A QUALITY APPRAISAL OF TWO SHOULDER CUTS OF BEEF UNDER FOUR ROASTING CONDITIONS

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ABSTRACT

Consumer size round bone shoulder and cross rib roasts of beef were cooked at each of two oven temperatures: 107°C and 163°C to each of two internal temperatures: 70°C and 80°C. For each roast type, two roasts were cut from both sides of each of four animals yielding a total of 16 round bone shoulder roasts and 16 cross rib roasts. A Latin Square design replicated four times was used to assess the effect of the four cooking conditions. Treatment arrangement permitted assessment of differences between animals, sides and roast cuts as well as cooking conditions. Quality assessment included edible yield, proximate analysis, force to shear the cooked sample and sensory panel judging. Shear force values obtained on all muscles occurring within the two roast types were combined into weighted means for each roast type. Costs per edible portion were considered.

Yields for the round bone shoulder roast were not different among cooking conditions. However for the cross rib, yields were significantly lower when cooking was done at the lower oven temperature and to the higher internal temperature due mainly to higher evaporation losses. In all cases, edible yield was higher for the cross rib roasts than for the round bone shoulder roasts due to the larger proportion of bone present in the latter. The cross rib roasts were still slightly more expensive per serving than the round bone

shoulder roasts when the retail price difference between the two was $0.20 per pound. For both roast types edible yield tended to be higher for the first cut than for the second cut, however this was only partially attributable to bone. Fat trimmed from the exterior of the roasts and intermuscular waste were also greater in the second cut of the round bone shoulder and cross rib, respectively. Proximate composition of the edible yield was not different between the two roast types. There were minimal differences in yield among animals and no differences in yield between right and left sides of animals.

Weighted means of shear values indicated that both roast types were most tender when cooked at the lower oven temperature of 107°C and to the higher internal temperature at this oven temperature; this was the condition which least favored edible yield. At the oven temperature of 163°C, cooking to the higher internal temperature increased the tenderness of the round bone shoulder roast only. Of all muscles studied, the tenderness of only four muscles differed appreciably among roasting conditions. The deltoideus, deep pectoral, triceps brachii (lateral head) and brachialis muscles in the round bone shoulder were significantly more tender when cooked at 107°C to 80°C than when cooked at 163°C to 70°C. Significant differences among animals were found in weighted means of muscle shear values. No differences in tenderness were found between right and left sides of animals.

The round bone shoulder roast was most well-liked by a 26 member untrained panel when cooked at 107°C to 80°C, however the cross rib roast was equally well-liked under all cooking conditions. Criticisms of tenderness were reflected in hedonic scores to a greater extent in the round bone shoulder roast than in the cross rib roast. As yields for the round bone shoulder were not appreciably different among roasting conditions, its tenderness response clearly defined its best roasting condition, 107°C to 80°C. With the cross rib however, as yields were affected appreciably by the roasting conditions and its tenderness response was less defined, 107°C to 70°C was considered the best roasting condition.

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INTRODUCTION

Meat is the center of the menu and generally the most expensive item of the day's main meal. Of all meats, beef is the most popular in North America. For maximum palatability it is agreed that beef should be tender (Macdonald, 1963). However, steers are not all steaks and prime rib roasts; in fact, of the beef carcass only 26 to 28.5% is considered to be made up of tender cuts (Swift Canadian Co., Limited, 1961; Council of Canadian Beef Producers, 1964). A variable additional amount is made tender by grinding.

Most cookbooks recommend using moist heat to cook chuck or shoulder roasts. Meat that is pot-roasted or braised can be very acceptable, but it is quite a different product from a dry-heat cooked roast. In 1965, Nielsen and Hall showed that blade roasts cooked by dry heat were juicier than those cooked by braising. Several studies have shown that, other things being equal, most people prefer the flavor achieved by a cooking environment that permits surface evaporation, the flavor that has been associated with steaks, rib roasts and loin cuts (Cover, 1941a; Cover and Shrode, 1955; Griswold, 1955a; Hood, 1960).

Early research has shown that the triceps brachii (TB) from the chuck can be as tender as the longissimus dorsi (LD) of the rib when both are roasted at low temperatures (Cover, 1943).

However, slow cooking such as that used by Cover (1943) has been given very little consideration for use in the home as the long cooking time was considered inconvenient. However, with today's automatic ovens and more homemakers working outside the home, a long cooking time may be a convenience rather than a nuisance. Costs for fuel energy have been found negligible between heating at 107°C and 163°C (Nielsen and Hall, 1965).

Research work, for consistent results, is most commonly conducted with individual muscles. However consumers have access to roasts that generally contain several muscles. Accordingly, in the present study, roasts were used as the primary experimental sample, while the behavior of individual muscles was examined on a sub-unit basis.

In 1965, Nielsen and Hall reported findings in favor of slow, dry heat cooking of blade roasts. The present work involved the study of two other common cuts from the chuck, the round bone shoulder (RBS) and cross rib (CR). These roasts were cooked to 70°C and 80°C at both 107°C and 163°C. The objective was to establish the best dry heat cooking method for both roasts and to establish their relative advantage to the consumer. Quality assessment included edible yield, force to shear the cooked sample, sensory panel judging and proximate analysis.

For the sake of brevity, the names of the two roast types being examined and the majority of the muscle names have been abbreviated. For quick reference see glossary in Appendix D.

REVIEW OF LITERATURE

With meat that is consistent in breed, rearing practice, slaughter conditions and aging, the tenderness of the cooked product will be dependent on its location in the carcass and the cooking method. In this study the two types of meat being examined are both from the shoulder of the animal and within replicates, originated from the same animal. Hence, background features of the meat were common among all treatments studied.

Retail Shoulder Cuts of Beef

The cutting of a carcass or wholesale cuts into retail cuts is not standardized throughout North America. However, essentially all the methods agree with the recommendation of Ramsbottom and Strandine (1948) that muscles of similar tenderness should be grouped so that the occurrence of tender and less tender portions within a roast or steak is minimized.

The Canadian methods of dividing the beef carcass into wholesale and retail cuts are similar to those described in the United States as Chicago or midwestern style (National Live Stock and Meat Board, 6th ed.), except that by the Canadian method, two ribs instead of one are left on the hindquarter (Council of Canadian Beef Producers, 1964).

Beef carcasses are sold to retailers in the form of wholesale cuts, that is, as sides, quarters and small units known as primal cuts. A small amount of fat and bone is trimmed away when a carcass is cut into wholesale cuts (Pecot et al., 1965).

From the forequarter come the primal cuts known as the rib, the square-cut chuck, the foreshank, the short plate, and the brisket.

In separating the forequarter into primal cuts, the first cut removes the short plate, the brisket and the foreshank (Lattin and Carson, 1934). Next, the rib is removed;

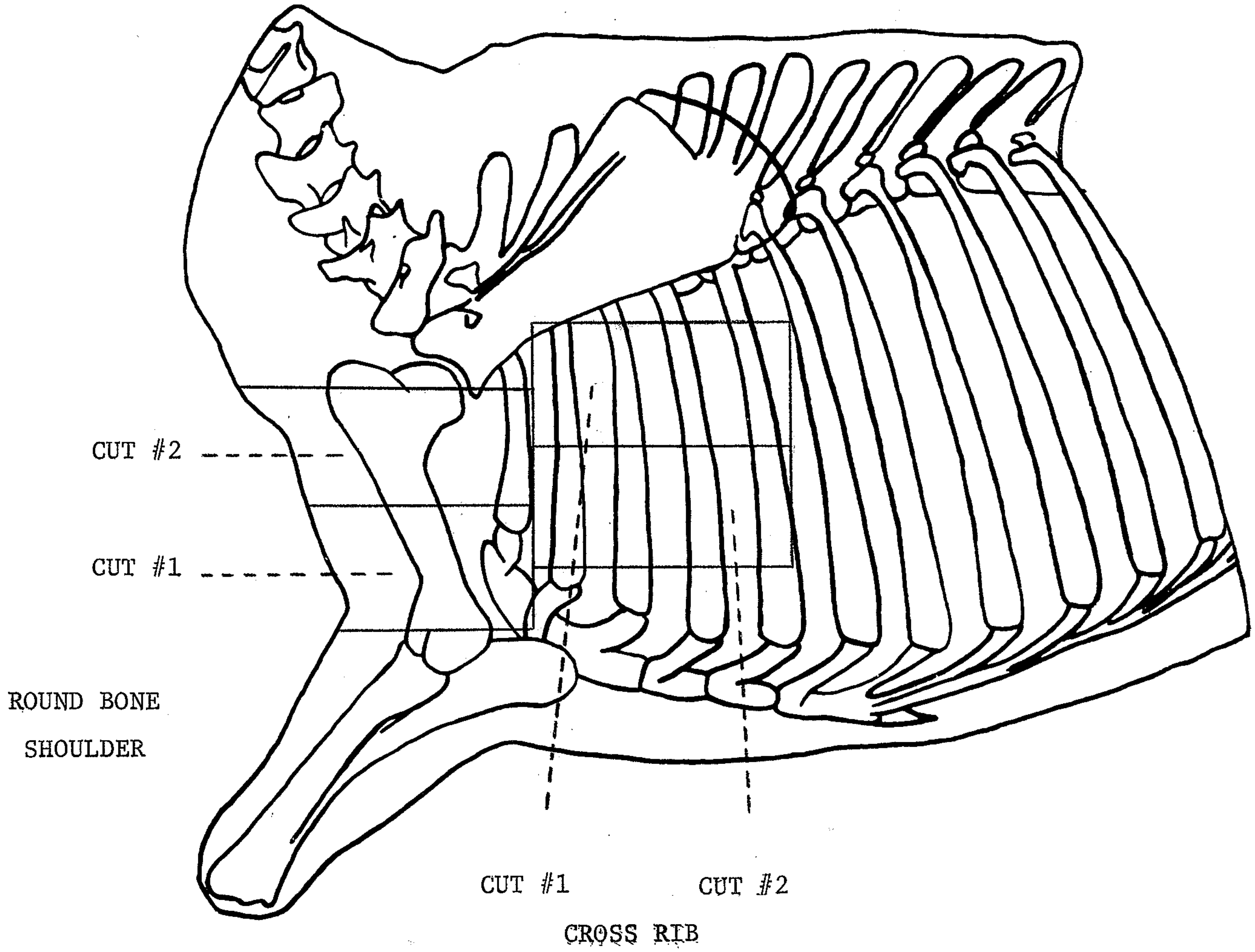


FIGURE 1. Location of the roasts in the forequarter.

it is cut between the fifth and sixth ribs counting from the neck end of the forequarter. The remainder is called the chuck and the neck, or combining the two, the square-cut chuck. The trimming of retail cuts may be slight or extensive depending on such factors as the finish of the carcass, the price of the meat and the demands of consumers (Pecot et al., 1965).

The square-cut chuck accounts for 25 to 26% of the beef carcass and yields retail cuts such as blade roasts and steaks, arm roasts and steaks, boneless chuck roasts, CR roasts, ground beef and stewing beef (Council of Canadian Beef Producers, 1964).

Blade roasts and steaks are taken from the upper part of the square-cut chuck, next to the prime rib side. They are cut above the CR roasts, approximately perpendicular to them (Figure 1). The roasts are also called blade pot-roasts (National Live Stock and Meat Board, 6th ed.).

The CR roast is taken from the lower side of the square-cut chuck, next to the prime rib (Figure 1). It contains about four ribs and can be called the short-rib or the Boston cut or the English cut. The ribs can vary in length from two to six inches and the cut is often described as rectangular (National Live Stock and Meat Board, 6th ed.).

Arm roasts and steaks contain the knuckle bone and may or may not contain cross sections of the ribs depending on the method of cutting. These cuts are also known as the

RBS, the round shoulder and the shoulder (Figure 1). Frequently the term pot-roast is included in the roast labels, for example, arm pot-roast, shoulder pot-roast etc.

Any part of the square-cut chuck may be deboned, rolled and labelled as a boneless chuck or shoulder roast, however it is usually taken from the forward side of the chuck. If it is mainly from the neck it is labelled as boneless neck (Lattin and Carson, 1934).

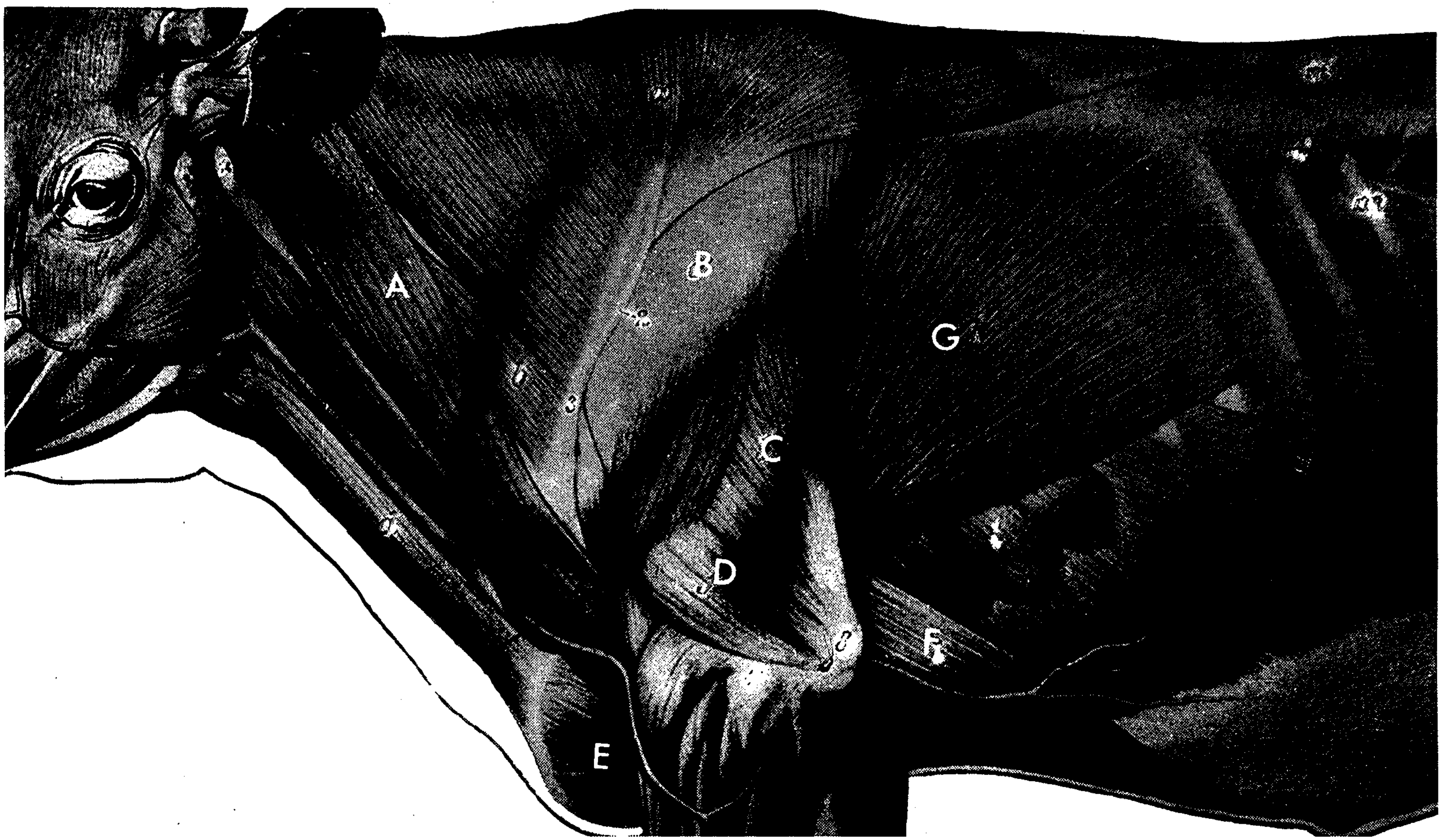
Stewing beef and hamburger are made from trimmings from the neck, shank and flank.

Description of the Muscles present in the Round Bone Shoulder and Cross Rib Roasts

This section will deal with a brief description of the location and action of each of the muscles that the author was able to identify in the two roast types used in the study, the RBS and CR. Figure 1 shows the exact location of the roasts in the forequarter of the carcass and Figure 2 shows the location of several of the identified superficial muscles in the animal. The muscles of both roast types are the muscles of the thoracic limb with the exception of two muscles of the CR roast; the scalenus dorsalis which occurs in the neck and the external and internal intercostals which occur in the thorax. Figures 3 - 6 show the location of the muscles within the cuts before trimming and/or boning; they also show in progression the change in proportion of the muscles and bones from the first cut through to the second cut. The figures are divided into two sections; the CR is the upper section and the RBS, the lower.

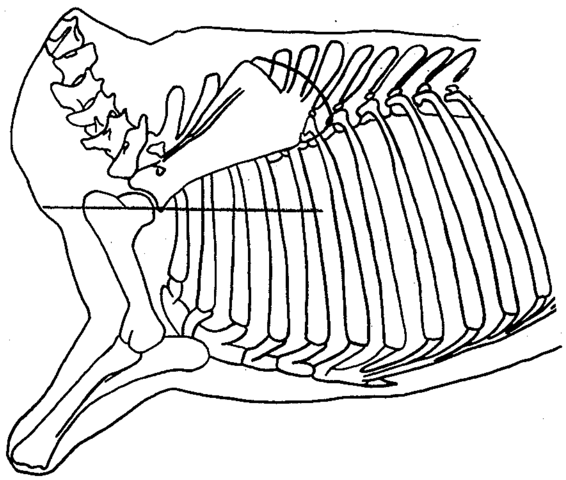
The reader is referred to "The Anatomy of the Domestic Animals" by Sisson and Grossman (1947) for more detailed descriptions than are given in the following discussion.

The muscles identified, in order of decreasing proportion, in the RBS and CR roasts, were as follows:



A, Brachiocephalicus; B, Deltoideus; C, Triceps brachii (long head); D, Triceps brachii (lateral head); E, Superficial pectoral; F, Deep pectoral; G, Latissimus dorsi.

FIGURE 2. Superficial muscles of the neck, shoulder and thorax present in the two roasts. (From Sisson and Grossman, 1947)



Muscles

- A Brachiocephalicus
- B Deep pectoral
- C Tendon of biceps brachii
- D Coracobrachialis
- E Deltoideus
- F Teres minor*
- G Triceps brachii (long head)
- H Tensor fasciae antibrachii
- I Latissimus dorsi
- J Sternocephalicus*
- K Subscapularis*
- L Teres major
- M Scalenus ventralis*
- N Scalenus dorsalis
- O Serratus ventralis*
- P Intercostal muscles

Bones

- 1 Humerus
- 2 Scapula
- 3 Ribs

Rib Fingers - muscle P

*Not visible in the roasts used.

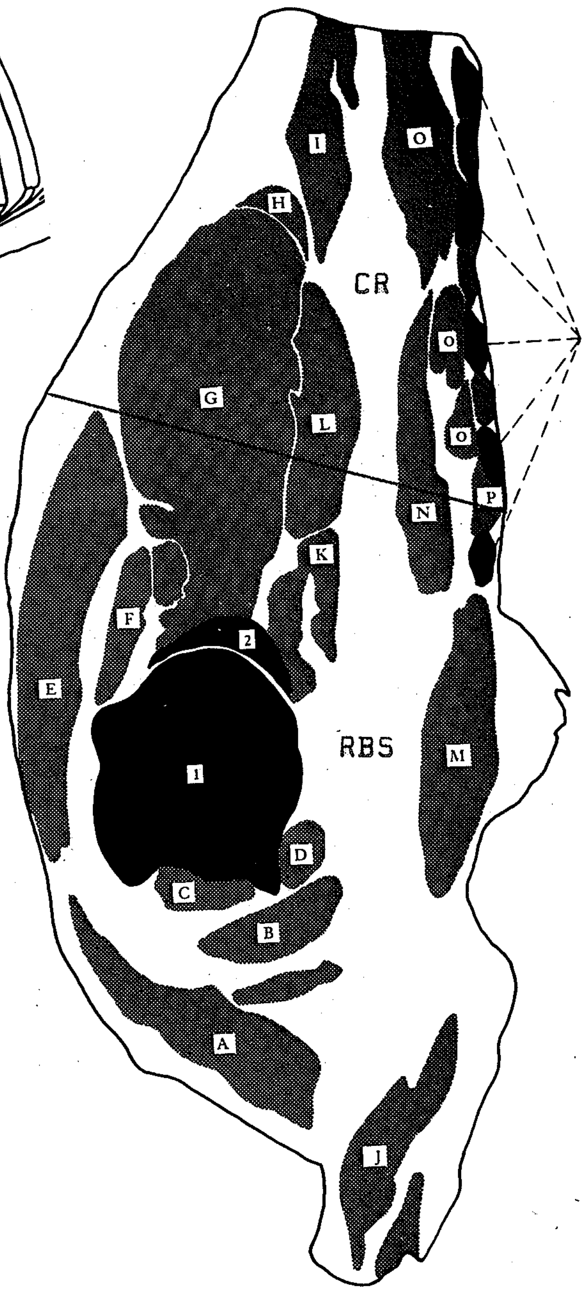
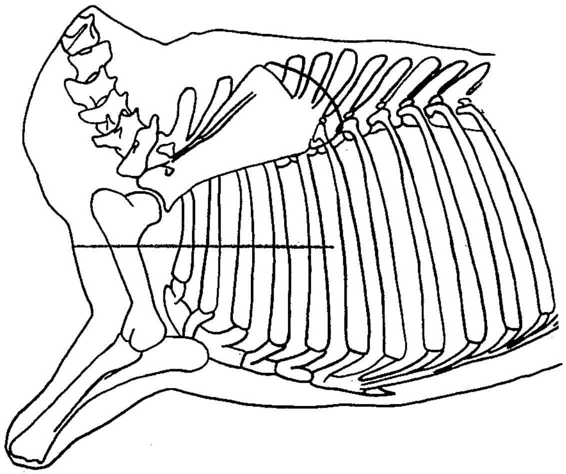
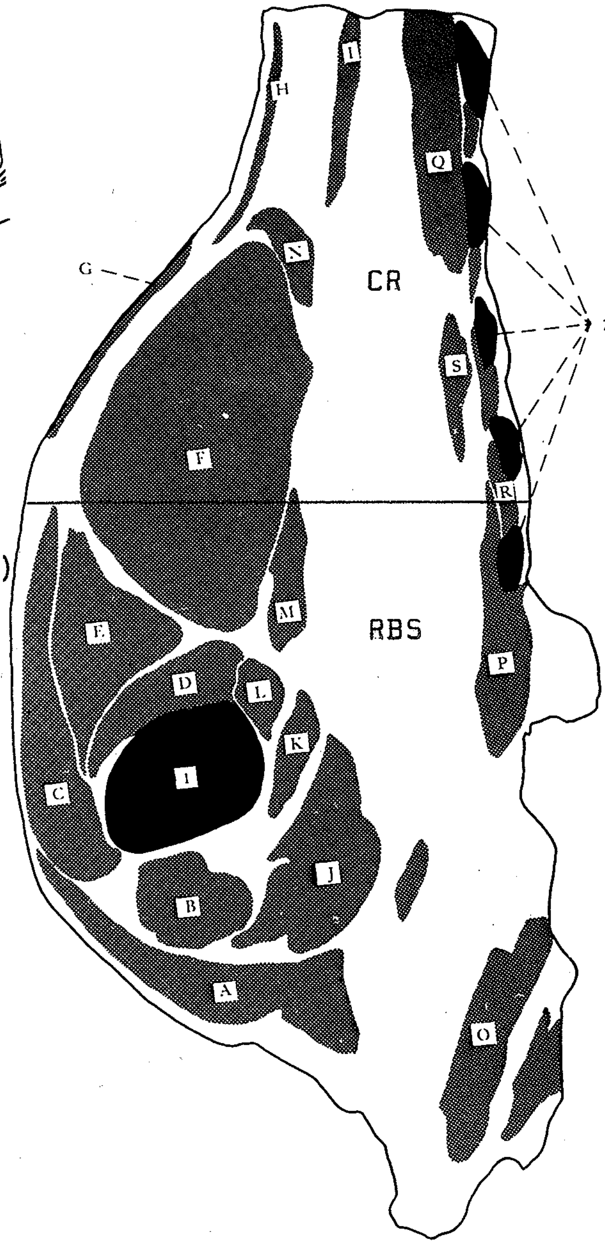


FIGURE 3. Size and shape of the muscles and bones of the square-cut chuck at the position indicated on the skeletal diagram of the carcass. (From Tucker *et al.*, 1952)





Muscles

A Brachiocephalicus
B Biceps brachii
C Deltoideus
D Brachialis
E Triceps brachii (lateral head)
F Triceps brachii (long head)
G Cutaneus omo-brachialis*
H Cutaneus trunci*
I Latissimus dorsi
J Deep pectoral
K Coracobrachialis
L Triceps brachii (medial head)
M Teres major
N Tensor fasciae antibrachii
O Sternocephalicus*
P Scalenus ventralis*
Q Serratus ventralis*
R Intercostal muscles
S Scalenus dorsalis

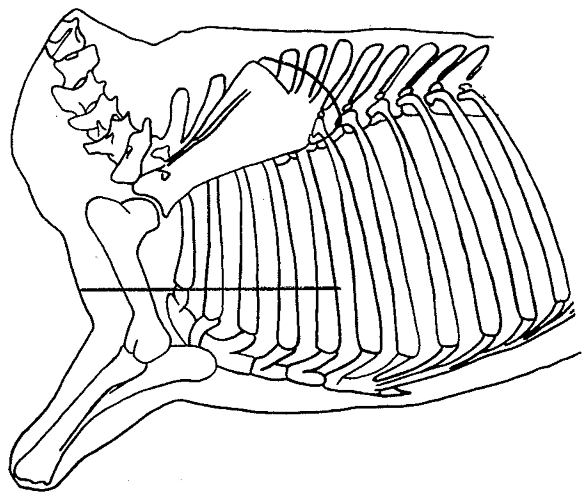
Bones

1 Humerus
2 Ribs

Rib Fingers - muscle R

*Not visible in the roasts used.

FIGURE 4. Size and shape of the muscles and bones of the square-cut chuck at the position indicated on the skeletal diagram of the carcass. (From Tucker et al., 1952)



Muscles

- A Brachiocephalicus
- B Biceps brachii
- C Brachialis
- D Triceps brachii (lateral head)
- E Triceps brachii (long head)
- F Tensor fasciae antibrachii
- G Cutaneus trunci*
- H Coracobrachialis
- I Triceps brachii (medial head)
- J Deep pectoral
- K Superficial pectoral
- L Rectus thoracis*
- M Intercostal muscles
- N Serratus ventralis*

Bones

- 1 Humerus
- 2 Ribs

Rib Fingers - muscle M

*Not visible in the roasts used.

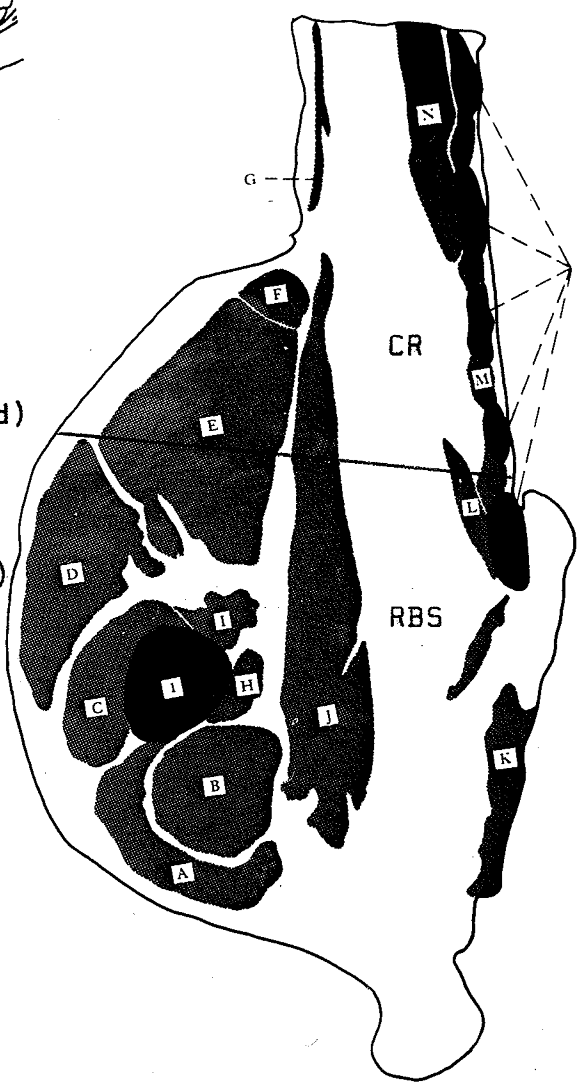
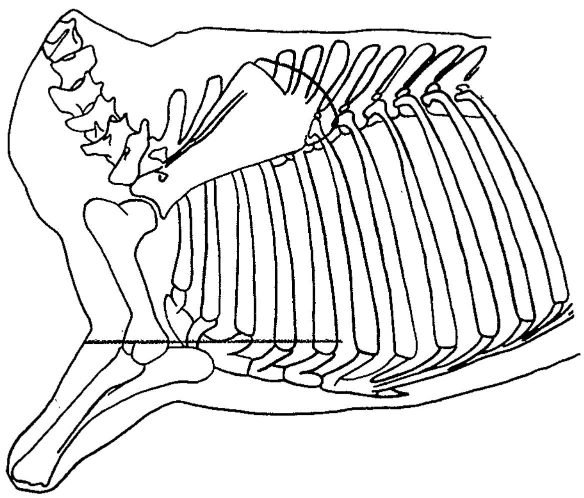
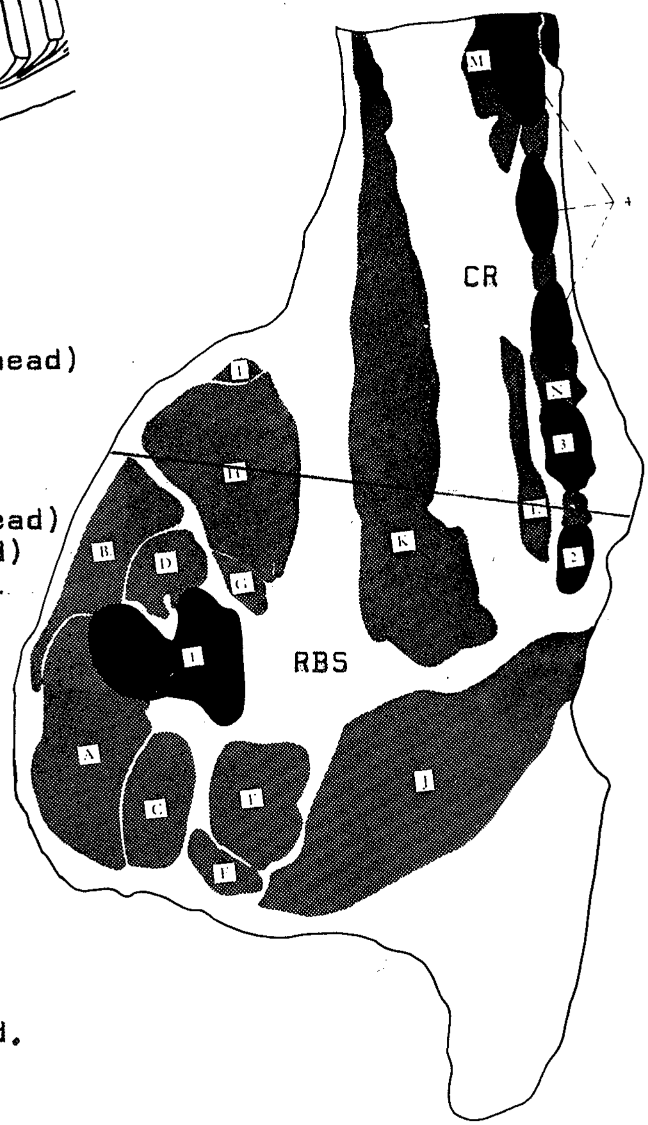


FIGURE 5. Size and shape of the muscles and bones of the square-cut chuck at the position indicated on the skeletal diagram of the carcass. (From Tucker _et al._, 1952)





Muscles

- A Extensor carpi radialis*
- B Triceps brachii (lateral head)
- C Brachialis
- D Anconeus*
- E Brachiocephalicus
- F Biceps brachii
- G Triceps brachii (medial head)
- H Triceps brachii (long head)
- I Tensor fasciae antibrachii
- J Superficial pectoral
- K Deep pectoral
- L Rectus thoracis*
- M Serratus ventralis*
- N Intercostal muscles

Bones

- 1 Humerus
- 2 Sternum cartilage
- 3 Costal cartilage
- 4 Ribs

Rib Fingers - muscle N

*Not visible in the roasts used.

FIGURE 6. Size and shape of the muscles and bones of the square-cut chuck at the position indicated on the skeletal diagram of the carcass. (From Tucker et al., 1952)

RBS	CR
Triceps brachii (TB) (long head)	Triceps brachii (TB) (long head)
Deep pectoral (DP)	Intercostal muscles (IM)
Triceps brachii (TB) (lateral head)	Teres major (TM)
Biceps brachii (BB)	Latissimus dorsi (LTD)
Brachiocephalicus (BC)	Deep pectoral (DP)
Deltoideus (DE)	Scalenus dorsalis (SD)
Brachialis (BR)	Tensor fasciae antibrachii (TFA)
Tendon of Biceps brachii (TBB)	
Coracobrachialis (CB)	
Superficial pectoral (SP)	
Triceps brachii (TB) (medial head)	

The SD (Figures 3 and 4) arises on the transverse processes of the fourth, fifth and sixth cervical vertibrae and ends on the fourth rib. It is composed of several small fleshy bundles and acts with the scalenus ventralis to flex the neck and fix or pull forward the first rib during respiration. Acting alone, it inclines the neck laterally.

The IM (Figures 3 - 6) extend the entire length of the intercostal spaces and are subdivided by a thin fascia into external and internal sets. The fibers of the external intercostal muscles are directed downward and backward and there is a considerable admixture of tendinous tissue. The thickness of the external set diminishes ventrally while that of the internal set diminishes dorsally. The fibers of the internal set are directed downward and forward and there is a smaller amount of tendinous tissue than in the external set. It is commonly stated that the function of the external set is to pull the ribs forward in inspiration, while the internal set have the opposite action. But apparently they act together, narrowing the intercostal spaces and thus preventing the wall from being pushed out or pulled in during respiration.

Thoracic Limb

The muscles of the thoracic limb are divided into four groups: the muscles of the shoulder girdle, the muscles of the shoulder, the muscles of the arm, and the muscles of the forearm and manus. The fourth group of muscles are those of the wholesale cut known as the shank and since they do not occur in either of the two roast types, they will not be discussed.

Shoulder Girdle. The muscles of the shoulder girdle connect the thoracic limb with the head, neck and trunk and may be subdivided into dorsal and ventral sets.

The LTD (Figures 2 - 4) forms part of the dorsal set and occurs in the CR only. It is wide, shaped like a right-angled triangle and lies under the skin and cutaneous muscle on the lateral wall of the thorax, from the spine to the arm. It draws the humerus upward and backward, flexes the shoulder joint, and draws the trunk forward if the limb is advanced and fixed.

The remainder of the shoulder girdle muscles to be described belong to the ventral division. The BC (Figures 2 - 6) occurs in the RBS roast and is composed of two parts. It extends along the side of the neck from the head to the arm and draws the limb forward when the head and neck are fixed and conversely when the limb is fixed, it extends the head and neck. The two portions, acting separately, incline the head and neck to the same side.

The SP and DP muscles (Figures 2, 5, 6, and 2 - 6, respectively) form a large fleshy mass which occupies the space between the ventral part of the chest-wall and the shoulder and arm. The two muscles are covered and separated from one another by a thin membrane called the pectoral fascia. The function of the SP is to adduct and advance the limb and to tense the fascia of the forearm. The DP adducts and retracts the limb and draws the trunk forward if the limb is advanced and fixed. The SP occurs in the RBS only while the DP, the larger of the two muscles, occurs in both roasts.

Shoulder. The muscles of the shoulder arise on the scapula and end on the arm. They may be divided into lateral and medial groups.

The DE (Figures 2 - 4) belongs to the lateral group and lies partly on the TB in the angle between the scapula and humerus and partly on the infraspinatus (IF) and teres minor. It is clearly divided into two parts which act together to flex the shoulder joint and abduct the arm.

The CB (Figures 3 - 5) lies on the medial surface of the shoulder joint and the arm, and is part of the medial set. It adducts the arm and flexes the shoulder joint.

The TM (Figures 3 and 4) also part of the medial group, is flat, widest about its middle, and lies chiefly on the medial face of the TB. Its function is the same as that of the CB.

Arm. The muscles of the arm arise from the scapula and the humerus and are inserted into the forearm.

The BB (Figures 4 - 6) is a fusiform muscle which lies on the exterior surface of the humerus. It is enclosed in a double sheath of fascia and has numerous tendinous intersections. The muscle flexes the elbow joint, fixes the shoulder and elbow in standing, assists the extensor carpi radialis and tenses the fascia of the forearm. The TBB (Figure 3) is long and thin, and like the BB, it is enclosed in a double sheath of fascia.

The BR (Figures 4 - 6) occupies the musculo-spiral groove of the humerus, flexes the elbow and is almost entirely fleshy.

The TFA (Figures 3 - 6) is a thin muscle which lies chiefly on the medial surface of the TB. Its action is to tense the fascia of the forearm and to extend the elbow joint.

The TB (Figures 2 - 6) together with the TFA constitutes the large muscular mass which fills the angle between the posterior border of the scapula and humerus. It is divisible into three heads.

The long head (Figures 2 - 6) is the largest and longest of the three heads and also the largest muscle in both roast types. It is thick and triangular and extends from the posterior border of the scapula to the olecranon. It extends the elbow joint and flexes the shoulder, and is penetrated by a tendinous intersection from which many fibers take origin obliquely.

The lateral head (Figures 2, 4 - 6) is a strong, quadrilateral muscle which lies on the lateral surface of the arm, and extends the shoulder joint.

The medial head (Figures 4 - 6) is the smallest of the three heads. It is situated on the medial surface of the arm and extends from the middle third of the humerus to the olecranon. Its function is to extend the elbow joint.

The involvement of these muscles in respiration and in movement of the head, neck, shoulders and front limbs indicates that these muscles should definitely be classed as "working" muscles.

The Structure of Muscle

As normally prepared for the meat trade, the beef carcass represents the portion of the body remaining after removal of the blood, head, feet, hide, digestive tract, intestines, bladder, heart, trachea, lungs, kidney, spleen, liver and adhering fatty tissue. On the average about 55% of the live weight of the animal remains on the carcass (Swift Canadian Co., Limited, 1961). The carcass itself consists of muscular, connective and fatty tissues, bone, large blood vessels and nerves.

Muscular Tissue

Muscular tissue accounts for only 49 to 68% of the carcass and varies inversely with that of fatty tissue, the latter being determined by such factors as age, breed and plane of nutrition (Callow, 1948). It is called striated, or cross-striped because of the parallel cross-stripes or striae which characterize its microscopic appearance, skeletal because it forms the muscles which are attached to the skeleton, somatic because it helps to form the body wall and voluntary because the movements accomplished are in some instances under conscious control.

The essential structural unit of all muscular tissue is the fiber. Fibers are long, narrow, multinucleated cells composed of a continuous mass of soft contractile matter in a tubular sheath or sarcolemma. Microdissection of a fiber shows cross-striped myofibrils surrounded by a fluid material called sarcoplasm. The cross-striations are due to alternating light (I) and dark (A) bands along the length of the myofibril. Each I band is bisected by a thin dark line called the Z line. The combination of an A and I band is called a sarcomere. Contraction of a muscle fiber is based on the sliding together of the actin and myosin myofilaments in the sarcomere (Kimber *et al.*, 1966).

Muscle fiber diameter normally varies within and along the length of any one muscle (American Meat Institute Foundation, 1960) and increases with increased animal age (Brady, 1937). As early as 1907, Lehmann observed that the most tender muscles had the smallest muscle fibers. Later workers (Moran and Smith, 1929; Hammond, 1932; Carpenter *et al.*, 1963) found similar evidence for the role of muscle fiber diameter in tenderness and Hiner *et al.* (1953) reported a significant correlation (r = 0.83) between muscle fiber diameter and relative tenderness in eight beef muscles.

Connective Tissue

Surrounding the muscle as a whole is a sheath of connective tissue, the epimysium. From the inner surface of the latter, septa of connective tissue penetrate into the muscle, separating the muscle fibers into bundles called fasiculi. These separating septa constitute the perimysium which contains the large blood vessels and nerves. From the perimysium a fine connective tissue framework, called the endomysium, passes further inwards to surround each individual muscle fiber.

According to Hammond (1932) texture, as seen by the eye, is a function of the size of the bundles of fibers into which the perimysial septa of connective tissue divide the muscle longitudinally. Fine-grained muscles such as the LD have small bundles and are more tender than coarse-grained muscles such as the semimembranosus (SM) which have large bundles (Brady, 1937; Hammond, 1940). The size of the bundles is determined not only by the number of fibers but also by the size of the latter. Coarseness of texture increases with age, but in muscles where the fibers are small it does not become quite so apparent as in those where they are large (Satorius and Child, 1938).

The size of the bundles is not the only factor determining texture, however. The amount of the perimysium around each bundle and the distinctiveness of the latter are also important; the perimysial layer being thin and the fasiculi indistinct in tender muscles (Ramsbottom _et al_., 1945; Ramsbottom and Strandine, 1949).

Connective tissue includes formed elements and an amorphous ground substance in which the formed elements are embedded. The latter consist of the fibers of collagen, which are straight, inextensible and non-branching; of elastin, which are elastic, branching and yellow in color; and of reticulin, which resembles collagen but is associated with substantial quantities of a lipid (Szczesniak and Torgeson, 1965). The proportion of these fibers and the composition of the ground substance differ with the tissue.

The smallest amount of structure to which the properties of collagen can be attributed is the protofibril. These are progressively aggregated into filaments, fibrils, primitive fibers and finally collagen fibers (Briskey *et al.*, 1966). Although there are some dissenting views, most workers agree that the connective tissue content of muscle ultimately affects the tenderness of the meat (Callow, 1957) and that the collagenous fibers are less abundant in more tender meat (Hiner *et al.*, 1955). Elastin forms thin, homogenous fibers and occurs in considerable amounts in the muscles of the rump only (Briskey *et al.*, 1966). Reticular fibers occur where connective tissue adjoins other tissues, as between the endomysial collagenous fibers and muscle fiber membranes or sarcolemma (American Meat Institute Foundation, 1960).

Fatty Tissue

Fat in meat occurs as adipose tissue, marbling and separable fat. Adipose tissue is a specialized form of connective tissue serving as a supporting substance, as a protective, insulating, contour-building, filling and structural material and as a depot of utilizable neutral fat (American Meat Institute Foundation, 1960). Marbling is the visible deposition of fat throughout the muscle tissue and separable fat refers to the fat deposition between muscles and on the surface of the cut (Szczesniak and Torgeson, 1965).

As the animal is fattened, a previously undifferentiated cell begins to store small globules of neutral fat. Eventually these coalesce into one large globule or adult cell, pushing the cytoplast and the nucleus of the cell to one side (American Meat Institute Foundation, 1960). The shape of the fat cell is spherical, but, when the cells accumulate in large masses to form fatty tissue, the shape is often polyhedral (Lowe, 1955). Fat tends to be deposited first around the internal organs and subcutaneously, later, around and between the muscles, and finally, as marbling (Griswold, 1962). Hammond (1940) states that the neck and thorax have large amounts of intermuscular fat whereas the leg has very little.

The term finish refers to the amount, quality and color of the marbling and separable fat and is one of the criteria used in grading beef carcasses. It has generally been thought to influence the tenderness of the meat however, studies reported on this relationship vary. Hankins and Ellis (1939), Wierbicki et al. (1956) and Sleeth et al. (1958) found no significant correlation between the degree of marbling and tenderness, and Simone et al. (1955) and Cover et al. (1958) found no significant correlation between the amount of separable fat and tenderness. Opposite views are represented by Batterman et al. (1952), Helser et al. (1930)

and Pearson and Miller (1950) who found that better-fattened animals yielded more tender meat than the less-well-finished ones.

Macdonald (1963) states that there is a mechanical advantage to marbling if the fat and its supporting connective tissue are more tender than the lean. Other workers (Batterman et al., 1952; Callow, 1957) feel that fat deposition must have at least an indirect relationship to tenderness, since the proportion of connective tissue decreases as the animal fattens.

Intramuscular fat content influences the sensation of juiciness. Juiciness in cooked meat has two organoleptic components. The first is the impression of wetness during the first few chews produced by the rapid release of meat fluid; the second is one of sustained juiciness largely due to the stimulatory effect of fat on salivation (American Meat Institute Foundation, 1960). This function of the latter explains why, for example, meat from young or less-well-finished animals gives an initial impression of juiciness but, due to the relative absence of intramuscular fat, ultimately a dry sensation (Gaddis et al., 1950). Since sustained juiciness during chewing leaves a more lasting impression than does the initial release of fluid, it is reasonable that juiciness scores have been correlated with intramuscular fat content rather than moisture content (Cover et al., 1958; Macdonald, 1963; American Meat Institute Foundation, 1960).

From the preceding discussion it appears that the structure of "working" muscles is characterized by a large muscle fiber diameter and primary bundle size and extensive development of intra and intermuscular connective tissue, conditions, all of which, are associated with toughness. Work reported on the structure of the shoulder muscles has been relatively minor; however in view of that which has been reported it appears some of the muscles adhere rather closely to this characterization while others do not. Brady (1937), Satorius and Child (1938) and Hiner et al. (1953) reported that the diameter of the muscle fibers of the LD and TB did not differ. Ramsbottom et al. (1945) from a study of 25 beef muscles reported that the fibers of the SP had the greatest diameter and those of the poas major (PM), the smallest and that the muscle fiber diameters of the TB, DP, LD and LTD lay between these two extremes. Ramsbottom et al. (1945) also reported that the SP exhibited well-defined fasiculi with extensive perimysia. The LTD and the TB were reported to contain more collagenous connective tissue fibers than the PM but less than the SP and the BF, respectively (Ramsbottom et al., 1945; Hiner et al., 1955).

The Chemical Composition of Muscle Tissue

Although the average consumer thinks of meat as a simple, fibrous protein food which contains bone and fat in varying amounts, it is in fact, a biological system, and as such is an extremely complex entity.

Water, proteins and fat are the major constituents of meat, with non-protein nitrogenous substances, carbohydrates and salts occurring in small amounts. Specific values for individual cuts of meat depend upon the species from which the cut of meat is obtained, the degree of fatness to which the animal has been fed prior to slaughter, and the direct effects of cutting and trimming (Triebold and Aurand, 1963). Raw lean muscle in broad chemical terms consists of about 75% water, 18% protein, 3% fat, 1.6% non-protein nitrogenous substances, 1.2% carbohydrate, 0.7% inorganic salts and a small balance of traces of vitamins etc. (Lawrie, 1968).

Water

Water is held in muscle in three ways: a) by adsorption on the hydrophilic groups of the protein chains; b) by condensation of randomly orientated water molecules in the hydrated surface, similar to the formation of water molecule clusters in a gas; and c) by capillary condensation (Hamm, 1960). The first two constitute the true water of hydration of the muscle proteins while the remainder is free water in the classic sense, but is mechanically immobilized within the framework of the muscle proteins. This last segment amounts to about 95% of the total moisture content of raw muscle and is the portion considered in many of the recent studies of water holding capacity (WHC) of meat (Paul, 1965). Changes in the connective tissue proteins, as well as the muscle fiber proteins during heating, influence the changes in WHC, especially the alteration of collagen from the fibrous to the gelatinous state (Hamm and Deatherage, 1960).

Proteins

The proteins are second only to water as the most abundant substance in muscle tissue and are, without doubt, the most important constituent. Basically, proteins are long-chain polypeptides composed of amino acids, linked together by peptide bonds. Skeletal muscle protein is composed primarily of the globulin complex actomyosin, which actually consists of two proteins, actin and myosin. Myogen, tropomyosin, myoglobin, collagen, reticulin, elastin, nucleoproteins and enzymes are present in lesser amounts.

Myosin. Myosin is the most abundant of all muscle proteins accounting for about 38% of the total (Szczesniak and Torgeson, 1965). It contains large amounts of glutamic and aspartic acids, appreciable amounts of dibasic amino acids, shows a strong affinity for calcium and magnesium and is readily subject to adenosinetriphosphatase activity (American Meat Institute Foundation, 1960).

Actin. About 13% of all the muscle proteins are actin.

It can exist in either of two forms: as a monomer, termed G-actin (globular), or as a polymer, termed F-actin (fibrous), which is able to interact with myosin to form actomyosin, the protein responsible for the contractile properties of muscle (American Meat Institute Foundation, 1960). As we normally encounter it, meat consists of F-actin and myosin.

Myogen. Myogen is a sarcoplasmal protein which consists of a heterogenous mixture of metabolic enzymes (Briskey *et al*., 1966). It comprises approximately 30% of the total muscle proteins.

Tropomyosin. Tropomyosin accounts for 5 - 10% of all the muscle proteins and although there is some evidence that it is located in the Z band, very little is positively known of its function (Briskey *et al*., 1966).

Myoglobin. Myoglobin consists of a protein moiety (globin) complexed with a nonpeptide moiety (heme) composed of an iron atom and a porphyrin. It is the primary pigment of muscle and is thus responsible for the color of both fresh and cooked meat (Triebold and Aurand, 1963).

Collagen. Collagen is the only protein containing hydroxyproline in appreciable amounts and it is the only significant source of hydroxylysine. It contains large amounts of glycine and proline and appreciable amounts of dibasic and diacidic amino acids. It does not contain tryptophan and cystine (Briskey *et al*., 1966). The collagen molecule consists of three peptide chains wound together in ropelike fashion to produce a triple helix which is stabilized by a regular array of interchain hydrogen bonds. The most common amino acid sequence of the peptide chains is glycine-proline-hydroxyproline (American Meat Institute Foundation, 1960).

Reticulin. The status of reticulin, whether it be a precursor, a collagen, or a degraded form of collagen, is still a matter of speculation. To date, insufficient attention has been paid to the possible contribution of reticulin to the toughness of meat, which, although similar to collagen, is not easily degraded by heat (Briskey *et al.*, 1966).

Elastin. The amino acid composition of elastin is unusual for an animal protein in that the content of hydrophilic side chains is very low and about 50% of the tissue is composed of glycine and alanine. Its structure is entirely noncrystalline and consists of randomly kinked linear chains cross-linked at intervals by firm chemical bonds (Briskey *et al.*, 1966).

Nucleoproteins. Nucleoproteins are present in the nuclei and cytoplasm of meat cells (Triebold and Aurand, 1963). They are dissociable into protein and the nucleic acid components ribonucleic acid (RNA) and deoxyribonucleic acid (DNA). The nucleic acid component is a polymer made of units containing a purine or pyrimidine base in an N-glycosidic linkage with the 5-carbon sugar. The protein component usually contains a high percentage of the basic amino acids, lysine, histidine, and arginine and is joined to the nucleic acid by salt linkages between the acidic nucleic acid and the basic protein (American Meat Institute Foundation, 1960).

Enzymes. Enzymes are primarily protein in nature and catalyze virtually every reaction in the living cell (Triebold and Aurand, 1963). Their chemistry is similar to that of the other muscle proteins.

Fat

The fat of muscular tissue consists principally of true fat, that is, esters of glycerol with fatty acids. Phospholipids, steroids, protein fragments, free fatty acids and water are present in small amounts (American Meat Institute Foundation, 1960). Mixed triglycerides predominate in meat fats and are accompanied by small quantities of substances which are soluble in fat solvents, for example, vitamins A, D, E and K and cholesterol derivatives. Only the saturated fatty acids, stearic and palmitic and the unsaturated fatty acid, oleic are present in substantial amounts in the fat of muscular tissue (American Meat Institute Foundation, 1960).

Inorganic Constituents

The inorganic material of beef skeletal muscle tissue is essentially composed of the elements: calcium, phosphorus, potassium, chlorine, sodium, iron and magnesium (American Meat Institute Foundation, 1960).

Non-protein Nitrogenous Substances

The non-protein nitrogenous substances of skeletal muscle tissue include creatine, inosine monophosphate, di- and tri-phosphopyridine, the nucleic acids, DNA and RNA, amino acids, carnosine and anserine (Briskey et al., 1966).

Carbohydrates

Although they are utilized for energy by the animal, carbohydrates are present in muscle tissue only in trace amounts. As mentioned earlier, the pentose sugars ribose and deoxyribose are components of nucleic acids. Glycogen, the form in which the animal stores glucose in the tissues, is converted to lactic acid after slaughter. Chondroitin sulfates and hyaluronic acid are complex carbohydrate substances which form part of the ground substance in which the connective tissue proteins are embedded (Triebold and Aurand, 1963).

With regard to tenderness, the most recognized difference in chemical composition between "working" muscles and less-well-worked muscles is that of collagen content. Little work has been reported on the shoulder muscles, however, based on analyses done on the biceps femoris (BF) from the bottom round (Irvin and Cover, 1959), also classed as a "working" muscle, they are considered to contain a higher proportion of collagen than less-well-worked muscles.

Cooking Method

Webster defined "tenderness" as "easily impressed, broken, cut, masticated...;" this quality is the hope of all beef consumers. They also desire good flavor and juiciness as well as a high yield of edible product containing a large proportion of lean meat in relation to fat and bone. Bone and fat may be purchased more cheaply in other forms. But the first consideration of beef consumers is for beef that can be "easily impressed, broken, cut or masticated."

The Effect of Cooking Method on Tenderness

Although it was known early in this century that tenderness was influenced by both the connective tissue component and the muscle fiber component of meat, of the two, the connective tissue component was thought to be the principal cause of natural toughness. As a result, muscles or cuts of meat were classified as tender or less tender on the basis of connective tissue content and the amount the muscle was used in the daily activity of the animal. Dry heat methods such as roasting and broiling were considered suitable only for cuts containing no tough connective tissue. Moist heat methods such as braising and stewing were recommended for less tender cuts as these cuts were thought to contain so much and such tough connective tissue that they could be made tender only by cooking for a long time by moist heat. Connective tissue was known to be made up principally of the protein collagen which was thought to be converted to gelatin only when subjected to moist heat for a long time. The theory was that the collagenous connective tissue required a moist atmosphere and long cooking to soften it by conversion of collagen to gelatin.

At the beginning of this century, experimental meat cookery was directed mainly towards developing and testing methods of roasting beef which would be suitable for the home (Cover, 1929; Cline <u>et al</u>., 1930a; Cline <u>et al</u>., 1930b; Cline <u>et al</u>., 1932, Cline and Foster, 1933; Cline and Swenson, 1934). Cline <u>et al</u>., (1930b) recognized that the flavor achieved by a cooking environment which permits surface evaporation was preferred. They expressed the concern that according to traditional recommendations of meat cookery, this method of cooking, that is, roasting, was reserved for only naturally tender cuts which constitute only approximately one-quarter of the beef carcass. As a result, much of this work was directed also towards determining whether less tender cuts of beef could be roasted successfully. However, more significant than the repeated success by these workers of roasting less tender cuts of beef such as the chuck and rump were the indications of a relationship between oven temperature and tenderness.

Cover (1937), in the most controlled study to date, compared oven temperatures of 125°C and 225°C with paired prime rib (9th, 10th, 11th ribs) (LD) and round bone chuck

(TB) roasts which were cooked to internal temperatures of 63°C and 80°C. Rump (BF), half-ham of pork (SM) and leg of lamb (BF) roasts were cooked to an internal temperature of 80°C. The response of all roasts was not alike. Panel scores on specific muscles indicated that when cooked at the lower oven temperature of 125°C, well-done round bone chuck and rump roasts were appreciably more tender but well-done prime rib and half-ham of pork roasts were only slightly more tender. There was little difference in the results of the two oven temperatures for the well-done leg of lamb or for the medium-rare prime rib and round bone chuck roasts. Below an internal temperature of 63°C at both oven temperatures and in the 225°C oven the time-temperature curves were similar for all roasts. However, in the 125°C oven between 65°C and 75°C the time-temperature curves of the round bone chuck and rump roasts showed a marked flattening. This decrease in slope was noticeable but less pronounced in the prime rib and half-ham of pork roasts and was only slightly noticeable in the leg of lamb roasts. Thus in the range of 65°C to 75°C at an oven temperature of 125°C the rate of heat penetration was appreciably slower in the round bone chuck and rump roasts than in the more tender cuts. Cover concluded that any apparent relationship between tenderness and oven temperature was better explained on the basis of a difference in the time required for cooking which is indicative of the rate of heat penetration. At 125°C well-done chuck roasts required six hours longer than at 225°C, rump roasts five hours longer and prime rib and half-ham of pork roasts three and one-quarter hours longer. Well-done leg of lamb and medium-rare prime rib and round bone chuck roasts required less than two hours longer at 125°C than at 225°C.

To study the effect of rate of heat penetration on tenderness further, Cover (1941a) accelerated heat penetration with heavy metal skewers inserted into the center of the roast. She cooked paired round (SM), arm-bone chuck (TB), and standing rib (LD) roasts at an oven temperature of 125°C to an internal temperature of 80°C; one pair-mate was cooked with skewers, the other without. In all cases, the skewers decreased the cooking time and losses, and tenderness. Again, differences in tenderness were greatest when the difference in cooking time was greatest and least when cooking time difference was least. Round roasts cooked without skewers showed the greatest increases in tenderness and required 5.2 hours longer than those cooked with skewers; arm-bone chuck roasts showed the second greatest increases in tenderness and required four hours longer; standing rib roasts showed the least increases in tenderness and required only 2.1 hours longer.

In a second experiment to study the effect of rate of heat penetration on tenderness, Cover (1941b) cooked paired bottom round roasts from eight carcasses at a controlled temperature of 90°C. One pair-mate was submerged in water in a large water bath, the other was roasted in an uncovered pan in the oven. The roasts were cooked to a similar degree of doneness, the water-cooked to an internal temperature of 85°C and the oven-cooked to an internal temperature of 80°C. There was a vast difference in the time required for cooking. The oven-cooked roasts required 23 hours while the water-cooked roasts required only 3 hours. Tenderness judgements were 100% in favor of the oven-cooked roasts. This result held a double significance for Cover. Not only did it supply further evidence that slow rates of heat penetration were more effective in tendering less tender cuts but it affirmed her conviction that added moisture was not necessary to make tough meat tender.

Cover (1943) was puzzled by her findings that tender and less tender cuts differed in their tenderness response to slow rates of heat penetration but not to fast rates of heat penetration (1937, 1941a). To clarify these observations she compared the extremely low oven temperature of 80°C with that of 125°C. Paired standing rib (LD) and arm-bone chuck (TB) roasts were cooked to well-done and paired bottom round (BF) roasts were cooked to rare and well-done. In all cases, scores for tenderness and Warner-Bratzler shear force values favored the lower oven temperature and again the greatest differences in tenderness occurred when the difference in rate of heat penetration was greatest. Well-done arm-bone chuck roasts required 34.9 hours longer at 80°C than at 125°C;

well-done round roasts required 23.5 hours longer; standing rib roasts required 15.9 hours longer and rare round roasts required 5.8 hours longer. As losses were about equal at the two oven temperatures Cover suggested that perhaps at the lower oven temperature of 80°C the water of hydration was released slowly enough from the meat proteins so that it was used efficiently for collagen conversion.

Cover's work in 1943 did not further the understanding of the cause of the tenderness response of tender and less tender cuts to slow and fast rates of heat penetration as she had hoped, but served rather to reaffirm her earlier findings. Nevertheless, this work made undeniable the observation that tender and less tender cuts respond differently to slow rates of heat penetration. This, coupled with her finding that moisture was not necessary to make tough meat tender which was in complete disagreement with a so-called "principle" of meat cookery had a significant effect on the various directions research on meat tenderness as related to cooking method have taken. In the following discussion some of the areas studied have been grouped as follows:

(1) "Moist Heat" Versus "Dry Heat"

(2) Dry Heat Temperature Comparisons

"Moist Heat" Versus "Dry Heat". The initial response to Cover's work (1937, 1941a, 1941b, 1943) was to investigate the tenderness response of tender and less tender muscles to moist and dry heat and to various degrees of doneness within each of these media. In fact, it can possibly be considered the main response, as work comparing dry heat temperatures only, has been relatively minor.

It appears that some of this work was directed primarily to practical applications while some was concerned mainly with clarifying theoretical questions. For example, work comparing moist heat cookery with low temperature oven roasting was concerned with finding the best cooking method for less tender cuts (Cover and Shrode, 1955; Griswold, 1955a, 1955b, Hood, 1960; Nielsen and Hall, 1965). On the other hand, comparisons of braised and broiled meats were mainly of theoretical interest as rapid dry heat cookery was known to be less successful with less tender cuts than slow dry heat; these studies served to compare dry and moist cooking where rates of heat penetration were both rapid (Cover and Smith, 1956; Cover *et al.*, 1957; Cover, 1959; Cover and Hostetler, 1960; Cover *et al.*, 1962 a, b, c, d).

Theoretical. Cover *et al.* (1957) using the maximum and minimum heat treatments ever applied to meat under normal household conditions justified traditional recommendations of meat cookery. Paired loin (LD) and bottom round (BF) steaks from 26 yearling steers were cooked to two degrees of doneness by broiling (internal temperatures of 61°C and 80°C) and by braising (internal temperatures of

$85^{o}C$ and $100^{o}C$ + 25 minutes = "fork tender"). Panel scores for tenderness were subdivided into scores for tenderness of obvious connective tissue and scores for tenderness of the muscle fibers. Scores for juiciness decreased in both muscles with increasing doneness within each method of cooking, however this was less marked in the LD. Shear force values and panel muscle fiber scores indicated that the LD was appreciably more tender broiled rare than well-done but showed no differences between the two degrees of doneness for braising. In contrast, the BF was significantly more tender by both shears and muscle fiber scores braised very well-done than to $85^{o}C$. Shear values were not different when the BF was broiled to two stages of doneness, however scores for tenderness of the muscle fibers were significantly higher for rare steaks. In both muscles, braising very well-done increased the tenderness of the connective tissue to the greatest extent, however obvious connective tissue was found less frequently and was more tender in the LD than in the BF. Shear values and muscle fiber scores indicated that the LD was significantly more tender than the BF when both were broiled rare, but after braising both to very well-done the BF was more tender.

Thus tender and less tender muscles differ in their response to moist and dry heat and to degrees of doneness within each of these media. Severe cooking conditions appeared to toughen the LD but the most severe of the four cooking conditions, that which tendered the connective tissue of both muscles to the greatest extent, seemed to tender the BF to the greatest extent. In fact, under this cooking condition, the BF which is regarded as a less tender muscle, became more tender than the LD which is regarded as a tender muscle. If the connective tissue of both muscles has been tendered to the greatest extent, then the only other factor contributing to toughness is the muscle fiber.

A "principle" of meat cookery, applicable only to the muscle fiber, states that high heat toughens protein. This principle was the basis for recommending that mild heat treatments be used in cooking cuts containing only small amounts of tender connective tissue. Thus it was recommended that tender cuts, that is, cuts composed mainly of myofibrillar protein, be cooked to low internal temperatures at low oven temperatures when the thickness of the cut necessitated a long exposure, and at high temperatures for short time periods when the cut was thin. However, for cuts containing proportionately more connective tissue, severe heat treatments, such as, high internal temperatures and a moist atmosphere, were recommended. Although this severe heat treatment theoretically toughened the myofibrillar proteins, this was considered less important than the softening of the large amounts of tough connective tissue.

However, results from Cover _et al._ (1957) indicated that braising very well-done tendered not only the connective tissue but also the muscle fibers of the BF. The results from the LD, on the other hand, were in line with the older theories, that severe heat treatment toughens the myofibrillar proteins. Both Cover and Smith (1956) and Cover *et al.* (1957) noted that in the LD braised very well-done small bundles of muscle fibers sometimes fell apart readily into strings but these strings were tough indicating that these bundles of fibers were not easily broken across the grain. In contrast, in the BF braised very well-done, bundles of muscle fibers not only separated easily, but also broke readily across the grain. The fragments were tiny, hard and dry and gave a mealy feel in the mouth which was associated with unusual tenderness.

Thus traditional recommendations of meat cookery based on assumed differences in the tendering effect of moist and dry heat as well as compositional differences of the raw cuts were justified experimentally by Cover *et al.* (1957). However, due to the inconsistencies between scores for juiciness, collagen degradation, scores for tenderness of connective tissue, scores for tenderness of the muscle fibers and shear force values reported by Cover and Smith (1956) and Cover *et al.* (1957) the responses are not clearly understood. More extensive characterization of the sensory impression of meat tenderness (Cover, 1959; Cover and Hostetler, 1960; Cover *et al.*, 1962 a, b, c, d) has begun to clarify these inconsistencies; however it has not furthered the understanding of the cause of the response of the muscle fibers of tender and less tender muscles to moist and dry heat and to degrees of doneness within each of these media.

Hamm and Deatherage (1960) suggested that a toughening reaction in muscle fibers to heat could be the tightening of the network of protein structure during denaturation as new stable cross linkages are formed between the peptide chains. Buy why would this occur in the protein structure of the LD and not in the BF?

Paul (1952) reported that histological examination of the semitendinosus (ST) revealed cracks in the fibers after rigor had diminished and that on longer storage these cracks developed into breaks and even into granulated areas in the fibers. Cover _et al_. (1962c) suggested that these breaks may be associated with panel scores for ease of fragmentation and mealiness of the muscle fibers. If they are associated - do these breaks occur in both muscles - and to the same extent? If they do occur in both muscles and to the same extent and they are associated with scores for ease of fragmentation and mealiness, the reason why more severe heat treatment accentuates the breaks in the BF and not in the LD remains unanswered.

Practical. The majority of the work comparing moist and dry heating shows that roasting less tender cuts at relatively low oven temperatures yields a product which is at least comparable in tenderness and flavor to braising, and is definitely superior in juiciness.

Cover and Shrode (1955) comparing oven-roasting at 150°C with pot-roasting reported that the BF from the bottom round was appreciably more tender by both panel scores and shear values when pot-roasted than when oven-roasted. With the LD of the prime rib, IF of the chuck and SM of the top round, however, the differences in tenderness were much less marked. In all cases, scores for juiciness favored the dry heat method. The end-point temperature for oven-roasting was 80°C while pot-roasted prime rib and chuck roasts were cooked to 93°C and top and bottom round roasts were cooked to 98°C. The results of Cover et al. (1957) indicated that the LD is about equally tough when cooked to well-done by either moist or dry heat. As the moist heat method was appreciably more effective in tendering the BF and somewhat more effective in tendering the IF and SM, the oven temperature of 150°C appears to be too high to allow sufficient time for collagen hydrolysis. However, as the IF and SM reacted similarly to the cooking conditions as the LD, which is regarded as a tender muscle, it suggests that perhaps these muscles are more tender than they have previously been thought to be.

In the same year, Griswold (1955a, 1955b) reported that palatability scores and collagen losses were higher for top and bottom round steaks roasted at 121°C and 149°C to 85°C than for those cooked to the same internal temperature by braising. Shear values were not different between braised meat and that roasted at 149°C. Meat roasted at 121°C scored higher in all palatability factors with the exception of juiciness, and had significantly lower shear values and higher collagen losses than meat roasted at 149°C. These findings support Cover's earlier work (1937, 1941a, 1941b, 1943).

Hood (1960) found that scores for flavor, tenderness and juiciness were higher and shear values and cooking losses were lower for roasts from the TB muscle cooked at 149°C to 76.5°C when they were not wrapped in heavy aluminum foil than when they were. Thus dry heat roasting at this oven temperature appears to allow sufficient time for collagen hydrolysis in the TB muscle.

Nielsen and Hall (1965) reported that blade roasts can be successfully oven-roasted at either 107°C or 163°C to an internal temperature of 70°C or braised to "fork tenderness" depending upon the homemaker's personal preference. Scores for tenderness, flavor and general acceptability showed no differences between braising and roasting. However, scores for juiciness favored roasting. Shear values were not different between braising and roasting at 107°C, however, values for both were appreciably lower than for roasting at 163°C. Total cooking losses were greater for braising than for either of the oven temperatures.

Thus, when roasting is compared with braising for less tender cuts, roasting yields a product which is at least comparable in tenderness and flavor to braising and definitely superior in juiciness. However, little work has been reported comparing a variety of dry heat temperatures with braising. Griswold (1955a) compared oven temperatures of 121°C and 149°C with braising and Nielsen and Hall (1965) compared temperatures of 107°C and 163°C with braising. In both cases, shear values favored the lower oven temperature. Cover (1937, 1943) compared oven temperatures and degrees of doneness and found that a low oven temperature (125°C, 80°C) was most effective in tendering less tender cuts when cooking was continued to 80°C rather than to 63°C. When Cover (1941b) compared braising with roasting both at the controlled temperature of 90°C to the well-done stage, roasting yielded a more tender product. However, although Cover's early studies (1937, 1941a, 1941b, 1943) clearly indicated the effectiveness of long, slow cooking by dry heat in tendering less tender cuts they did not take on a practical application due to the time-factor involved. More recent work to determine that combination of oven and internal temperature which is most effective in tendering less tender cuts within a reasonable length of time has been minor. However extensive work has been done (Marshall *et al.*, 1959; 1960; Hunt *et al.*, 1963) to determine that combination of roast size, oven temperature and internal temperature which will maximize edible yield in less tender cuts, with little regard to tenderness.

Dry Heat Temperature Comparisons. To gain further understanding of the mechanisms involved in tendering less tender cuts by long, slow dry heat roasting Bramblett *et al.* (1959) cooked five muscles (adductor, BF, gracilis, SM and ST from six paired beef rounds at 63°C for 30 hours and at 68°C for 18 hours. Meat cooked at 63°C required an average of 12 hours to reach an internal temperature of 57°C and after 18 more hours of cooking reached an internal temperature of 60°C. At 68°C an internal temperature of 57°C was attained after only 8 hours; after 10 more hours of cooking the internal temperature was 65°C. Shear force values and scores for tenderness indicated that all muscles were significantly more tender when cooked at 63°C than at 68°C. At 63°C cooking losses were consistently lower and press fluid yields, scores for juiciness, texture and appearance were higher for all muscles. A highly significant negative correlation (-.73) for the length of time the internal temperature of the meat was held in the range of 57-60°C and shear values led these worker to conclude that in this temperature range changes take place in both the muscle fibers and connective tissue which result in more tender meat.

Ramsbottom *et al.* (1945) found that meat samples weighing from 100 to 200 grams each took longer to cook, were consistently more tender and showed less variation in tenderness when cooked in an oven at 163°C, than when cooked in lard at 121°C to 76.7°C.

Nielsen and Hall (1965) comparing oven temperatures of 107°C and 163°C on paired blade and rump roasts cooked to 70°C concluded that both cuts could be roasted successfully at either oven temperature, however blades were appreciably more tender by shear cooked at 107°C. Scores for tenderness, flavor and general acceptability showed no differences among the roasts, however, scores for juiciness were lower for rumps at 107°C than for blades at both oven temperatures and rumps at 163°C. Blades roasted at 107°C were more tender by shear than those roasted at 163°C and rumps roasted at 163°C. Blades and rumps were equally tender by shear when roasted at 107°C. Shear values were not different for rumps at 107°C and 163°C. Rumps had greater total losses than blade roasts at both oven temperatures. Rumps showed no differences in total cooking losses between oven temperatures. However blades showed appreciably higher losses when roasted at 107°C than when roasted at 163°C.

Traditional recommendations for meat cookery, although over-simplified, are in fact, sound. Tender cuts are tender to the palate only when toughening of the myofibrillar proteins is minimized whereas less tender cuts are tender only when connective tissue, softened by conversion of collagen to gelatin, is tender to the palate. Such severe heat treatments as long, slow cooking by dry heat and short, fast cooking by moist heat, to the well-done stage appear to tenderize the connective tissue of less tender cuts sufficiently. The moisture in moist heat, originally thought to be required for collagen hydrolysis, promotes a relatively rapid rate of heat penetration so that the internal temperature of the meat reaches the temperature of the medium in a short time and is held there for the remainder of the cooking period. Heat penetration curves for one-inch bottom round (BF) steaks weighing approximately half a pound (Cover et al., 1957) indicated that an internal temperature of 100°C was attained after 15 to 20 minutes of cooking. As a tender product is obtained by holding the internal temperature of these steaks at 100°C for only 25 to 30 minutes, it appears that collagen degradation is rapid at this temperature.

Little is known about the mechanisms involved in tendering less tender cuts by long, slow dry heat roasting, but it appears that the length of time the internal temperature of the meat is held between 65°C and 75°C is responsible for connective tissue softening. Cover (1943) reported that in bottom round roasts cooked to well-done at an oven temperature of 80°C the connective tissue appeared to be completely changed from its hard and tough state to a moist, viscous mass which was without resistance to either the knife or teeth.

The Effect of Dry Heat Temperatures on Yield

Paired top round roasts weighing approximately 5, 10 and 15 pounds were cooked at 149°C to internal temperatures of 60, 65, 70, 75 and 80°C by Marshall et al. (1959). Seven replications were made for each degree of doneness yielding a total of 105 roasts. Decreases in edible yield with increasing doneness were due primarily to evaporation loss which increased with increasing doneness in all roast sizes until an internal temperature of 75°C was reached. Above 75°C losses from 10 and 15 pound roasts appeared to stabilize while those from 5 pound roasts continued to rise. Drip loss increased with increasing internal temperature but the effect was much less pronounced than that on evaporation. Total losses were lower and consequently yields were higher for 10 and 15 pound roasts than for 5 pound roasts at all internal temperatures with the exception of 60°C. At 60°C yields in actual 70 gram portions were similar for all three sizes and were the highest obtained (4.7 portions per pound of raw weight).

A total of 72 roasts, that is, eight sets of top round roasts weighing approximately 10 pounds each were cooked at each of three oven temperatures, 93, 107 and 121°C, to each of three internal temperatures, 60, 70 and 80°C, by Marshall *et al*. (1960). Losses through drippings and evaporation increased with increasing internal temperature at each oven temperature. Evaporation loss was highest in the 93°C oven and drip loss was highest in the 121°C oven. Trim loss, which consisted mainly of excess fat, was greatest in the 93°C oven and at the internal temperature of 60°C. Juice lost during slicing and handling was greatest at the internal temperature of 60°C. Total preparation losses increased with increasing doneness and were highest in the 93°C oven. At an internal temperature of 60°C the highest yield was obtained in the 107°C oven; at 70°C the highest yield was obtained in the 121°C oven; and at 80°C the highest yield was obtained in the 107°C oven. The number of 70 gram portions obtained was highest (4.3 portions per pound of raw meat) from roasts cooked at 107°C to 60°C.

Hunt *et al.* (1963) compared yields on five sets of top round roasts weighing approximately 10 pounds each, cooked at each of five oven temperatures, 135, 149, 163, 177, and 191°C, to each of three internal temperatures, 60, 70 and 80°C. Total preparation losses, that is losses through drippings, evaporation and fat trim, and conversely yields, were not affected by oven temperature but the effect of internal temperature was highly significant. Portions weighing 70 grams obtained from each pound of raw meat numbered 4.0 at an internal temperature of 60°C, 3.7 at 70°C and 3.2 at 80°C.

Marshall *et al.* (1959, 1960) and Hunt *et al.* (1963) gave no data on shear values or acceptability but stated that shear values were not different and that spot checks of the tenderness, juiciness and flavor of the roasts indicated that all were acceptable.

Within the past 30 years relatively little work has been done on the shoulder cuts, which constitute approximately one-quarter of the beef carcass. Nielsen and Hall (1965) obtained a satisfactory product by cooking blade roasts at 107°C or 163°C to 70°C. However, Cover's early work (1937, 1943) indicated that low temperature roasting was most effective in tendering less tender cuts when cooking was continued to an internal temperature of 80°C.

Very little information is available regarding the yields of various cuts. Cooking losses are recorded in work dealing specifically with tenderness. However, in the most recent publication dealing with yields (Pecot *et al.*, 1965), due to the lack of adequate information, a value of 33% was used for the cooking losses of all large cuts cooked by moist heat. A value of 27% was used for cuts cooked by dry heat and braised steaks. Regarding carving wastes, which in some cases, may constitute a large proportion of the total preparation losses, extremely little information is available. Accordingly, in the present study the tenderness and yields of RBS and CR roasts cooked at 107°C and 163°C to 70°C and 80°C were assessed.

METHOD

A detailed study of intermuscle tenderness, intercut tenderness, cooked edible yield and nutritive value was done on RBS and CR roasts of beef cooked at each of two oven temperatures: 107°C and 163°C to each of two internal temperatures: 70°C and 80°C. A Latin Square design replicated four times was used to assess the effect of the four cooking conditions. Treatment arrangement permitted assessment of differences between animals, sides and roast cuts as well as cooking conditions (Appendices A and B).

Procuring and Handling of the Meat

Meat was obtained from four animals of known history (Appendix C), purchased for the project from a local packer. The carcasses were graded Canada Good and aged nine days under commercial packing house conditions.

Under the supervision of the author, two RBS roasts and two CR roasts, each three inches thick, were cut from each side of each animal giving a total of sixteen RBS roasts and sixteen CR roasts (Figure 1).

After storing overnight in a refrigerator at 5°C the roasts were wrapped in waxed paper and heavy aluminum foil, frozen and held at -26°C for a period of one to five weeks.

To facilitate dissection of the roasts after cooking all muscles within each roast were identified and each roast was sketched. Figures 3 - 6 illustrate the changes that occur in the size and shape of the muscles and bones from the first cut to the second cut of both roast types.

Preparation of the Meat

Prior to cooking the roasts were thawed at 5°C for forty-eight hours, trimmed to consumer size and tied. These trimming specifications were chosen after discussion with local butchers and careful examination of approximately twenty-five roasts sold commercially.

RBS Roasts. The fat from the exterior of the animal was trimmed to three-eighths of an inch. The SP muscle and one rib bone were removed and the remaining fat lying between the SP and DP was trimmed to three-eighths of an inch (Figure 5).

CR Roasts. The fat from the exterior of the animal was trimmed to three-eighths of an inch and the fat situated between the SD, LTD, TM and serratus ventralis (SV) was trimmed to one-quarter of an inch (Figure 3).

Both the bones and the roasts were weighed to an accuracy of .1 gram before and after cooking to permit calculations of bone losses, drip and evaporation during cooking.

Cooking Procedure

The cooking order for the animals and for the roasts of the first animal used were randomized. Thereafter, the assignment of treatments to cuts was "fixed" so as to expose each cut to each treatment. The order of cooking for the RBS roasts is given in Appendix A and for the CR roasts is given in Appendix B.

Cooking was done in two household style Moffat electric ranges (Model 30M40). The internal temperatures of the meat and the oven temperature fluctuations were measured with type T copper constantan, six inch insertion length, Honeywell Sabrecouples which were attached to a Honeywell temperature calibrated potentiometer (Model 2736). Two roasts, set on racks in individual shallow aluminum pans were placed in each oven at each cooking time. One thermocouple was inserted into the center of each roast, that is, into the BB muscle of the RBS roasts and the TB (long head) of the CR roasts (Figures 3 and 5) and one thermocouple was placed in the center of the oven. The ovens, automatically set at 107°C and 163°C with roasts in them fluctuated between 101°C and 113°C and 160°C and 170°C, respectively. Cooking was continued until the desired internal temperatures were reached: 70°C and 80°C.

<u>Cooked Edible Yield</u>

After cooling to room temperature, all obvious waste such as fat and connective tissue was removed from the muscles and weighed. The separated muscles were weighed, wrapped individually in plastic bags and held overnight at 5°C before being evaluated by a taste panel and tested with the Warner-Bratzler shear. The SV in the CR roast (Figures 3 - 6) was appreciably smaller than the figures illustrate and was inseparable from the IM. Thus it is included in yields for the IM.

The weight of the drippings was obtained by subtracting the total weight of the string tying the roast and the weight of the pan and rack before cooking from the total weight of the string, pan and rack after cooking. Volatile cooking losses for each roast were calculated as the difference between the weight of the uncooked roast and bone and the combined weight of the cooked roast, bone and drippings. Cooked edible yield expressed as a percentage of the entire trimmed uncooked roast was calculated using the following formulas:

(Weight of uncooked roast and bone) - (cooking losses through drippings and evaporation + carving losses due to bone, exterior fat and intermuscular fat and connective tissue) = weight of cooked lean meat.

$$\frac{\text{Weight of cooked lean meat}}{\text{Weight of uncooked roast and bone}} \times 100 = \text{percent cooked edible yield}$$

Sensory Evaluation

A consumer panel of twenty-six people connected with the School of Home Economics evaluated the meat using a 9-point hedonic scale (Figure 7). To structure the "comments" the panelists were asked to check which factor they would most liked to have seen improved - color, flavor, juiciness, or tenderness. Judging by the same twenty-six people was done twice a week for a period of four weeks at individual unenclosed stations in a foods laboratory. Information on the purpose of the study and careful instructions regarding the

Hedonic Scale

Name________________________ Date______________________

In the order in which they are presented, taste each sample and then check in the space below the phrase that best describes your attitude towards it.

Sample Code Number	Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely

Which characteristic would you most like to see improved in each sample (Choose 1).

Sample Code Number	Tenderness	Juiciness	Color	Flavor	Comment

FIGURE 7. Questionnaire used for sensory panel judging

test were given to the panelists at the first session. The judges were allowed to rinse with distilled water and eat unsalted soda crackers as often as they wished. At each session, all treatments on one roast type, that is, four samples presented simultaneously in randomized order, were evaluated.

Sample Preparation. The muscles chosen for the panel evaluation were the largest muscles within each roast type and were therefore thought to be representative of each roast type. From the CR roasts the TB (long head) was used however in the RBS roasts because no one muscle was large enough to obtain twenty-six samples, thirteen samples were taken from each of both the TB (long head) and the DP (Figures 3 and 5). The muscles were cut in half and designated as right and left sides to be used alternately for panel sampling and shear determinations (Appendices A and B). As the muscle fibers of the TB (long head) ran approximately perpendicular to the cut surface of the roasts this muscle was cut parallel to the muscle fibers. Those of the DP on the other hand, ran parallel to the cut surface. Thus, division of the DP into right and left sides was made by cutting perpendicular to the muscle fibers. Samples, 3/4 x 3/4 x 1/4 of an inch were cut perpendicular to the muscle fibers from the same portion within each replicate. The TB (long head) and the DP from the RBS roasts were presented alternately to the panelists. Each panelist, therefore, evaluated each of these muscles twice (Appendix A).

Shear Determinations

Where possible, a maximum of five, one-half inch diameter cores cut parallel to the muscle fibers were taken from each muscle for each replicate. The size of the muscle, the direction of the muscle fibers and the extent to which the muscle fibers were twisted by the string tying the roasts determined the number of cores taken. The order in which the right and left sides of the TB (long head) and the DP of the RBS roasts were used is given in Appendix A and the order for the TB (long head) of the CR roasts is given in Appendix B. After cutting with the Warner-Bratzler shear, the cores were wrapped in waxed paper, overwrapped with heavy aluminum foil and held at $-26^{\circ}C$ for six months before being analyzed for percent moisture, protein, fat and ash.

To assess the effect of the cooking conditions on the entire roast weighted means of shear values were calculated using the formula:

$$\frac{(\%\ \text{muscle A contributing to edible yield})(\text{shear value for muscle A}) + (\%\ \text{muscle B etc.}}{\text{Total}\ \%\ \text{cooked edible yield}}$$

Chemical Analysis

Proximate analysis of the cooked edible yield was done by the Department of Animal Science, University of Manitoba by standard AOAC (1965) methods. All determinations were done in duplicate.

Statistical Analysis

Where F tests showed significant differences between means, Tukey's w-procedure was used to determine which means were significantly different (Snedecor and Cochran, 1967). As the experimental sample consisted of only four animals, differences were considered significant only at $P < .01$, unless stated otherwise.

RESULTS AND DISCUSSION

Tenderness is recognized as being the most important quality in meat (Macdonald, 1963). Thus the majority of meat research has been directed to that quality and for consistent results has been done mainly with individual muscles. However the cuts of meat that consumers have access to generally contain several muscles which will show at least slight differences in tenderness (Ramsbottom and Strandine, 1948). The cost of meat is also uppermost in the minds of consumers. Cooking losses are recorded in work dealing with tenderness and some research work has dealt specifically with cooked edible yield. This study was designed to assess yields and the tenderness of the entire roasts.

Although the meat was obtained from steers of similar genetic background and raised under similar conditions, some degree of variability was noted among the animals. The significant differences among animals affecting edible yield included evaporation loss and bone loss for the RBS and CR, respectively. For both roast types significant differences among animals were found in weighted means of muscle shear values which reflected individual muscle differences. No differences were noted between right and left sides of the animals.

Yield

Edible yield is that portion of the cooked roast which remains after removing the bone, exterior fat, intermuscular fat and connective tissue. Differences in edible yield are then the result of differences in cooking losses which are primarily due to cooking conditions and differences in carving wastes which are essentially due to the initial physical composition of the roasts.

The RBS showed no real differences in edible yield among cooking conditions (Table I). However the CR, showed significantly higher yields when cooked at the higher oven temperature and when cooked to the lower internal temperature due mainly to lower evaporation losses (Table I). As evaporation is continuous during heating the higher losses for the CR may be explained by the differences in cooking times between the two roast types. The RBS roasts required fewer minutes per pound to cook than the CR roasts (Table II) as they were larger than the latter (Tables III and IV). Cooking time is inversely related to surface area and as weight increases the ratio of surface area to weight decreases (Lowe, 1955). Cooking time is also dependent on the structure of the cut. Nielsen and Hall (1965) found that time per pound was less and evaporation losses were lower for four pound blade roasts than for "chunkier" rump roasts of the same weight. Blade and RBS roasts are similar in that both are composed of several muscles and intermuscular fat and connective tissue tends to be extensive whereas the CR and rump roasts both have only one major muscle. The TB (long head) is the largest muscle of both the RBS and CR (Tables V and VI) however it accounts for an appreciably greater proportion of the CR than the RBS.

The more marked effect of the cooking conditions on evaporation losses in the CR may also have been due to the fact that the trimmed CR before cooking contained proportionately more lean, fat and connective tissue than the RBS (Tables III and IV) and after cooking had a significantly higher yield of edible lean than the RBS (Table I) inferring a higher content of lean initially. Raw lean is approximately 75% moisture (Lawrie, 1968). Similarly, the higher evaporation

TABLE I

Percentage of Cooking Losses, Carving Waste and Cooked Edible Yield for Both Types of Roasts under Four Cooking Conditions[1]

Roast Type	Characteristic		Cooking Conditions (°C.)			
			107 - 70	107 - 80	163 - 70	163 - 80
RBS	Cooking Losses	Bone change	0.88	1.22	1.89	1.29
		Drippings	4.68	4.67	4.25	6.78
		Evaporation	29.21	33.59	27.13	31.17
		Total	33.89	38.26	31.38	37.95
CR		Bone change	0.79	0.92	0.84	0.96
		Drippings	2.41^{a}	4.62^{bc}	3.31^{ab}	4.74^{c}
		Evaporation	28.20^{ab}	35.93^{b}	22.56^{a}	31.46^{b}
		Total	30.61^{ab}	40.55^{c}	25.87^{a}	36.20^{bc}
RBS	Carving Waste	Bone	10.50	10.56	12.01	10.22
		Exterior fat	6.40	7.88	7.25	5.77
		I.F. & C.T.[2]	8.88	8.00	10.77	9.75
		Total^{A}	25.78	26.44	30.03	25.74
CR		Bone	3.86	4.03	4.08	3.38
		Exterior fat	6.85	6.60	8.24	5.35
		I.F. & C.T.	9.53	6.92	10.53	8.18
		Total^{B}	20.24	17.55	22.85	16.91
RBS	Cooked Edible Yield	Total^{C}	40.33	35.30	38.59	36.31
CR		Total^{D}	49.15^{bc}	41.90^{a}	51.28^{c}	46.89^{b}

[1] Each value is the mean of four replicates

[2] Intermuscular fat and connective tissue

[AB] Significantly different

[CD] Significantly different

[abc] Means in rows not bearing a superscript or bearing the same superscript are not significantly different.

TABLE II

Average Cooking Time for Both Types of Roasts under Four Cooking Conditions (Minutes/Pound)

Roast Type	Cooking Conditions (°C.)			
	107 - 70	107 - 80	163 - 70	163 - 80
RBS	111	146	34	52
CR	136	215	43	63

TABLE III

Physical Composition of Raw RBS Roasts Before and After Trimming

Description	Mean	Position	
		Cut 1	Cut 2
Untrimmed weight (g)	3226.7	3132.8	3320.6
Bone[1] (%)	9.61	7.44	11.78
L.F. & C.T.[2] (%)	90.39	92.56	88.22
Trim (%)	20.80	20.45	21.14
Remainder (%)	79.20	79.55	78.86
Bone (%)	9.61	7.44	11.78
L.F. & C.T. (%)	69.59	72.11	67.08
Trimmed weight (g)	2556.1	2486.6	2625.6
Bone (%)	12.41	9.38	14.90
L.F. & C.T. (%)	87.86	90.62	85.10

[1]Values given are for the humerus bone only
[2]Lean, fat and connective tissue

TABLE IV

Physical Composition of Raw CR Roasts
Before and After Trimming

Description	Mean	Position	
		Cut 1	Cut 2
Untrimmed weight (g)	1706.2	1859.4	1553.0
Rib bones (%)	4.23	3.69	4.77
Blade bone (%)	0.52	1.04	0.0
L.F. & C.T.[1] (%)	95.25	95.27	95.23
Trim (%)	9.72	4.77	14.68
Blade bone (%)	0.52	1.04	0.0
Fat (%)	9.20	3.73	14.68
Remainder (%)	90.28	95.23	85.32
Rib bones (%)	4.23	3.69	4.77
L.F. & C.T. (%)	86.05	91.54	80.55
Trimmed weight (g)	1544.8	1769.6	1320.0
Rib bones (%)	4.72	3.86	5.57
L.F. & C.T. (%)	95.28	96.14	94.43

[1]Lean, fat and connective tissue

TABLE V

Percentage of Each Muscle Contributing to the Cooked Edible Yield of RBS Roasts[1]

Muscles	Cooking Conditions (°C.)[a]			
	107 - 70	107 - 80	163 - 70	163 - 80
TB (long head)	8.88	7.47	7.67	8.89
DP	8.06	6.72	6.94	7.55
TB (lateral head)	5.37	4.42	3.83	4.16
BB	4.02	3.84	4.04	3.96
BC	3.04	4.22	4.66	2.92
DE	3.65	2.45	5.17	3.37
BR	2.78	2.73	2.52	2.40
TBB	1.17	1.13	1.41	1.10
CC	0.86	0.81	1.16	1.17
SP[2]	1.96	0.86	0.75	0.36
TB (medial head)	0.54	0.65	0.44	0.43
Total	40.33	35.30	38.59	36.31

[1] Each value is the mean of four replicates
[2] Not analyzed due to insufficient values
[a] For each muscle, means among cooking conditions are not significantly different

TABLE VI

Percentage of Each Muscle Contributing to the Cooked Edible Yield of CR Roasts[1]

Muscles	Cooking Conditions (°C.)			
	107 - 70	107 - 80	163 - 70	163 - 80
TB (long head)	20.72[ab]	18.00[a]	23.99[b]	22.40[ab]
IM[2]	11.67	10.50	11.86	9.06
TM	5.58	5.50	5.58	4.51
LTD	3.13	3.52	4.15	4.12
DP[3]	4.33	1.55	1.98	3.31
SD	1.80	1.46	2.17	2.11
TFA	1.92	1.37	1.55	1.38
Total	49.15[bc]	41.90[a]	51.28[c]	46.89[b]

[1]Each value is the mean of four replicates
[2]Includes the SV
[3]Not analyzed due to insufficient values
[abc]Means in rows not bearing superscripts or bearing the same superscript are not significantly different.

losses for the rump roasts in Nielsen and Hall's (1965) study may have been partially attributable to this.

Yields were appreciably higher for the CR than for the RBS, in all cases (Table I). The main factor accounting for differences in edible yield was carving loss, attributable to bone, exterior fat, intermuscular fat and connective tissue. Due to a larger amount of bone, total carving wastes were appreciably higher for the RBS than for the CR. Waste, apart from bone however, was not different between the two roast types (Table I). Because there are more muscles in the RBS, more loss due to intermuscular fat and connective tissue was expected. The CR, however, realized appreciable waste along the rib bones due to the large amounts of connective tissue in which they are enclosed. Although inedible, the numerous heavy bands of connective tissue occurring within the BB and the band of connective tissue occurring in the TB (long head) were not included in carving waste.

With the exception of the TB (long head) muscle of the CR roast, the percentage of each muscle contributing to the edible yield was unaffected by the roasting conditions (Tables V and VI). The TB (long head) was appreciably larger when cooked at 163°C to 70°C than when cooked at 107°C to 80°C. As the muscles of both roast types showed appreciable variation in size among animals, roasting conditions significantly affected the losses of only this one muscle due likely to the fact that it is present in the largest proportion.

For both roast types edible yield tended to be greater in the first cut due to appreciably lower total carving wastes (RBS $P < .05$), (Table VII). Waste due to bone was significantly greater in the second cut of both roast types as both the humerus bone of the RBS roasts and the rib bones of the CR roasts widen from the first cut through to the second cut (RBS $P < .05$), (Figure 1).

In the RBS, waste due to fat trimmed from the exterior of the roast was also appreciably greater for the second cut than for the first cut ($P < .05$), (Table VII). From Table III it appears that trimming of the two cuts to consumer size was not different. However, from Table VII it is apparent that trimming of the exterior fat from the second cut was inadequate. Nevertheless, edible yield will always be at least slightly lower in the second cut due to the larger proportion of bone present.

In trimming the CR roasts to consumer size, the second cut was trimmed approximately 10% more than the first cut due to large amounts of fat lying between the SV, TM, LTD and SD in the second cut (Table IV), (Figure 3). However, intermuscular waste was still appreciably greater in the second cut (Table VII) because as the rib bones widen from the first cut through to the second cut, the enclosing connective tissue also becomes thicker.

TABLE VII

Percentage of Cooking Losses, Carving Waste and Cooked Edible Yield for Both Roast Types as Affected by Position within the Carcass[1]

Characteristic	RBS		CR	
	Cut 1	Cut 2	Cut 1	Cut 2
Cooking Losses				
Bone change	1.24	1.39	0.63[a]	1.13[b]
Drippings	4.29	5.90	3.91	3.63
Evaporation	33.41	27.14	32.42	26.66
Total	37.70	33.04	36.33	30.29
Carving Waste				
Bone	8.14	13.51	3.23[a]	4.44[b]
Exterior fat	4.40	9.25	5.66	7.85
I.F. & C.T.[2]	9.30	9.40	5.89[a]	11.70[b]
Total	21.84	32.16	14.78[a]	23.99[b]
Cooked Edible Yield Total	40.46	34.80	48.89	45.72

[1]Each value is the mean of eight replicates
[2]Intermuscular fat and connective tissue
[ab]For each roast type means in rows not bearing a superscript or bearing the same superscript are not significantly different.

The term bone change (Tables I and VII) denotes the weight loss of the bone during cooking and is therefore a composite of drip and evaporation. Bone change was significantly greater in the second cut of the CR as the increased thickness of the connective tissue enclosing the rib bones made bone dissection more difficult and consequently some connective tissue remained on them. In all cases, bone change was negligible and not different from that reported by Paul et al. (1950). Thus, bone losses do not increase total cooking losses appreciably contrary to suggestions by Pecot et al. (1965).

The muscles of the RBS showed no appreciable differences in size between cuts, however, the three largest muscles, that is, the TB (long head), DP and TB (lateral head) were all slightly larger in the first cut (Table VIII). In the first cut of the CR, the TB (long head) is smaller, however the IM are significantly larger and the rest of the larger muscles are all slightly larger. Only the TFA is significantly larger in the second cut.

The several small muscles separated rather extensively by intermuscular fat and connective tissue and the location of the bone in the center of the roast make the RBS more difficult to carve than the CR. The division of the CR by the butcher between the SD, TM, LTD and SV muscles lends itself naturally to carving, as large even slices are easily

TABLE VIII

Percentage of Each Muscle Contributing to the Cooked Edible Yield of the First and Second Cuts for Both Roast Types[1]

Muscles	RBS		Muscles	CR	
	Cut 1	Cut 2		Cut 1	Cut 2
TB (long head)	8.77	7.69	TB (long head)	19.02	23.53
DP	8.50	6.13	IM	12.35[b]	9.20[a]
TB (lateral head)	5.44	3.45	TM	7.64	2.94
BB	3.92	4.00	LTD	4.44	3.02
BC	3.65	3.77	DP[3]	4.05	1.53
DE	3.00	4.32	SD	0.92	2.85
BR	2.88	2.34	TFA	0.47[a]	2.65[b]
TBB	1.04	1.35			
CB	0.99	1.02			
SP[2]	1.61	0.35			
TB (medial head)	0.66	0.38			
Total	40.46	34.80	Total	48.89	45.72

[1]Each value is the mean of eight replicates

[2,3]Not analyzed due to insufficient values

[a,b]For each roast type means in rows not bearing superscripts or bearing the same superscript are not significantly different.

obtained from the section containing the TB (long head), TM, LTD and TFA (Figure 3). In the lower section, the SD can be separated from the ribs and depending on its size can be sliced or left whole and then the SV and the lean between the ribs can be removed. The RBS is more easily carved after the bone has been removed; this can be done by first cutting around the bone to loosen it from its connective tissue and then cutting to it between the BR and BC (Figure 5). The muscles can then be separated and sliced individually. Both the BB and the TBB are enclosed in a heavy sheath of connective tissue which should be removed before slicing. The greater ease in carving makes the CR a roast which the consumer would choose to carve at the table and as larger slices have more "eye appeal" it is also one which the consumer would choose to serve to guests.

Proximate Analysis

For both roast types only moisture content and protein content were appreciably affected by the roasting conditions and in all instances differences in protein content were direct reflections of differences in moisture content (Table IX). As expected, differences in moisture content reflected differences in evaporation losses (Table I). Extending the degree of doneness significantly decreased the moisture content of both roast types. However, cooking at the lower oven temperature significantly decreased the moisture content of the CR roast only.

TABLE IX

Proximate Composition of Cooked Edible Yield for Both Roast Types

Roast Type	Nutrients	Cooking Conditions (°C.)			
		107 - 70	107 - 80	163 - 70	163 - 80
RBS	Moisture	59.79[ab]	57.62[a]	62.34[b]	57.79[a]
	Protein	32.98[ab]	34.68[b]	30.52[a]	34.55[b]
	Fat	6.14	6.55	6.06	6.55
	Minerals	1.09	1.15	1.08	1.11
CR	Moisture	61.10[b]	58.05[a]	64.53[c]	61.97[bc]
	Protein	31.19[b]	33.92[c]	29.01[a]	30.52[ab]
	Fat	6.61	6.91	5.38	6.43
	Minerals	1.10	1.12	1.08	1.08

[abc]Means in rows not bearing a superscript or bearing the same superscript are not significantly different.

As most cookbooks recommend that these cuts be cooked by moist heat, values cited in current proximate composition tables are for a braised or pot-roasted product (Watt *et al.*, 1963; Pecot *et al.*, 1965). Comparison of these values obtained for roasted meat (Table IX) with those cited for pot-roasted meat (Watt *et al.*, 1963; Pecot *et al.*, 1965) indicated no real differences. Where differences in protein content occurred they were again, reflections of moisture content.

Costs Per Edible Portion

Table X shows the costs of three ounce edible portions of these roasts assuming the current price differential. Waste due to bone reduced edible yield in the RBS to the extent that the average cost per serving was only $0.0225 more for the CR than for the RBS. The cost per serving for the second cut of the RBS was $0.02 more than that of the first cut of the CR and equal to that of the second cut of the CR. As the two roast types do not differ in proximate composition, strictly on the basis of economics the RBS is a better buy than the CR. However, when other factors are taken into consideration, such as the greater ease in carving and the added "eye appeal" of the larger slices, the higher cost per serving for the CR becomes less significant.

The more marked effect of the cooking conditions on evaporation losses in the CR than in the RBS is magnified in costs per edible portion. The CR realized a difference of

TABLE X

Cost[1] Per Edible Portion[2] For Both Roast Types as Affected by Cooking Condition and Position within the Carcass

Roast Type	Price per pound raw	Cooking Conditions (°C.)				Position	
		107 - 70	107 - 80	163 - 70	163 - 80	Cut 1	Cut 2
RBS	$0.59	$0.27	.31	.29	.31	.27	.32
CR	0.79	.30	.35	.29	.32	.30	.32

[1] On sale as of January 1970
[2] 3-ounce serving

Note: Calculation of cost per edible portion: Price per pound raw x $\frac{0.1875 \text{ lb.}}{\text{Percent cooked edible yield}}$

$0.06 per serving between its maximum and minimum yields whereas in the RBS this difference was $0.04 (Tables I and X).

Marshall et al. (1959) reported that evaporation accounted for approximately one-half of the total preparation losses in five pound top round roasts. Edible yield was approximately 63% when cooking was done at 149°C to 70°C and approximately 60% when cooking was extended to 80°C. Top round roasts are usually boneless and appear to contain slightly less intermuscular waste than the CR. However, their price per pound is approximately $0.30 more than that of the CR. A rather interesting comparison would be to determine the costs per edible portion of the CR and top round roasts when both were of the same weight and cooked under the same conditions. Using the formula given in Table X, the percentage yields given by Marshall et al. (1959), and a price of $1.09 per pound raw, the cost per edible portion for the top round was calculated to be $0.32 when cooking was done at 149°C to 70°C and $0.34 when cooking was extended to 80°C. These costs are comparable to those of the CR (Table X).

Shear Strength Measurements

Shear strength values indicate the number of pounds required to shear through a cylinder of meat. Tough meat offers greater resistance to shear and therefore exhibits higher shear values while low shear values are associated with tender meat.

Weighted means of shear values indicated that both roast types were most tender when cooked at the lower oven temperature of 107°C and when cooked to the greater degree of doneness at this oven temperature; the condition which least favored edible yield (Tables XI and I). Cooking at the lower oven temperature of 107°C significantly increased the tenderness of both roast types. When the oven temperature was 107°C increasing the stage of doneness significantly increased the tenderness of both roast types, however, when the oven temperature was 163°C increasing the stage of doneness significantly increased the tenderness of the RBS roast only.

When considered in the light of Cover's earlier work (1937, 1941a, 1941b, 1943), the marked effect of roasting at the lower oven temperature of 107°C and to the greater degree of doneness at this oven temperature on the tenderness response of both roast types, indicates that both are less tender cuts. Cover (1937) reported that low temperature roasting was more effective in tendering the TB of the round bone chuck than the LD of the prime rib and that TB was appreciably more tender at the lower oven temperature when the end-point was 80°C than when it was 63°C. In the LD the effect of degree of doneness on tenderness was much less marked. In 1943, Cover reported that the BF from the round cooked at 80°C was more tender when cooking was extended from 63°C to 80°C.

That only the RBS was more tender cooked to an internal temperature of 80°C at the oven temperature of 163°C appears to indicate that it is somewhat less tender initially

TABLE XI

Weighted Means[1] of Muscle Shear Values for Both Roast Types

Roast Type	Cooking Conditions (°C.)			
	107 - 70	107 - 80	163 - 70	163 - 80
RBS	5.60[b]	3.96[a]	7.31[c]	5.44[b]
CR	5.10[ab]	4.17[a]	6.26[b]	5.64[b]

[1] Means weighted according to percentage of each muscle in roast

[a,b,c] Means in rows bearing the same superscript are not significantly different.

than the CR. Increasing the degree of doneness in less tender cuts has been found to increase tenderness even when the rate of heat penetration is fast. The BF from the round in Cover's study in 1943 was less tender cooked at 125°C than 80°C regardless of degree of doneness, but more tender at 125°C when the internal temperature was 80°C than when it was 63°C. Cover et al. (1957) found that the BF was appreciably more tender when braised to 100°C + 25 minutes than to 85°C. On the other hand, as tender cuts become progressively less tender with increasing doneness (Cover et al., 1957) and the CR showed no differences in tenderness between degrees of doneness when cooked at 163°C, it can not be classed as a tender cut. It could appropriately be classed as a medium tender cut.

With the exception of the TBB in the RBS, all muscles in both roast types were most tender when cooked at 107°C to 80°C; the condition which least favored edible yield (Tables XII, XIII and I). However, the effect of the roasting conditions on the tenderness of individual muscles was significant for only four of the muscles in the RBS and none of those in the CR. Ramsbottom et al. (1945) and Visser et al. (1960) reported that meat samples cooked in the oven showed less variation in tenderness than those cooked in fat where the rate of heat penetration is considerably faster. All four muscles from the RBS, that is, the DP, TB (lateral head), DE and BR were appreciably more tender when cooked at 107°C to

TABLE XII

Tenderness by Shear for the Muscles of the RBS Roast[1]

Muscles	Cooking Conditions (°C.) 107 - 70	107 - 80	163 - 70	163 - 80	Between Cuts
TB (long head)	5.18	3.39	6.33	5.09	NS
DP	5.90[ab]	3.98[a]	7.36[b]	5.98[ab]	NS
TB (lateral head)	4.59[ab]	3.60[a]	10.14[c]	7.36[bc]	NS
BB	5.89	5.16	6.64	5.94	NS
BC	5.81	3.46	6.68	4.45	NS
DE	6.81[bc]	4.22[a]	8.00[c]	4.65[ab]	NS
BR	7.32[ab]	4.75[a]	9.85[b]	6.14[ab]	NS
TBB	5.06	6.17	7.20	4.93	NS
CC	5.75	3.97	5.62	5.22	NS
SP[2]	6.20	(2.65)[3]	(4.90)[3]	(5.10)[3]	
TB (medial head)[4]	5.58	3.08	-[5]	5.50	

[1]Each value represents the mean of 1 - 5 readings on each of four replicates
[2,4]Not analyzed due to insufficient values
[3]Values in parenthesis are from one roast only
[5]Cores were unobtainable
[abc]Means in rows not bearing superscripts or bearing the same superscript are not significantly different.

TABLE XIII

Tenderness by Shear for the Muscles of the CR Roast[1]

Muscles	Cooking Conditions (^{o}C.)[a]				Between Cuts
	107 - 70	107 - 80	163 - 70	163 - 80	
TB (long head)	4.64	3.24	5.28	4.98	NS
IM	4.94	4.70	6.84	5.51	NS
TM	6.39	4.64	7.00	6.12	NS
LTD	6.34	5.36	7.41	5.99	NS
DP[2]	6.07	4.00	(5.20)[5]	7.58	
SD[3]	6.20	2.70	7.10	5.60	
TFA[4]	6.37	5.00	8.00	10.02	

[1]Each value represents the mean of 1 - 5 readings on each of four replicates
[2,3,4]Not analyzed due to insufficient values
[5]Value in parenthesis from one roast only
[a]For each muscle means among cooking conditions are not significantly different.

80°C than when cooked at 163°C to 70°C. The TB (lateral head) was significantly more tender when cooked at the lower oven temperature regardless of degree of doneness while the DE was significantly more tender when cooked to 80°C regardless of oven temperature (Table XII).

The effectiveness of long slow dry heat roasting in tendering less tender cuts is thought to be due to the length of time the internal temperature of the meat is held between 65°C and 75°C (Cover, 1943). Cooking time was three or more times longer at the lower oven temperature (Table II). To extend the degree of doneness by 10°C took half again as much time at both oven temperatures for both roast types. As the TB (lateral head) was appreciably more tender at 107°C where cooking time was three or more times longer than at 163°C it appears that it is less tender than the DE.

Statistical analysis indicated that the muscles within each roast type and between roast types under all cooking conditions were not different in tenderness. However, the fact that the DP, DE, BR and TB (lateral head) were all appreciably more tender when cooked at 107°C to 80°C than when cooked at 163°C to 70°C when considered in light of Cover's (1937) findings with the TB and LD appears to indicate that these muscles are less tender than the rest of those in the RBS and those in the CR. Perhaps more replications would clarify this. Ramsbottom _et al._ (1945) reported that four of the muscles which occur in these roasts ranked in order of decreasing tenderness by shear, histological and organoleptic ratings as follows: TB, DP, LTD and SP.

The muscles of both roast types showed no differences in tenderness between cuts and comparison of shear values for the TB (long head) and DP which occur in both roast types indicated no differences. Ramsbottom et al. (1945) reported that the LTD was progressively more tender from the insertion end to the origin end of the muscle, while the DP was uniformly tender throughout.

Sensory Evaluation

In the RBS, the panel scored only the muscles cooked at 107°C to 80°C significantly higher than those cooked at 163°C to 70°C (Table XIV). The weighted mean of the shear values of the TB (long head) and DP in the RBS was significantly lower when cooking was done at 107°C to 80°C than at 163°C to 70°C. However, the weighted means were also significantly lower when cooking was done at the lower oven temperature regardless of internal temperature and when cooking was done to the greater degree of doneness regardless of oven temperature. Thus the panel sensed only the largest difference noted by the shear. The TB (long head) of the CR was equally well-liked under all roasting conditions (Table XIV) although it exhibited a slightly lower shear value when cooked at the lower oven temperature to the greater degree of doneness.

Critical comments of the judges regarding the most

TABLE XIV

Tenderness by Shear[1] and Hedonic Scores[2] for Both Roast Types

Roast Type	Measurement	Cooking Conditions ($^oC.$)			
		107 - 70	107 - 80	163 - 70	163 - 80
RBS	Shear (lbs.)	5.52[b]	3.67[a]	6.82[b]	5.50[b]
	Hedonic Score	6.07[ab]	6.42[b]	5.82[a]	5.87[ab]
CR	Shear (lbs.)	4.64	3.24	5.28	4.98
	Hedonic Score	6.12	5.95	5.95	6.12

[1]Values given for the RBS roast are weighted means of the TB (long head) and the DP; those given for the CR roast are the shear values for the TB (long head).

[2]Higher score = more liked; maximum = 9

[a,b]Means in rows not bearing a superscript or bearing the same superscript are not significantly different.

deficient acceptability characteristic in each roast are summarized in Figure 8. They indicate that the roast with the highest shear value, the RBS cooked at 163°C to 70°C (Table XIV), was the one most criticized for lacking tenderness. Thus the panel was sensing the differences noted by the shearing instrument. Lack of juiciness was obvious in both roast types when cooked at 107°C to both stages of doneness, although criticism was less frequent for the lesser degree of doneness. Roasts cooked more rapidly at 163°C to the greater degree of doneness also obviously lacked juiciness. However, tenderness was recognized as being more important than juiciness because the drier but more tender RBS roast was liked better than the juicier less tender one. It is interesting that "lack of flavor" criticisms were high for the CR roasts cooked at 163°C to 70°C. For this roast, color too, was judged deficient. This roast was consistently redder than the other treatments confirming observations by other workers that more rapid heat penetration brings about less pigment change (Cover and Hostetler, 1960).

Both roast types were most criticized for lacking tenderness when cooking was done at 163°C to an internal temperature of 70°C. Tenderness criticisms were not only more frequent for the RBS than for the CR under this condition, but they were also reflected in hedonic scores. The CR was equally well-liked under all cooking conditions. A possible explanation for this was given by Cover _et al._ (1962a). Due

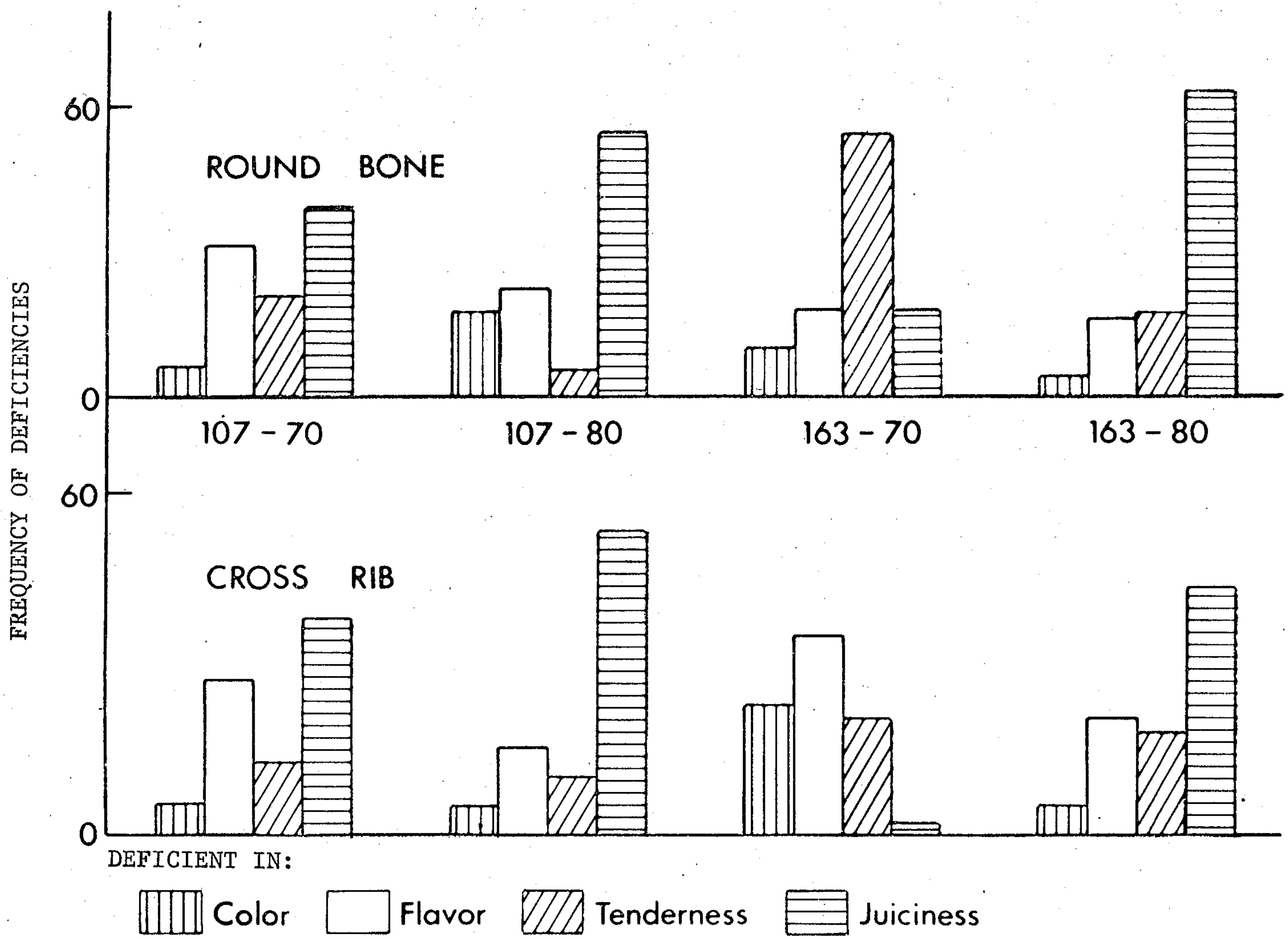


FIGURE 8. Frequency of judges' comments regarding the most deficient acceptability characteristic.

to a structural difference in the connective tissue of the LD and BF these workers found that although the BF broiled to 80°C contained less collagen nitrogen than the LD broiled to 61°C, the connective tissue was scored tougher in the BF. The low scores for tenderness of connective tissue appeared to reflect strands or lumps which were difficult to masticate and they formed a network that was easily identified by the tongue. Such heavy strands were seldom encountered in the LD. Although the samples contained no visible connective tissue if that which was invisible was in the form of strands in the RBS and not in the CR, then it is logical that lack of tenderness criticisms would be reflected in hedonic scores in the former but not in the latter. Under all cooking conditions lack of tenderness criticisms were reflected in hedonic scores to a greater extent in the RBS than in the CR.

Cover et al. (1962d) concluded that tender cuts are tender to the palate only when myofibrillar protein toughening is minimized whereas less tender cuts are tender only when connective tissue softened by conversion of collagen to gelatin is tender to the palate. The more marked influence of tenderness criticisms on hedonic scores for the RBS adds further evidence to the indications that it is less tender than the CR.

Cover et al. (1962d) also found that rare meat is soft and juicy and may be swallowed with little chewing. Both the CR and RBS were critized least for lacking juiciness when cooked at 163°C to 70°C however criticism was much less frequent for the CR. Thus juiciness likely favored hedonic scores for the CR under this condition.

The ultimate decision concerning the best method for dry heat roasting RBS and CR roasts must consider both edible yield which determines cost, and tenderness which largely determines the hedonic response in eating.

Cooking at 107°C to 80°C is clearly the best method for roasting the RBS. While edible yield showed no real differences among cooking conditions, shear values were significantly lower and hedonic scores were significantly higher when cooking was done at 107°C to 80°C. Thus, because of its tenderness response it must be recognized as a less tender cut, but clearly it can be tendered by adequate and slow cooking.

Cooking at 107°C to 70°C is the best method for roasting the CR, however, the decision is less straight forward. Tenderness in the CR was increased both by cooking at the lower oven temperature and to the greater degree of doneness at the lower oven temperature, however, it was equally well-liked under all cooking conditions. While extending the degree of doneness at the lower oven temperature increased tenderness, it also increased the cost per serving by $0.05. At 107°C to 70°C, the cost per serving was only $0.01 more than that for its maximum yield, 163°C to 70°C. Thus, 107°C to 70°C is more favorable to yield than 107°C to 80°C and more favorable to tenderness than 163°C to 70°C.

When all factors are considered, the two roast types are an equally good buy. The tenderness response of the RBS clearly defined its best roasting condition, 107°C to 80°C. Under this condition the cost per serving is $0.01 more than that for the CR under its best roasting condition, 107°C to 70°C. However, as the CR was equally well-liked under all roasting conditions and its tenderness response less defined, considering all roasting conditions, the average cost for the CR is $0.005 more than that for the RBS cooked for optimum acceptability. As the two roast types do not differ in proximate composition, strictly on the basis of dollars and cents, the RBS is a better buy than the CR. However, considering the greater ease in carving, the added "eye appeal" of the larger slices, and the fact that the roasting condition is less defined, the additional cost for the CR becomes less significant.

Between cuts also, strictly on the basis of economics, the RBS is a better buy than the CR. However, if the bone in the RBS tended to be large, the cost per serving for the CR would likely be comparable. It is striking that the waste along the rib bones in the second cut of the CR reduced edible yield to the extent that the cost per serving equalled that of the second cut of the RBS. In the raw roasts, this waste in the second cut of the CR is far less obvious than the waste due to bone in the second cut of the RBS. Thus the appearance of the second cut of the CR is extremely deceptive. With the high cost of meat today, consumers would without doubt, appreciate more information on "hidden" wastes in various cuts.

Recommended cooking methods for cuts containing several muscles are now based on tenderness assessments of the larger muscles within the cuts. The TB (long head), the largest muscle within both the CR and the RBS, showed no significant differences in tenderness among the roasting conditions. In fact, of all muscles studied, the tenderness of only four of those in the RBS was appreciably affected by the roasting conditions. However, for both roast types, weighted means of shear values were significantly different among the roasting conditions. Thus, as the consumer uses the entire roast, a cooking recommendation based on tenderness assessments of each of the muscles within the cut, weighted according to the proportion in which they are present, is by far more advantageous.

CONCLUSIONS

From the results of this study it can be concluded that:

1. Edible yield was not different among cooking conditions for the RBS roasts.
2. Yields for the CR roast were significantly lower when cooking was done at the lower oven temperature and to the greater degree of doneness due mainly to higher evaporation losses.
3. In all cases, edible yield was higher for the CR than for the RBS due to the appreciably higher proportion of bone in the latter.
4. Edible yield tended to be higher for the first cut than for the second cut of both roast types however this was only partially due to bone. Fat trimmed from the exterior of the roasts and intermuscular waste were also greater in the second cut of the RBS and CR, respectively.
5. Proximate composition of the edible yield was not different between the two roast types.
6. Within roast types differences in protein content were direct reflections of differences in moisture content.
7. Both roast types were most tender by shear when cooked at the lower oven temperature of 107^{o}C and when cooked to the greater degree of doneness at this oven temperature.
8. At the oven temperature of 163^{o}C, only the RBS was significantly more tender when the end-point was extended from 70^{o}C to 80^{o}C.

9. With the exception of the TBB, all muscles in both roast types were most tender when cooked at 107°C to 80°C.
10. The effect of the roasting conditions on tenderness was significant for only four muscles in the RBS, that is, the DP, DE, BR and TB (lateral head).
11. All four muscles were significantly more tender when cooked at 107°C to 80°C than when cooked at 163°C to 70°C.
12. The RBS was most well-liked when cooked at 107°C to 80°C.
13. The CR was equally well-liked under all cooking conditions.
14. Tenderness influenced hedonic scores to a greater extent in the RBS than in the CR under all cooking conditions.

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APPENDIX

APPENDIX A

Assignment of Round Bone Shoulder Roast Treatments

Replicate No.		Right		Left	
1	Animal #2	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	$107^{o}C.$	$163^{o}C.$	$107^{o}C.$	$163^{o}C.$
	Internal Temperature	$80^{o}C.$	$80^{o}C.$	$70^{o}C.$	$70^{o}C.$
	Sensory Evaluation	Right, TBLH[1]	Right, TBLH	Right, TBLH	Right, TBLH
		Right, DP[2]	Right, DP	Right, DP	Right, DP
	Shear Determinations	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
		Left, DP	Left, DP	Left, DP	Left, DP
2	Animal #1	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	$163^{o}C.$	$107^{o}C.$	$163^{o}C.$	$107^{o}C.$
	Internal Temperature	$70^{o}C.$	$80^{o}C.$	$80^{o}C.$	$70^{o}C.$
	Sensory Evaluation	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
		Left, DP	Left, DP	Left, DP	Left, DP
	Shear Determinations	Right, TBLH	Right, TBLH	Right, TBLH	Right, TBLH
		Right, DP	Right, DP	Right, DP	Right, DP
3	Animal #4	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	$107^{o}C.$	$163^{o}C.$	$107^{o}C.$	$163^{o}C.$
	Internal Temperature	$70^{o}C.$	$70^{o}C.$	$80^{o}C.$	$80^{o}C.$
	Sensory Evaluation	Right, TBLH	Right, TBLH	Right, TBLH	Right, TBLH
		Right, DP	Right, DP	Right, DP	Right, DP
	Shear Determinations	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
		Left, DP	Left, DP	Left, DP	Left, DP
4	Animal #3	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	$163^{o}C.$	$107^{o}C.$	$163^{o}C.$	$107^{o}C.$
	Internal Temperature	$80^{o}C.$	$70^{o}C.$	$70^{o}C.$	$80^{o}C.$
	Sensory Evaluation	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
		Left, DP	Left, DP	Left, DP	Left, DP
	Shear Determinations	Right, TBLH	Right, TBLH	Right, TBLH	Right, TBLH
		Right, DP	Right, DP	Right, DP	Right, DP

[1] Triceps brachii, long head
[2] Deep pectoral

APPENDIX B

Assignment of Cross Rib Roast Treatments

Replicate No.		Right		Left	
1	Animal #3	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	107°C.	107°C.	163°C.	163°C.
	Internal Temperature	70°C.	80°C.	80°C.	70°C.
	Sensory Evaluation	Right, TBLH[1]	Right, TBLH	Right, TBLH	Right, TBLH
	Shear Determinations	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
2	Animal #2	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	163°C.	107°C.	107°C.	163°C.
	Internal Temperature	70°C.	70°C.	80°C.	80°C.
	Sensory Evaluation	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
	Shear Determinations	Right, TBLH	Right, TBLH	Right, TBLH	Right, TBLH
3	Animal #1	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	163°C.	163°C.	107°C.	107°C.
	Internal Temperature	80°C.	70°C.	70°C.	80°C.
	Sensory Evaluation	Right, TBLH	Right, TBLH	Right, TBLH	Right, TBLH
	Shear Determinations	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
4	Animal #4	Cut #1	Cut #2	Cut #1	Cut #2
	Oven Temperature	107°C.	163°C.	163°C.	107°C.
	Internal Temperature	80°C.	80°C.	70°C.	70°C.
	Sensory Evaluation	Left, TBLH	Left, TBLH	Left, TBLH	Left, TBLH
	Shear Determinations	Right, TBLH	Right, TBLH	Right, TBLH	Right, TBLH

[1] Triceps brachii, long head

APPENDIX C

Animal Histories

Animal #1 - bought at the Foxwarren Calf Sale
- weight: 825 pounds
- age: 14 months
- the calf was bought not purebred
- finished on: 50% oats, 50% barley, beet pulp and beef fattening

Animal #2 - bought at the Foxwarren Calf Sale
- weight: 920 pounds
- age: 13 months
- the calf was raised not purebred
- finished on: 70% oats and 30% wheat rolled with beet pulp

Animal #3 - bought at the Foxwarren Calf Sale
- weight: 925 pounds
- age: 13 months
- the calf was raised not purebred
- finished on: 70% oats and 30% wheat rolled with beet pulp

Animal #4 - bought at a 4-H Calf Sale
- weight: 825 pounds
- age: 16 months
- finished on: boiled barley, oat chop and molasses

APPENDIX D

Glossary of Abbreviations

Roasts

CR - Cross rib
RBS - Round bone shoulder

Muscles

BB - Biceps brachii
BC - Brachiocephalicus
BF - Biceps femoris
BR - Brachialis
CB - Coracobrachialis
DE - Deltoideus
DP - Deep pectoral
IF - Infraspinatus
IM - Intercostal muscles
LD - Longissimus dorsi
LTD - Latissimus dorsi
SD - Scalenus dorsalis
SM - Semimembranosus
SP - Superficial pectoral
ST - Semitendinosus
SV - Serratus ventralis
TB - Triceps brachii
TB (lateral head) - Triceps brachii (lateral head)
TB (long head) - Triceps brachii (long head)
TB (medial head) - Triceps brachii (medial head)
TBB - Tendon of Biceps brachii
TFA - Tensor fasciae antibrachii
TM - Teres major
PM - Poas major