phosphate (23).

The muscles of the round of beef are characterized by large bundles (fasciculi), and connective tissue (perimysium) surrounding the bundles. A cross section through the center of the round contains twelve identifiable muscles. The two muscles chosen for this study are from the bottom round, the <u>semitendinosus</u> and <u>semimembranosus</u> muscles. Both of these muscles run the full length of the round and are classified as "long" muscles.

Characteristics of Collagen

Connective tissue contains fibers in its intercellular substance. As this substance and the cells present numerous variations, this type of tissue may be subdivided into various categories. The classification is difficult and inexact, for the different categories are linked by transitional forms (23).

The fibrous constituents of connective tissue may be divided into two main parts: (a) the collagenous or white fibers, and (b) elastic or yellow fibers which are embedded in an amorphous ground substance, jelly-like in nature, which "cements" them together. Reticulin fiber is classified in a separate category, or in the collagen group, although its precise relationship to classical collagen fiber is moot (22).

Collagen is defined in terms of its properties. It is a fibrous protein occurring in wide, straight, unbranching white bundles with high tensile strength and low elasticity. Collagen has characteristic 640 Å periodicity by small angle x-ray diffraction and by electron microscopy. It contains two unique amino acids, hydroxyproline and hydroxylysine (23). Table 1 lists the amino acid composition of collagen (40).

The carbohydrate content of collagen is low. This may be derived from ground substances and probably functions as interfibrillary cement.

Many models have been proposed for the structure of collagen but none have been established in full detail or beyond debate. The

Table 1

Amino Acid Content of Collagen[1]

Grams of Amino Acid in 100 grams of Protein

Acid	Per Cent	Acid	Per Cent
Alanine	9.5	Cystine	-
Glycine	27.2	Cysteine	-
Valine	3.4	Methionine	0.8
Leucine)	5.6	Arginine	8.59
)			
Isoleucine)		Histidine	0.74
Proline	15.1	Lysine	4.47
Phenylalanine	2.5	Aspartic Acid	6.3
Tyrosine	1.0	Glutamic Acid	11.3
Tryptophan	-	Amide N	0.66
Serine	3.37	Hydroxyproline	14.0
Threonine	2.28	Hydroxylysine	1.1

[1]Tristram (40)

polypeptide chain is assumed to be helically coiled (17).

Collagen dissolves in boiling water and yields a solution of animal glue or gelatin. In weak acids and alkalis the collagenous fibers swell. In acid solution, pepsin digests the collagenous bundles. Concentrated acids and alkalis destroy collagen. Collagen forms an insoluble product with the salts of heavy metals and with tannic acid. The tanning of leather is based on the treatment of the collagenous feltwork of the skin with tannic acid (23).

Characteristics of Elastin

Elastic or yellow fibers occur in the connective tissue as a loose network of fine fibers, which branch and anastomose. Elastic fibers are homogeneous and appear as straight branching fibers. Upon stretching, they yield readily, but return to their normal length when released. If the fibers appear in large numbers, they are yellowish in color (23).

Chemically, elastic fibers and collagen have approximately the same concentration of non-polar groups, e.g. glycine. However, elastin contains virtually no polar amino acids such as hydroxyproline, glutamine and arginine. Table 2 gives the amino acid content of elastin (40).

Elastin is an albuminoid which is highly resistant to boiling water, acids and alkalis, and through the action of alkalis it can be isolated from the other constituents of the tissue. Elastin is slowly digested by both pepsin and trypsin.

Table 2

Amino Acid Content of Elastin[1]

Grams of Amino Acid in 100 grams of Protein

Acid	Per Cent	Acid	Per Cent
Alanine	6.15	Cystine	0.6
Glycine	28.2	Cysteine	-
Valine	13.8	Methionine	0.03
Leucine	7.3	Arginine	1.1
Isoleucine	3.4	Histidine	0.04
Proline	15.6	Lysine	0.5
Phenylalanine	4.8	Aspartic Acid	0.6
Tyrosine	1.4	Glutamic Acid	3.3
Tryptophan	-	Amide N	1.73
Serine	1.0	Hydroxyproline	-
Threonine	1.1	Hydroxylysine	-

[1]Tristram (40)

Determination of Collagen and Elastin in Skeletal Muscle

Schepilewsky

In 1899, Schepilewsky (38) first extracted collagen by dissolving out the other proteins in meat with a five per cent sodium hydroxide solution at room temperature, and later with hot 0.5 per cent sodium hydroxide. The nitrogen in the filtrate was determined and was assumed to result from the conversion of the collagen to gelatin. The results are shown in Table 3.

Lehmann

In 1907, Lehmann (20) attempted to correlate mechanical and chemical determinations. A machine (dexometer) was devised which imitated the action of human biting as nearly as possible. Chemical studies (Schepilewsky's method) were done also on the same meat. Lehmann was careful to describe the extent of trimming of perimysium and fascia before removing the samples, a point of utmost importance in interpreting results. The range of values for psoas was 0.3 to 0.5 per cent collagen and for flank skin muscle 0.8 to 1.5 per cent.

Mitchell

Mitchell and workers (25) developed a chemical method for the determination of collagen in 1927. Collagen was converted to gelatin under pressure and elastin extracted by digesting other proteins with trypsin. The collagen was separated by washing with water only. Since collagen is soluble in 1 N sodium hydroxide, the authors felt there

Table 3

Per Cent Connective Tissue

In Two Different Muscles[1]

Animal	Connective Tissue	
	psoas	flank skin muscle
	%	%
I - 7 yr. old cow	0.493	0.961
	0.533	0.796
II - 3 yr. old ox	0.188	1.473
	0.188	1.243
III - 11 yr. old cow	0.423	1.411
	0.312	1.482
IV - $2\frac{1}{2}$-3 yr. old cattle	0.323	0.774
	0.323	0.756

[1]Schepilewsky (38)

would be a loss of collagen in the filtrate. The values for collagen nitrogen as per cent of total nitrogen were 8.85 in the psoas muscle; longissimus dorsi muscle, 8.2, and for the round, 10.6 per cent.

Morgan

Later, Morgan (26) adapted Mitchell's method to cooked samples. The changes were principally in the pretreatment of the sample. The cooked meat was ground in a ball mill for ninety minutes, washed exhaustively, and autoclaved at 15 to 18 pounds pressure for two hours. The residue was washed thoroughly with hot water and nitrogen was determined on the aliquots of the filtrate and washings. Quantitative determinations for tyrosine and tryotophan were carried out to correct for any non-gelatin protein in the final filtrate. The per cent collagen nitrogen in total nitrogen was 10.6 per cent in raw meat and 7.9 per cent in cooked meat.

E.C. Bate Smith

E.C. Bate Smith (2,3) outlined a scheme for the approximate determination of the proteins of muscle in 1934. The soluble proteins were extracted with seven per cent lithium chloride instead of sodium hydroxide. Exhaustive extraction with 0.01 N hydrochloric acid was substituted for the tryptic digestion used in previous methods. With tryptic digestion the collagen nitrogen was ten per cent of the total coagulable nitrogen in beef round. With hydrochloric acid extraction of fresh rabbit muscle, 13 to 24 per cent of the total protein was collagen and one per cent of the total protein was elastin. This method was very involved, as it

allowed quantitative determination of the soluble as well as the insoluble proteins. Since no provision was made for the removal of fat and phospholipids, error was probable.

Lowry

Lowry (21) devised a gravimetric method for the determination of collagen and elastin after exhaustive washings with 0.1 N sodium hydroxide to remove other proteins. The average collagen in 21 rat adductor muscles was 4.3 per cent of the dry weight of the tissue. The average elastin in ten rat adductor muscles was 1.1 per cent of the dry weight of the tissue.

Hartley

Hartley (14) used the Waring Blendor and the centrifuge to speed up the Lowry method, and also controlled the pH during the extraction of the soluble proteins. A pH of 5.0 for raw meat and 5.2 for cooked meat produced the most complete extraction. Hartley assumed with this procedure that gelatin is the only source of nitrogen in the final filtrate.

Griswold

Griswold (12) compared the Lowry and Hartley methods and concluded the Lowry method gave the more accurate results. With both cooked and uncooked semitendinosus muscle of beef the Hartley method produced consistently higher results. The collagen content of the raw samples averaged 2.42 per cent with the Hartley method, and 1.05 per cent with the Lowry method. Griswold attributed the difference to the inclusion

of some non-gelatin nitrogen with the gelatin nitrogen in the Hartley analysis. Analyses of steer-hide collagen indicated that when contaminating proteins are absent, or present only in traces, the two methods checked within five per cent. Cooked meat showed an increase of collagen, an average of 3.62 per cent, by the Hartley method. Samples analyzed by the Lowry method showed consistent losses of collagen on cooking, an average of 0.63 per cent collagen. Since collagen is hydrolyzed to gelatin during cooking, losses in collagen would be expected in cooked meat.

Lampitt

Lampitt (18,19) suggested still further changes in the Lowry method. The initial mixing was done in a Waring Blendor to permit the use of a larger and more representative sample. The autoclaving period was divided into two three-hour periods. The liquid was poured off and replaced with fresh water at the half-way point. The altered procedure insured a more complete conversion of the collagen to gelatin. The silverside (round) of beef contained three per cent collagen and the shin of beef contained 13 per cent collagen, expressed as percentage of the total solids.

Neuman and Logan

Collagen is unique in its high content of the amino acid hydroxyproline. Heuman and Logan (27) devised a method for the determination of the hydroxyproline content of collagen by oxidizing with hydrogen peroxide in a copper solution and using paradimethylaminobenzaldehyde as

an indicator and reading the resulting color with a spectrophotometer. The original work was done on ligaments and tendons and later work (28) on muscle. The hydroxyproline content of collagen was ascertained to be 13.5 per cent. The figure 7.46 was established to convert hydroxyproline to its equivalent of collagen and to correct for color contributed by tyrosine. Neuman and Logan worked primarily on organs but a series of tests on beef shoulder produced an average of 2.08 per cent collagen.

Lampitt (19) determined the hydroxyproline by the Neuman and Logan method but used the aqueous autoclave extract from the Lowry method. Consistently higher results were obtained by weight difference method (Lowry) than with the hydroxyproline method (Neuman and Logan). Silverside (round) of beef contained 3.74 per cent collagen by the Lowry method and 3.38 per cent collagen by the Neuman and Logan method. It was felt that this indicated that some non-collagenous material is not extracted by the alkaline reagent but is dissolved on autoclaving with water. Lampitt concluded the most satisfactory method for the determination of collagen in muscle was the modified Lowry method and determination of hydroxyproline by the color method.

Wierbicki and Deatherage (41) used the Neuman and Logan method on samples of the longissimus dorsi muscle of cattle reported the connective tissue (alkali insoluble proteins) contains 12.39 0.40 per cent hydroxyproline. Using this figure and the figure of 1.5 to 2.3 per cent of hydroxyproline in elastin, the relative amounts of collagen and elastin in the connective tissue of the longissimus dorsi muscle of cattle are 84 per cent collagen and 16 per cent elastin.

EXPERIMENTAL PROCEDURE

Preparation of Steaks

Six pairs of matched rounds, rump on, choice grade, were obtained from a wholesale meat dealer. The *semitendinosus* and *semimembranosus* muscles were removed from each round. Approximately two inches were removed from each end of the muscles and nine one-inch steaks were cut from the center portion. The steaks were numbered from one to nine starting with the anterior end. Each steak was weighed, wrapped individually in Saran wrap, frozen in a blast freezer at -40°C, and then stored at -10°C. The steaks were thawed in a refrigerator at 4°C for 16-18 hours. Steaks one, two, five and six were cooked and steaks three, four, eight and nine were used for chemical determinations. This meant that two adjacent steaks situated near the end and two from the center were used for each type of determination.

Cooking Procedure

The steaks were braised by a method formulated in this laboratory by Paul and Bean (29). The steaks and pans were weighed before and after removing from the oven for the determination of total cooking losses.

Determinations on Cooked Meat

Shear Force

Three cores (one-half inch in diameter) from each steak were sheared on the Warner-Bratzler shear machine. The cores were cut from the same spot in each steak and numbered so that core number one from the second steak would be a continuation of core number one from the first steak.

Press Fluid

A ten to fourteen gram sample was removed from each steak, placed in the Carver Laboratory Press and held under 12,000 pounds pressure per square inch for ten minutes.

Moisture

The remainder of the cooked steak was ground three times in a Hobart meat grinder, Model K5A. Ten grams of the ground meat was weighed on the Brabender balance and dried in the semiautomatic Brabender, Model FD4, until constant weight was reached.

Fat Extraction

After the moisture was removed the residue was weighed on tared fat-free filter paper and extracted with ether in the Goldfisch extractor Model 1138 for three hours (1). At the end of the three hour period the ether was removed and the residue in the filter paper was dried in an oven for thirty minutes at 100°C. The difference in the weight of the

original filter paper and sample and the final weight of the paper and residue was the crude fat.

Nitrogen

Approximately 0.25 grams of the moisture-free, and fat-free residue was weighed on tared nitrogen-free filter paper and nitrogen was determined in duplicate by the boric acid modification of the Kjeldahl-Gunning method (37).

Determinations on Uncooked Meat

pH

The outer edge of the raw steak was trimmed and the remainder was ground five times in the Hobart meat grinder, Model K5A. Approximately five grams of the ground meat was added to one hundred milliliters of distilled water and slurries were made in duplicate in the Waring Blendor. Determinations of the pH were made on the Beckman pH meter, Model H2.

Moisture, Fat and Nitrogen

The moisture, fat and nitrogen determinations were done in the same manner as on the cooked muscle.

Collagen and Elastin by Weight Difference

The Lowry method (21) with modifications by Lampitt (18,19) was used. The supernatant and washings after autoclaving were saved for

the hydroxyproline determinations. The percentages of collagen and elastin were calculated on the basis of the non-fat solids.

Collagen by Hydroxyproline Analysis

The supernatant and washings collected after autoclaving in the collagen and elastin determinations by weight difference were placed in a 250 milliliter volumetric flask and brought to volume. A twenty milliliter aliquot was acidified and evaporated to dryness. The residue was autoclaved with two milliliters of 6 N hydrochloric acid for six hours at twenty pounds pressure. The resulting hydrolysate was neutralized and diluted to twenty-five milliliters. One milliliter aliquots were used for color development by the Neuman and Logan method (27). A standard curve was made with each series. Determinations were read at 540 mu on a Coleman spectrophotometer, Model 11. Four color determinations were made on each uncooked steak.

RESULTS AND DISCUSSION

Statistical Treatment of Results

The data are given in tables i to xii in the APPENDIX. The Student-Fisher "t" test (8) was used to determine significant differences between consecutive and matched steaks.

In all analyses for the matched steaks the data for the right side were subtracted from the corresponding data for the left side. For the adjacent steaks the figures of the larger numbered steak were subtracted from those of the smaller numbered steak, i.e. one minus two, three minus four, etc.

Total Cooking Losses

Consecutive steaks number one and two on the right side of the semimembranosus muscle were the only steaks to show significant differences in total cooking losses. (Table 4)

The time of cooking was not analyzed for differences but there was little variation within the same muscle. The steaks from the semimembranosus muscle required longer time than the steaks from the semitendinosus muscle, due to the larger size of that muscle.

The average cooking loss for the semitendinosus muscle was 39 per cent and for the semimembranosus muscle it was 38 per cent. These are in agreement with Paul and Bean (29) whose cooking method was used.

Table 4

Summary of Student Fisher "t" test

for differences on total cooking losses

Steak No.	Consecutive	Match
<u>Semitendinosus</u>		
1-2 left	1.64	
1-2 right	-0.07	
1 match		-1.42
2 match		-1.96
5-6 left	-0.43	
5-6 right	-0.94	
5 match		0.49
6 match		1.17
<u>Semimembranosus</u>		
1-2 left	2.21	
1-2 right	-4.07**	
1 match		-1.68
2 match		-1.42
5-6 left	-1.61	
5-6 right	-1.02	
5 match		-0.86
6 match		1.26

* Significant at 5% level
** Significant at 1% level

Total cooking loss in that study was 39 per cent and 41 per cent for the semitendinosus and semimembranosus muscles respectively.

With the exception of animal 6 there was close agreement among animals. In the meat from this animal cooking losses were consistently higher in both the semitendinosus and semimembranosus muscles.

It is difficult to evaluate total cooking loss figures since method, time, and temperature of cooking are determining factors. Paul (30) compared total losses of two methods of cooking. One-inch steaks of the semitendinosus muscle were roasted and braised. A loss of 28.24 per cent was recorded after roasting compared to 35.96 per cent after braising. For the semimembranosus muscle these figures were 26.58 per cent with dry heat and 33.12 per cent after braising.

Satorius and Child (35) compared total cooking losses of steaks from the semitendinosus muscle after roasting to different internal temperatures. At 58°C an average loss of 17.89 per cent was recorded and at 75°C the loss increased to 29.49 per cent. The 39 per cent loss for the semitendinosus muscle reported in this study would not seem out of line as a final temperature of 98°C was recorded.

Shear Force on Cooked Steaks

As stated in the experimental procedure three one-half inch cores were cut from each steak. Since these cores were numbered by location and the location was the same for each steak, they were not averaged. In reality, the "t" test for shear force is carried out on position

within the steak as well as position in the muscle.

Table 5 shows that there was a significant difference at the 0.05 level for matched steak number two of the semitendinosus muscle. Consecutive steaks number one and two on the right side of both the semitendinosus and semimembranosus muscles were significant at the 0.05 level. Steaks number one and two on the left side of the semimembranosus muscle showed significance at the 0.01 level.

This would suggest that steaks one and two or the extreme anterior end of both the semitendinosus and semimembranosus muscles would show differences in respect to shear force. Paul and Bratzler (32) studied end to end variations on shear within the semimembranosus muscle and concluded that the section from steak number three through steak number six was reasonably uniform with respect to shear.

The shear force values for the semitendinosus muscle ranged from 3.50 pounds to 14.25 pounds with an average of 7.13 pounds. For the semimembranosus muscle the range was from 3.00 pounds to 18.00 pounds with an average of 10.50 pounds. These figures represent shear force values for the whole length of the two muscles with the exception of the extreme ends, thus a wide range results. Also, because the location of the cores was the same throughout each muscle, several of the cuts were made through concentrated areas of connective tissue. This is in contrast to most shear force results as the common practice is to avoid any area showing obvious streaks of connective tissue and fat.

Table 5

Summary of Student Fisher "t" test

for differences of shear force on Cooked Steaks

Steak No.	Consecutive	Match
Semitendinosus		
1-2 left	-0.54	
1-2 right	2.30*	
1 match		-0.34
2 match		2.50*
5-6 left	-0.67	
5-6 right	-1.27	
5 match		0.27
6 match		0.63
Semimembranosus		
1-2 left	-3.46**	
1-2 right	-2.56*	
1 match		-0.89
2 match		-0.05
5-6 left	1.08	
5-6 right	1.04	
5 match		-0.37
6 match		-0.06

*Significant at 5% level
**Significant at 1% level

A standard method of braising has not been established; thus, average shear force values from different laboratories are not comparable. One variance that appears on comparison of these values is due to different grades of animals used in experimentation. As a rule the shear force values decrease with increases in grade of the animal. Paul and Bratzler (32) with good and prime grade beef had an average shear force value of 8.43 pounds for the semimembranosus muscle. Ramsbottom and Strandine (34) found average shear force values for the semitendinosus muscle to be 11.10 pounds and 11.90 pounds for the semimembranosus muscle from three heifers of U.S. good grade. Paul(30) with commercial grade cows observed average shear force value of 11.92 pounds for the semitendinosus muscle, and 11.55 pounds for the semimembranosus muscle. In this study with choice grade beef, the semitendinosus muscle averaged 7.13 pounds shear force and the semimembranosus muscle 10.50 pounds.

Press Fluid on Cooked Steaks

The differences on all figures for press fluid were insignificant for both the matched and consecutive steaks as shown in Table 6. The average press fluid was 35.00 and 33.00 per cent for the semitendinosus and semimembranosus muscles, respectively.

Satorius and Child (35) concluded that with different degrees of coagulation of the semitendinosus muscle, press fluid is decreased with each increment of internal temperature. The highest temperature recorded was 75°C with a resultant press fluid of 42.62 per cent. At 58°C the

Table 6

Summary of Student Fisher "t" test

for differences in press fluid of Cooked Steaks

Steak No.	Consecutive	Match
Semitendinosus		
1-2 left	0.95	
1-2 right	-2.33	
1 match		2.17
2 match		-0.89
5-6 left	-0.02	
5-6 right	-1.09	
5 match		0.96
6 match		-1.34
Semimembranosus		
1-2 left	2.40	
1-2 right	0.98	
1 match		1.30
2 match		1.18
5-6 left	1.40	
5-6 right	-0.26	
5 match		0.06
6 match		-1.01

* Significant at 5% level
** Significant at 1% level

press fluid was 51.77 per cent. In the study reported here the internal temperature at the end of the cooking period was 98°C, therefore, a still lower figure would be expected.

Gaddis and coworkers (10) determined press fluid was influenced by the amount of intramuscular fat. Lower values were obtained with increasing fat as fat particles tend to inhibit the loss of fluid. These workers recorded an average press fluid of 43.00 per cent from 500 pound steers and 40.00 per cent from 900 pound steers. These figures are both for the longissimus dorsi muscle roasted to an internal temperature of 60°C.

Gaddis (10) also states if meat is cooked to a state of doneness which involves a pronounced loss of moisture, the amount of fat present will have little effect on the press fluid. In this study the press fluid figures were markedly similar in all animals. The final cooking temperature of 98°C was evidently high enough to rule out any differences in press fluid due to varying amounts of fat.

Moisture Content of Cooked and Uncooked Steaks

Table 7 shows there was a significant difference in moisture content of steaks one and two after cooking. On the left side the difference was significant at the 0.05 level and on the right side at the 0.01 level. The moisture content of the semitendinosus muscle ranged from 52 per cent to 63.60 per cent with an average of 57.80 per cent. For the semimembranosus muscle the range was 47.55 per cent to 61.80 per cent

Table 7

Summary of Student Fisher "t" test

for differences in moisture content of cooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
1-2 left	3.26*	
1-2 right	4.49**	
1 match		1.14
2 match		0.28
5-6 left	-1.12	
5-6 right	1.27	
5 match		-0.62
6 match		1.65
Semimembranosus		
1-2 left	2.24	
1-2 right	1.37	
1 match		1.29
2 match		1.14
5-6 left	-0.09	
5-6 right	0.67	
5 match		2.50
6 match		2.41

* Significant at 5% level
** Significant at 1% level

Table 8

Summary of Student Fisher "t" test

for differences in moisture content of uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	5.70**	
3-4 right	4.89**	
3 match		0.95
4 match		0.69
8-9 left	0.04	
8-9 right	-1.51	
8 match		0.96
9 match		0.29
Semimembranosus		
3-4 left	7.23**	
3-4 right	8.72**	
3 match		2.85*
4 match		0.36
8-9 left	2.15	
8-9 right	0.13	
8 match		0.48
9 match		2.48

* Significant at 5% level
** Significant at 1% level

with an average of 54.68 per cent. There was little variation in moisture content for the cooked steaks except for steaks number one and two in animal 4. For both the semitendinosus and semimembranosus muscles in this animal the moisture figures were high at the anterior end of the muscles. This explains why steaks number one and two showed differences statistically.

The moistures of the uncooked steaks show significant differences at the 0.01 level in steaks number three and four for the left and right sides in both muscles as shown in Table 8. Matched steak number three in the semimembranosus muscle showed significance at the 0.05 level. The percentage range for the semitendinosus muscle was 70.00 per cent to 76.10 per cent with an average of 73.00 per cent. For the semimembranosus muscle the range was from 70.10 per cent to 74.95 per cent with an average of 72.50 per cent. There was little variation in moisture content of uncooked steaks in either muscle except in animal 6. In this animal the moisture content of the uncooked steaks was higher on the average than in the other animals.

Characteristically, muscle tissue contains a large proportion of water. The water content of fresh muscle varies little, and usually only when the fat content increases. Ramsbottom and Strandine (34) found the moisture content of fresh semitendinosus muscle was 73.4 per cent and 74.2 per cent for the semimembranosus muscle. Satorius and Child (35) recorded a figure of 74.59 per cent for uncooked semitendinosus muscle. All of these figures are in close agreement with the

average found in this study for moisture content of uncooked steaks.

Assuming the moisture content of the cooked steaks was similar to the above figures before cooking, the moisture content after cooking will be determined by the method of cooking and the final internal temperature. It is an accepted fact that moist heat produces greater weight loss than dry heat. Usually a higher final temperature is recorded with moist heat cooking methods which also adds to the total losses. Satorius and Child (35) studied moisture content with increases in temperature from 58°C to 75°C and recorded a decrease of moisture content from 70.94 per cent at 58°C to 66.91 per cent at 75°C. The data in this study representing a final temperature of 98°C are not out of line.

Fat Content of Cooked and Uncooked Steaks

In Table 9 the fat content is significantly different (0.01) in the cooked steaks for steaks number one and two of the semitendinosus muscle. Matched steaks number two of the semimembranosus muscle show significance at the 0.01 level.

In Table 10 the statistical data for uncooked steaks indicate significance for steaks number three and four of both the semitendinosus and semimembranosus muscles.

The moisture content of fresh muscle varies only when the fat content of the muscle increases or decreases appreciably. Table 8 shows a significant difference in the moisture content of steaks number three

Table 9

Summary of Student Fisher "t" test

for differences in fat content of cooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
1-2 left	-4.51**	
1-2 right	-5.54**	
1 match		-0.94
2 match		0.38
5-6 left	2.33	
5-6 right	-0.14	
5 match		1.08
6 match		-0.95
Semimembranosus		
1-2 left	-1.85	
1-2 right	0.66	
1 match		-0.47
2 match		3.20*
5-6 left	-0.27	
5-6 right	-1.36	
5 match		-0.01
6 match		-0.53

* Significant at 5% level
** Significant at 1% level

Table 10

Summary of Student Fisher "t" test

for differences in fat content of uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	-3.19*	
3-4 right	4.41**	
3 match		-0.64
4 match		1.68
8-9 left	0.90	
8-9 right	2.38	
8 match		-1.47
9 match		-0.63
Semimembranosus		
3-4 left	-8.41**	
3-4 right	-7.92**	
3 match		1.87
4 match		-1.68
8-9 left	-1.04	
8-9 right	0.32	
8 match		-0.56
9 match		2.98

* Significant at 5% level
** Significant at 1% level

and four of both uncooked muscles. The same steaks show differences in fat content in Table 10. The average fat content of the uncooked semitendinosus muscle was 20.00 per cent. Steaks three and four of this muscle had an average fat content of 22.14 per cent. The range for the whole muscle was from 11.00 per cent to 29.00 per cent and for steaks three and four the range was from 16.00 per cent to 29.00 per cent. This would indicate that the fat content of these two steaks was higher than the rest of the muscle and hence would effect the moisture content.

The average fat content of the uncooked semimembranosus muscle was 17.64 per cent. Uncooked steaks three and four of this muscle had an average of 15.12 per cent fat. The range for the whole muscle was from 8 per cent to 27 per cent. For steaks three and four the range was from 8 per cent to 22 per cent, indicating that the fat content was lower in these two steaks thus causing the difference statistically.

Thus it would appear reasonable to assume that the anterior end of either uncooked muscle varies in respect to fat content and hence in moisture content also. The same trend should be apparent in regard to the fat content of the cooked steaks with reference to differences in the anterior end of the muscles. Steaks number one and two of the semitendinosus muscle showed differences but steaks one and two of the semimembranosus muscle did not. This latter fact is difficult to explain except that matched steaks number two showed a difference, possibly indicating the beginning of a change in fat content of that muscle starting at steak three rather than from steaks one through four as

found in the semitendinosus muscle. The statistical data in Table 7 show significant difference in the moisture content of cooked steaks one and two of the semitendinosus muscle and no significant difference for the semimembranosus muscle.

Nitrogen Content of Cooked and Uncooked Steaks

Cooked steaks number one and two on the left side in the semitendinosus muscle were significantly different at the 0.05 level in nitrogen content.

Nitrogen in the cooked semitendinosus muscle ranged from 13.64 per cent to 14.83 per cent with an average of 14.24 per cent. The figures for the uncooked semitendinosus muscle ranged from 13.82 per cent to 15.18 per cent with an average of 14.50 per cent.

In the cooked semimembranosus muscle the range was from 13.46 per cent to 14.78 per cent with an average of 14.12 per cent; whereas, in the uncooked semimembranosus muscle the range was from 13.94 per cent to 15.36 per cent with an average of 14.65 per cent.

Paul (30) calculated the nitrogen content also on a moisture and fat-free basis in the semimembranosus, semitendinosus, adductor and biceps femoris muscles of the round and found an average value of 14.37 per cent. Paul felt that any variation in nitrogen content would be between types of cattle and between animals within the same type rather than within the same animal or muscle. In this study there was little variation in the nitrogen figures for all animals with the exception of animal 15, which had a lower nitrogen content than the others.

Table 11

Summary of Student Fisher "t" test

for differences in nitrogen content of cooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
1-2 left	2.96*	
1-2 right	0.00	
1 match		-0.36
2 match		-1.64
5-6 left	-0.21	
5-6 right	-0.52	
5 match		-1.15
6 match		-0.25
Semimembranosus		
1-2 left	0.53	
1-2 right	-0.86	
1 match		1.61
2 match		-0.27
5-6 left	2.21	
5-6 right	0.87	
5 match		0.50
6 match		1.83

* Significant at 5% level
** Significant at 1% level

Table 12

Summary of Student Fisher "t" test

for differences in nitrogen content of uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	-1.51	
3-4 right	-1.65	
3 match		2.52
4 match		1.69
8-9 left	-0.15	
8-9 right	-1.22	
8 match		-0.09
9 match		-0.94
Semimembranosus		
3-4 left	-0.43	
3-4 right	0.38	
3 match		-0.70
4 match		-0.07
8-9 left	0.98	
8-9 right	0.60	
8 match		0.01
9 match		0.04

* Significant at 5% level
** Significant at 1% level

Acidity of Uncooked Steaks

A difference significant at the 0.05 level was found in steaks eight and nine on the left side in the semitendinosus muscle. Matched steaks eight and nine of the semimembranosus muscle also showed significance at the 0.01 level.

All of the pH values were within the range of 5.2 to 5.7 with the exception of animal 4 in which the range was 6.3 to 6.8. Fenn and Maurer (9) state that the pH of muscle after post mortem changes range from 5.3 to 6.0. It was evident in animal 4 of this study that the pH value was too high to be considered in the normal range. E.C. Bate Smith (4) states that the rate of acidification of muscle post mortem varies with extraordinary variability from animal to animal and also from one area to another in a particular muscle. This last variation becomes nil after the acidity of the muscle reaches pH 6.2. The post mortem change in pH is due to the change of glycogen to lactic acid. Bate Smith has shown that strenuous exercise shortly before slaughter decreased the glycogen content of the muscles and limited the lowering of the pH post mortem. Meat with a pH of over 6 is described as darker in color, slimy and soft in texture. The slimy texture of the uncooked meat of animal 4 was the outstanding characteristic noticed during grinding.

Collagen Content of Uncooked Steaks

The collagen content of the raw steaks, determined by weight

Table 13

Summary of Student Fisher "t" test

for differences in pH of uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	0.04	
3-4 right	1.63	
3 match		-0.77
4 match		0.08
8-9 left	2.74*	
8-9 right	2.37	
8 match		0.51
9 match		1.01
Semimembranosus		
3-4 left	1.75	
3-4 right	1.61	
3 match		-1.25
4 match		-1.37
8-9 left	0.64	
8-9 right	0.17	
8 match		3.79*
9 match		3.75*

* Significant at 5% level
** Significant at 1% level

difference, was significantly different at the 0.05 level in steaks number three and four on the left side for both the semitendinosus and semimembranosus muscles (Table 14).

The collagen content when measured by hydroxyproline in the same steaks showed significance at the 0.05 level also in steaks number three and four on the left side in the semitendinosus muscle as shown in Table 15.

The average collagen content determined by weight difference was 3.57 per cent for the semitendinosus muscle and 3.95 per cent for the semimembranosus muscle. These averages are expressed as percentages of the moisture, fat-free solids. The average collagen content determined by hydroxyproline was 2.15 per cent in the semitendinosus muscle and 2.47 per cent in the semimembranosus muscle.

Lampitt (19) determined collagen by the same methods in silverside (round) of beef and found an average of 3.74 per cent collagen by weight difference and 3.38 per cent by hydroxyproline determination. These workers felt the consistently higher results obtained by weight difference than by the hydroxyproline method indicated that some non-collagenous material is not extracted by the alkaline reagents but is dissolved on autoclaving with water.

Prudent (33) studied the collagen content of four beef muscles aged for varying periods of time. The semitendinosus muscle had a value of 3.77 per cent of collagen, calculated on the dry basis, when using the Lowry (weight difference) method.

Table 14

Summary of Student Fisher "t" test

for collagen content determined by weight difference in uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	-3.52*	
3-4 right	-1.89	
3 match		-1.13
4 match		-0.24
8-9 left	1.05	
8-9 right	1.63	
8 match		0.08
9 match		1.35
Semimembranosus		
3-4 left	-3.45*	
3-4 right	-2.28	
3 match		-2.46
4 match		-2.20
8-9 left	-1.23	
8-9 right	0.87	
8 match		-0.70
9 match		1.05

* Significant at 5% level
** Significant at 1% level

Table 15

Summary of Student Fisher "t" test

for collagen content determined by hydroxyproline in uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	-2.90*	
3-4 right	-0.90	
3 match		-0.98
4 match		-0.002
8-9 left	-1.60	
8-9 right	2.31	
8 match		-1.30
9 match		1.72
Semimembranosus		
3-4 left	-0.94	
3-4 right	-2.02	
3 match		0.004
4 match		0.06
8-9 left	-1.36	
8-9 right	0.65	
8 match		-1.05
9 match		1.78

* Significant at 5% level
** Significant at 1% level

Due to the various ways of expressing collagen, comparisons are difficult. It may be expressed as per cent of the total nitrogen or as collagen nitrogen and either of these may be on a wet or dry basis. Another variant in comparing figures is whether the connective tissue covering of the muscle is removed. In this study this covering was removed as well as in the work of Lampitt (19) and Cover and Smith (7). Obviously, if this is not removed higher values for collagen will result.

Cover and Smith (7) working with the longissimus dorsi and biceps femoris muscles noted rather large differences in collagen content of the same muscle from different animals. Wilson et al. (42) reported considerable variation in the percentage of collagen between animals of the same grade and age in the longissimus dorsi muscle. The six animals used in this study were all choice grade. In animals one through four the collagen content by weight difference was within the range of 1.50 per cent to 3.50 per cent. In animals five and six the range was from 2.73 to 6.09 per cent. This would bear out the findings of the workers mentioned above. Since the "t" test showed little variation the difference between animals is greater than the difference between steaks from the same animal.

The collagen figures as determined by hydroxyproline content are dependent for comparison on the factor used for converting the hydroxyproline to collagen. Neuman and Logan (27) suggest the figure 7.46 which was used in this work. This figure was arrived at after analyzing samples of both organs and beef shoulder muscle. Wierbicki and Deatherage (41)

used a modification of the Neuman and Logan procedure on longissimus dorsi muscle of beef and suggested the conversion factor of 6.94.

Miller and Kastelic (24) reported four per cent of collagen in the semitendinosus muscle and two per cent in the semimembranosus muscle by hydroxyproline determination.

The results in this study may appear to be contrary to expectations, i.e., the collagen content of the semimembranosus muscle is higher than in the semitendinosus muscle. The reason for this will be discussed in the discussion of the elastin content.

Elastin Content of Uncooked Steaks

Consecutive steaks eight and nine, on the left side, of the semitendinosus muscle showed differences significant at the 0.05 level in elastin content determined by weight difference. In the semimembranosus muscle, steaks number three and four, on the right side, showed significance at the 0.01 level (Table 16).

The average elastin content of the semitendinosus muscle was 1.69 per cent; the average elastin content of the semimembranosus muscle was 0.57 per cent.

Miller and Kastelic (24) reported the elastin content, determined by hydroxyproline, in the semitendinosus muscle as 2.40 per cent and 0.8 per cent in the semimembranosus muscle. Prudent (33) reported the elastin content, determined by weight difference, in the semitendinosus muscle as 3.82 per cent.

Table 16

Summary of Student Fisher "t" test

for elastin content determined by weight difference in uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	-2.09	
3-4 right	-0.81	
3 match		0.22
4 match		0.97
8-9 left	3.15*	
8-9 right	2.15	
8 match		-0.09
9 match		-0.03
Semimembranosus		
3-4 left	-0.85	
3-4 right	-4.76**	
3 match		1.43
4 match		1.43
8-9 left	-2.11	
8-9 right	-0.81	
8 match		0.06
9 match		1.01

* Significant at 5% level
** Significant at 1% level

Most of the work on elastin has been done histologically. Harrison et al. (13) reported the semitendinosus muscle contains large numbers of elastic fibers in the connective tissue. This indicates that the elastin content of the semitendinosus muscle is larger than the elastin content of the semimembranosus muscle, as found in this study. At the same time Hiner et al. (15) reported the total connective tissue, including both collagen and elastin, is similar in both these muscles as determined histologically. Combining the average figures for collagen and elastin contents the total connective tissue found in this study was 5.26 per cent in the semitendinosus muscle and 4.52 per cent in the semimembranosus muscle. This means the difference in connective tissue between these two muscles is not in total amount but rather the type of connective tissue present.

Moisture, Fat-Free Weights of Uncooked Steaks

Table 17 gives the statistical analysis for differences of the moisture, fat-free residues of the uncooked steaks. Consecutive steaks number eight and nine on the right side in the semitendinosus muscle showed great differences. Consecutive steaks number three and four on both sides showed differences in the semimembranosus muscle. These results are expected in the latter steaks as they both showed marked differences in moisture as well as fat content. The significance in steaks eight and nine on the right side is less obvious although the fat figures for these steaks verge on significance.

Table 17

Summary of Student Fisher "t" test

for moisture, fat-free weights of uncooked steaks

Steak No.	Consecutive	Match
Semitendinosus		
3-4 left	-1.51	
3-4 right	2.02	
3 match		-0.51
4 match		1.47
8-9 left	-2.18	
8-9 right	-25.73**	
8 match		0.35
9 match		0.80
Semimembranosus		
3-4 left	31.82**	
3-4 right	2.80*	
3 match		0.60
4 match		0.48
8-9 left	-1.43	
8-9 right	-0.82	
8 match		-0.75
9 match		-0.40

* Significant at 5% level
** Significant at 1% level

SUMMARY AND CONCLUSIONS

The semitendinosus and semimembranosus muscles were used from six animals of choice grade. The center portion of each muscle was cut into nine one-inch steaks. Four steaks from each muscle were cooked and four were tested uncooked. Each cooked steak was tested for total cooking losses, shear force values, press fluid, moisture, fat and nitrogen. The tests made on the uncooked steaks were pH, moisture, fat, nitrogen, collagen and elastin by weight difference, and collagen by hydroxyproline determination. The laboratory results for both matched cuts and consecutive cuts were analyzed for differences with the Student Fisher "t" test. Tables 18 and 19 are composites of the statistical results of the consecutive steaks for both muscles.

This study shows it is possible to use consecutive one-inch steaks from both the semitendinosus and semimembranosus muscles of beef with the same assurance of accuracy as matched cuts from the right and left muscles of the same animal. It is therefore possible to set up experiments with only one side of beef rather than the whole animal. That part of the semitendinosus in which consecutive cuts are most homogeneous is the center, while consecutive cuts in the posterior half of the semimembranosus muscle are homogeneous.

Table 18

Composite Table of Statistical Analyses of Uncooked Steaks

Steak No.	pH	Moisture	Fat	Nitrogen	Collagen Wt. Diff.	Collagen HP	Elastin Wt. Diff.	Moisture Fat Free Wt.
Semitendinosus								
3-4 left		**	*		*	*		
3-4 right		**	**					
8-9 left	*						*	
8-9 right								**
Semimembranosus								
3-4 left		**	**		*			**
3-4 right		**	**				**	**
8-9 left								
8-9 right								

* Significant at 5% level

** Significant at 1% level

Table 19

Composite Table of Statistical Analyses of Cooked Steaks

Steak No.	Shear	Total Cook. Loss	Press Fluid	Moisture	Fat	Nitrogen
Semitendinosus						
1-2 left				*	**	*
1-2 right	*			**	**	
5-6 left						
5-6 right						
Semimembranosus						
1-2 left	**					
1-2 right	*	**				
5-6 left						
5-6 right						

* Significant at 5% level

** Significant at 1% level

In the semitendinosus muscle, marked differences appear in steaks one through four. Especially significant in these four steaks are differences in fat and moisture content in both the cooked and uncooked steaks. These differences did not carry through in the moisture, fat-free weights in uncooked steaks three and four, indicating there was compensation. Slight differences were shown in shear force value and nitrogen content in the cooked steaks and collagen content both by weight difference and hydroxyproline in the uncooked steaks. The variation in shear force value is expected as matched steak number two also showed significance in this factor. This might be due to differences between animals rather than within the same animal.

The differences in collagen content by both weight difference and hydroxyproline in the same steaks indicate definite variations within these steaks. Each test acts as a check on the other.

Cooked steaks number five and six of the semitendinosus muscle showed no variations in all the tests performed on these steaks.

Uncooked steaks number eight and nine of the semitendinosus muscle exhibited slight differences in the pH and elastin content on the left side. Statistical analyses of the pH using the hydrogen ion values produced essentially the same differences. The moisture, fat-free weight of the same steaks on the right side was significantly different but did not appear in the moisture or fat analysis which would indicate compensation.

In the semimembranosus muscle the variations were in the steaks numbered one through four. In the cooked steaks number one and two, the

shear force value was significantly different on both sides. In the same steaks, the total cooking losses were different on the right side.

Uncooked steaks three and four of the semimembranosus muscle showed great variations in moisture and fat content and, as would be expected, in the moisture-, fat-free weights. The collagen contents determined by weight difference showed variation on the left side and the elastin content on the right side.

Cooked steaks number five and six and uncooked steaks eight and nine of the semimembranosus were homogeneous in all the tests.

The matched steaks were homogeneous with a few exceptions. Notably, these exceptions were also in steaks one through four in the anterior and steaks eight and nine in the posterior end of the muscles.

On the basis of the six animals used in this study, which is admittedly a small sampling, it appears that the center of the semitendinosus muscle is homogeneous. This means that three or four consecutive steaks from the same muscle could be used for experimentation.

In the semimembranosus muscle, the posterior half of the muscle is homogeneous. This would allow five to six consecutive steaks that were similar.

These conslusions are in agreement with Ginger (11), who reported on tenderness variations within the same muscle and concluded that the posterior two-thirds of the semimembranosus muscle could be considered comparable.

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APPENDIX

Table i

Uncooked Steaks Animal I

Steak No.	pH	Moisture %	Fat %	Collagen Wt. Diff. %	Collagen H.P. %	Elastin %	Nitrogen %
Semitendinosus							
3-left	5.15	73.28	18.06	2.44	1.71	2.15	14.66
4-left	5.30	72.38	20.03	3.55	2.52	2.47	14.80
3-right	5.48	73.74	17.02	2.40	1.56	2.16	14.46
4-right	5.20	72.52	20.49	3.08	2.10	2.42	14.27
8-left	5.25	72.80	15.49	3.43	2.80	1.49	14.43
9-left	5.25	73.20	11.55	2.94	2.35	1.23	14.49
8-right	5.15	73.17	17.38	3.29	2.66	1.82	14.40
9-right	5.03	72.98	16.14	3.07	1.73	1.38	14.69
Semimembranosus							
3-left	5.15	74.35	7.87	1.98	2.11	1.02	14.41
4-left	5.00	72.80	15.00	2.88	1.91	0.55	14.62
3-right	5.73	74.13	10.01	2.04	1.80	0.12	14.69
4-right	5.63	73.20	15.87	4.31	1.91	0.37	14.65
8-left	5.65	73.05	14.77	2.22	2.25	0.54	14.57
9-left	5.54	72.70	15.10	2.68	2.55	0.61	14.14
8-right	5.50	73.37	14.01	2.12	2.10	0.23	14.48
9-right	5.50	73.15	15.38	2.03	1.92	0.28	14.48

Table ii

Cooked Steaks Animal I

Steak No.	Cook. Loss %	Shear lbs. force			Press Fluid %	Moisture %	Fat %	Nitrogen %
Semitendinosus								
1-left	42.55	5.00	5.00	5.75	34.12	58.30	11.87	14.80
2-left	43.28	6.75	6.25	5.50	33.78	56.00	17.11	14.72
1-right	43.09	7.00	6.00	7.00	32.55	57.40	10.71	14.83
2-right	42.86	5.75	6.50	5.00	33.88	57.05	13.25	14.50
5-left	42.40	4.25	5.50	6.25	31.16	55.03	16.31	14.33
6-left	41.99	6.00	4.75	6.50	32.17	55.80	14.82	14.62
5-right	35.25	4.75	6.00	5.75	33.61	55.60	14.05	14.49
6-right	49.64	6.25	6.00	5.50	35.16	54.00	20.94	14.59
Semimembranosus								
1-left	43.08	8.75	6.25	6.00	36.00	57.03	8.36	14.99
2-left	43.39	10.00	5.25	9.00	27.74	55.45	10.88	14.92
1-right	43.54	8.00	7.75	7.00	31.34	49.88	10.92	14.62
2-right	44.19	12.00	10.50	13.25	26.25	47.55	9.74	15.08
5-left	43.59	5.50	5.00	10.50	28.77	53.50	16.71	14.80
6-left	43.92	9.50	5.00	6.00	28.15	53.45	18.94	14.97
5-right	43.65	11.50	6.75	7.50	29.46	49.78	17.12	14.67
6-right	43.83	5.00	10.50	5.00	32.25	48.95	15.90	14.78

Table iii

Uncooked Steaks Animal II

Steak No.	pH	Moisture %	Fat %	Collagen Wt. Diff. %	Collagen H.P. %	Elastin %	Nitrogen %
Semitendinosus							
3-left	5.38	73.55	16.65	2.72	2.06	1.83	14.65
4-left	5.30	72.33	19.86	3.26	3.05	2.45	14.56
3-right	5.75	72.80	19.37	2.49	3.41	1.92	14.47
4-right	5.60	71.93	22.01	2.45	2.46	1.76	14.49
8-left	5.60	72.98	16.15	2.52	2.19	1.32	14.30
9-left	5.58	73.05	14.27	3.18	2.82	1.24	14.52
8-right	5.55	72.98	15.57	2.45	2.33	1.04	14.30
9-right	5.53	72.98	14.45	2.10	1.82	0.81	14.15
Semimembranosus							
3-left	5.50	73.60	12.12	1.75	1.93	0.27	14.28
4-left	5.51	72.10	18.22	2.34	3.46	0.49	14.17
3-right	5.50	72.88	15.58	2.22	2.06	0.26	14.01
4-right	5.53	72.25	18.04	2.49	2.40	0.40	14.37
8-left	5.70	71.38	24.10	2.35	3.30	0.65	14.19
9-left	5.70	71.68	21.87	1.58	2.51	0.55	14.37
8-right	5.60	71.23	23.51	2.08	3.42	0.28	14.46
9-right	5.55	71.90	20.32	2.48	3.22	0.38	14.41

Table iv

Cooked Steaks Animal II

Steak No.	Cook. Loss %	Shear lbs. force			Press Fluid %	Moisture %	Fat %	Nitrogen %
Semitendinosus								
1-left	44.23	8.50	9.00	9.25	32.70	56.40	10.17	14.61
2-left	43.65	9.00	7.00	9.50	34.10	56.55	10.59	14.59
1-right	44.25	7.25	8.00	9.25	31.75	56.68	10.81	15.16
2-right	44.44	9.00	7.25	6.50	32.45	55.58	14.51	14.85
5-left	43.55	7.75	5.75	6.00	34.67	54.50	16.82	14.74
6-left	44.33	5.50	7.00	8.50	35.22	54.00	14.38	14.75
5-right	43.90	5.50	7.00	7.00	33.57	55.00	18.36	14.96
6-right	43.31	5.50	4.75	6.50	34.53	54.45	17.86	14.85
Semimembranosus								
1-left	42.93	7.50	6.50	11.25	29.74	55.95	11.31	14.83
2-left	43.67	13.00	10.00	9.50	27.27	55.93	11.34	14.79
1-right	43.70	8.00	10.50	10.75	31.91	55.55	10.25	14.93
2-right	44.08	12.25	10.50	8.25	25.36	54.38	11.82	15.36
5-left	43.37	12.25	4.75	5.25	32.27	54.33	17.90	14.33
6-left	43.79	9.50	3.00	5.00	34.56	53.70	20.18	14.75
5-right	44.17	9.50	5.50	5.25	34.55	53.70	17.71	14.78
6-right	44.05	4.50	8.75	4.75	35.20	53.20	18.06	14.49

Table v

Uncooked Steaks Animal III

Steak No.	pH	Moisture %	Fat %	Collagen Wt. Diff. %	Collagen H.P. %	Elastin %	Nitrogen %
Semitendinosus							
3-left	5.70	73.08	16.65	2.46	2.28	2.17	14.59
4-left	5.60	72.40	18.97	2.69	2.03	2.25	14.70
3-right	5.60	73.40	15.71	2.24	3.57	2.06	14.38
4-right	5.60	72.60	18.32	1.99	3.58	1.83	14.54
8-left	5.55	72.20	17.68	3.20	2.67	1.87	14.55
9-left	5.55	73.00	16.28	2.55	2.70	1.39	14.67
8-right	5.50	72.60	16.66	2.35	2.45	1.86	14.83
9-right	5.45	72.80	16.17	2.28	1.98	1.29	14.69
Semimembranosus							
3-left	5.60	73.90	8.39	1.81	1.73	0.21	14.43
4-left	5.50	72.95	12.11	2.16	1.86	0.62	14.69
3-right	5.68	73.90	9.52	1.90	1.72	0.18	14.66
4-right	5.63	72.60	14.61	2.32	2.22	0.35	14.43
8-left	5.50	72.58	17.04	2.14	1.87	0.30	14.68
9-left	5.55	71.93	18.62	2.07	3.03	0.44	14.51
8-right	5.50	72.83	16.01	2.27	1.96	0.49	14.42
9-right	5.50	72.30	17.38	2.26	1.97	0.34	14.78

Table vi

Cooked Steaks Animal III

Steak No.	Cook. Loss %	Shear lbs. force			Press Fluid %	Moisture %	Fat %	Nitrogen %
Semitendinosus								
1-left	43.81	8.50	9.75	8.00	34.38	56.53	9.66	15.13
2-left	43.20	8.25	10.75	7.25	33.76	54.90	16.03	14.93
1-right	43.12	10.75	8.25	7.50	34.86	56.70	9.53	15.18
2-right	43.70	8.00	8.75	5.75	34.43	56.05	12.46	14.88
5-left	43.64	7.00	8.25	9.25	33.02	53.83	17.28	14.93
6-left	42.40	7.75	6.50	9.50	35.80	53.07	18.50	14.94
5-right	43.97	6.75	9.00	4.75	28.91	53.65	21.25	15.07
6-right	43.75	7.75	8.25	5.50	37.82	52.80	22.71	14.91
Semimembranosus								
1-left	41.95	13.50	12.50	11.00	32.98	54.88	12.94	15.14
2-left	42.19	17.00	11.75	17.00	31.72	54.48	13.35	15.23
1-right	42.34	10.50	10.50	11.50	29.02	54.20	15.43	15.10
2-right	42.72	13.75	11.50	14.00	28.67	55.10	11.46	14.95
5-left	43.53	16.00	9.00	11.75	32.99	54.00	12.76	15.05
6-left	43.55	14.25	9.50	5.75	28.57	54.38	14.72	14.88
5-right	42.75	9.50	8.75	13.00	27.88	52.55	16.78	15.09
6-right	43.21	15.50	5.50	6.00	26.42	53.50	16.47	15.06

Table vii

Uncooked Steaks Animal IV

Steak No.	pH	Moisture %	Fat %	Collagen		Elastin %	Nitrogen %
				Wt. Diff. %	H.P. %		
Semitendinosus							
3-left	6.78	72.55	18.70	2.42	2.49	1.85	14.41
4-left	6.85	71.73	21.73	2.61	2.84	2.14	14.53
3-right	6.73	72.30	18.01	2.63	1.86	1.68	13.94
4-right	6.70	71.05	22.79	3.50	2.56	1.96	14.30
8-left	6.58	72.30	16.21	2.26	2.18	1.25	14.44
9-left	6.55	72.00	16.91	1.22	2.42	1.00	14.04
8-right	6.70	72.15	16.91	3.60	2.50	1.20	14.05
9-right	6.60	72.25	17.05	0.88	2.33	0.89	14.24
Semimembranosus							
3-left	6.73	73.75	11.03	1.84	1.71	0.42	14.36
4-left	6.65	73.15	15.06	1.99	1.18	0.42	14.49
3-right	6.80	72.30	13.57	2.44	2.22	0.55	14.38
4-right	6.70	71.45	16.54	2.78	2.26	0.68	14.19
8-left	6.35	71.20	21.77	2.74	2.01	0.42	14.41
9-left	6.30	70.20	25.34	4.17	2.26	0.77	14.22
8-right	6.30	70.95	22.17	4.48	2.08	0.35	14.12
9-right	6.25	70.10	23.46	2.91	2.30	0.36	14.31

Table viii

Cooked Steaks Animal IV

Steak No.	Cook. Loss %	Shear lbs. force			Press Fluid %	Moisture %	Fat %	Nitrogen %
Semitendinosus								
1-left	31.52	4.50	4.00	4.25	35.81	63.60	7.84	14.73
2-left	30.71	4.25	4.25	4.75	35.74	62.80	12.55	14.31
1-right	32.41	4.75	4.75	5.25	35.33	60.80	12.52	14.01
2-right	32.52	4.75	5.50	5.25	36.99	60.50	13.28	14.60
5-left	29.10	4.50	4.00	3.50	41.55	60.93	20.82	14.79
6-left	30.16	5.00	5.25	4.25	39.39	60.85	18.38	14.84
5-right	30.66	4.50	6.00	4.50	40.32	58.90	18.64	14.74
6-right	31.11	5.50	5.00	4.00	39.09	59.30	16.14	14.83
Semimembranosus								
1-left	28.30	4.50	6.00	4.50	39.19	61.80	13.18	14.45
2-left	30.83	5.25	5.50	6.25	37.76	61.60	12.62	14.47
1-right	28.86	5.00	5.75	5.50	38.05	61.00	14.05	14.48
2-right	30.60	7.75	7.75	4.50	32.87	61.45	10.17	14.41
5-left	35.52	6.25	10.00	6.75	39.09	57.90	18.01	14.66
6-left	37.15	9.00	9.50	6.50	33.61	57.23	15.94	14.89
5-right	36.11	6.75	8.50	7.00	36.44	56.65	15.57	14.55
6-right	37.11	6.00	9.50	8.75	41.81	57.00	17.01	14.40

Table ix

Uncooked Steaks Animal V

Steak No.	pH	Moisture %	Fat %	Collagen Wt. Diff. %	Collagen H.P. %	Elastin %	Nitrogen %
Semitendinosus							
3-left	5.70	72.08	23.79	3.25	3.10	2.41	13.59
4-left	5.70	70.05	28.56	4.50	3.58	2.66	13.92
3-right	5.70	71.60	24.20	4.11	3.18	2.24	13.70
4-right	5.70	70.00	28.33	4.29	3.28	2.38	13.98
8-left	5.65	71.50	25.22	5.92	3.28	2.01	13.66
9-left	5.60	71.90	21.94	3.95	3.84	1.60	13.64
8-right	5.68	70.55	26.87	3.99	3.60	1.72	13.72
9-right	5.68	71.45	22.36	3.62	3.50	1.98	14.10
Semimembranosus							
3-left	5.65	72.75	17.20	2.73	2.66	0.47	13.62
4-left	5.60	71.80	21.98	2.81	2.81	0.81	13.68
3-right	5.55	72.45	18.16	2.82	2.38	0.33	14.05
4-right	5.55	71.60	22.36	3.13	2.24	0.36	13.86
8-left	5.58	71.40	24.64	4.66	2.20	0.31	13.85
9-left	5.60	71.00	25.74	6.09	3.37	0.43	13.93
8-right	5.48	70.30	27.41	4.79	3.25	0.48	13.98
9-right	5.48	71.03	25.22	3.44	2.70	0.51	13.46

Table x

Cooked Steaks Animal V

Steak No.	Cook. Loss %	Shear lbs. force			Press Fluid %	Moisture %	Fat %	Nitrogen %
Semitendinosus								
1-left	41.56	9.00	7.00	7.25	33.85	56.20	16.52	14.17
2-left	40.71	9.25	8.00	6.50	33.33	55.45	19.92	14.07
1-right	42.27	7.75	7.00	6.25	32.38	56.13	16.53	14.34
2-right	41.82	6.75	5.75	6.25	32.74	54.80	20.37	14.46
5-left	42.59	6.50	4.50	7.00	35.91	52.00	27.61	14.24
6-left	42.98	4.25	6.00	5.25	34.96	53.65	22.87	14.09
5-right	43.56	5.50	6.25	6.75	34.73	53.15	23.07	14.04
6-right	42.86	6.75	6.00	7.25	36.54	53.30	19.84	13.82
Semimembranosus								
1-left	42.53	13.00	5.00	14.00	28.18	55.65	14.60	14.11
2-left	43.42	18.00	9.25	15.00	25.95	54.25	16.69	14.14
1-right	41.99	11.75	7.25	13.25	30.67	55.70	12.63	13.94
2-right	42.93	9.50	5.50	13.50	29.91	54.75	15.34	14.29
5-left	41.20	11.25	4.50	5.50	35.09	52.25	26.06	14.28
6-left	44.48	9.50	2.25	3.50	36.17	52.15	26.34	14.94
5-right	42.69	5.75	4.50	12.75	35.56	51.50	26.89	13.97
6-right	42.56	8.25	4.75	3.75	31.34	50.70	29.64	13.98

Table xi

Uncooked Steaks Animal VI

Steak No.	pH	Moisture %	Fat %	Collagen Wt. Diff. %	Collagen H.P. %	Elastin %	Nitrogen %
Semitendinosus							
3-left	5.68	75.05	17.51	3.95	3.46	1.01	13.86
4-left	5.63	73.95	16.70	4.47	4.34	0.82	13.81
3-right	5.55	74.30	19.63	4.69	3.47	1.27	13.68
4-right	5.55	74.13	19.71	5.32	4.74	1.41	13.84
8-left	5.65	76.10	11.87	3.55	3.04	0.71	14.22
9-left	5.63	74.65	15.49	4.35	3.83	0.73	14.32
8-right	5.60	74.70	16.11	4.95	4.24	1.07	14.35
9-right	5.60	75.10	13.57	4.65	4.34	0.86	14.44
Semimembranosus							
3-left	5.40	74.35	11.79	3.18	3.09	0.36	14.21
4-left	5.45	73.38	15.43	3.97	3.67	0.42	13.89
3-right	5.50	74.95	9.96	3.29	3.04	0.17	14.00
4-right	5.50	74.30	14.94	4.01	3.75	0.30	14.08
8-left	5.48	73.90	16.17	3.95	3.38	0.35	14.11
9-left	5.48	73.70	16.65	4.08	3.70	0.65	14.11
8-right	5.35	74.00	16.08	3.63	3.32	0.37	14.32
9-right	5.43	74.00	15.87	4.28	3.55	0.55	13.81

Table xii

Cooked Steaks Animal VI

Steak No.	Cook. Loss %	Shear lbs. force			Press Fluid %	Moisture %	Fat %	Nitrogen %
Semitendinosus								
1-left	45.75	6.25	5.75	5.50	34.74	57.23	11.41	14.40
2-left	47.45	5.75	6.00	5.25	30.91	55.73	14.34	14.01
1-right	46.31	4.50	6.25	6.50	34.15	57.25	12.01	14.70
2-right	46.84	5.00	4.75	5.25	36.96	56.50	13.97	14.93
5-left	47.10	4.75	6.00	5.25	34.19	53.85	22.39	14.48
6-left	47.40	5.75	7.00	5.25	33.04	56.10	14.31	14.35
5-right	47.16	4.50	6.00	3.75	34.35	55.95	15.23	14.68
6-right	47.56	4.25	6.50	4.50	32.54	56.05	14.39	14.64
Semimembranosus								
1-left	45.06	9.25	4.50	5.50	31.62	56.50	9.36	14.53
2-left	45.19	11.00	5.25	5.75	30.91	56.35	10.31	14.24
1-right	45.29	7.50	8.50	7.75	23.30	56.63	8.66	14.28
2-right	46.27	8.25	9.25	11.00	29.71	55.80	8.93	13.98
5-left	46.75	6.50	4.25	4.50	29.71	55.40	15.77	14.68
6-left	46.39	10.75	4.25	4.75	25.94	56.63	12.65	14.49
5-right	46.35	5.25	5.75	12.00	33.58	55.35	13.08	14.40
6-right	46.13	4.00	7.25	10.75	32.62	55.03	14.98	14.44