# EFFECTS OF RAPID HEAT TREATMENTS ON BEEF TOP ROUND STEAKS

by

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# INTRODUCTION

Time saving methods of cooking meats are popular. With the microwave oven, cooking time is decreased by 1/10 to 1/2 that of conventional cooking (Fenton, 1957; Moore et al., 1966). In many instances food can be prepared in serving dishes, reducing clean up time.

An important consideration in the selection of any cooking method is the effect of heat treatment on the palatability of the meat. Marshall (1960), Deethardt et al. (1973) and Moore et al. (1966) compared microwave cookery to conventional methods for cooking meats. All of those authors found higher total cooking losses and lower palatability scores for the meat cooked in the microwave oven than by conventional methods. Clark et al. (1955), Clark and Van Duyne (1949) and Schock et al. (1970) reported the use of braising beef under pressure, a relatively rapid method, as acceptable.

Studies were reviewed concerning microwave cooking mainly for pork and poultry, but few studies were found on microwave cooking of beef. This experiment was designed to evaluate the effect of microwave cooking and pressure braising on sensory characteristics and related objective measurements on beef top round steaks cooked to two end point temperatures.

# REVIEW OF LITERATURE

## Gross structure and composition of muscle tissue

Meat is composed of striated voluntary muscles with the individual muscles being made up of muscle fibers, connective tissue and adipose tissue. The striated muscle fibers, which are surrounded by a thin, structureless membrane called the sarcolamma, are composed of myofibrils, nuclei and sarcoplasm containing materials such as fat droplets, glyogen granules, mitochondria and lysosomes (Paul, 1972). A portion of the myofibril, designated as a sarcomere, is considered the basic structural and functional muscular unit (Fukuzawa and Briskey, 1970). The individual muscle fibers within the bundle are enclosed in a framework of connective tissue called the endomysium. The fibers are grouped into bundles or fasciculi that are surrounded by the perimysium connective tissue sheath (Paul, 1972). The epimysium, a heavy sheath of connective tissue, surrounds the muscle as a whole (Paul, 1972).

Connective tissue is composed of collagenous, elastic and reticular fibers and ground substance. Collagen fibers are widely distributed in muscle. When heated, the fibers contract, soften and partially convert to gelatin, which influences muscle tenderness. Elastic fibers, which are scarce in muscle, have little effect on muscle tenderness (Paul, 1972; Cassens, 1971). Reticular fibers, chemically similar to collagen fibers, are considered by some researchers to be a form of immature collagen fibers (Hiner, 1955; Cassens, 1971). Collagenous, elastic and reticular fibers are embedded in a homogenous background material known as ground substance. This amorphous material varies from a fluid to a gel-like consistency.

Fat in muscle is in the form of marbling, separable fat and adipose tissue. Separable fat is found between muscles; whereas, marbling and adipose tissue are located in the perimysial spaces (Cassens, 1971). Fat cells that accumulate in large numbers and crowd out other cells are designated as adipose tissue (Paul, 1972). The cells of adipose tissue are larger in size than fat cells located in marbling. However, fat cells comprising marbling are distributed in easily visible quantities (Harrison et al., 1959).

Influence of muscle structure on tenderness

Muscle tenderness depends on a variety of factors including breed, age, sex, grade and animal weight. Muscle fiber diameter, quantity and distribution of fat and connective tissue have been associated with muscle tenderness (Harrison et al., 1959).

Since muscle fibers constitute 3/4 of the muscle volume, they are an important factor in muscle tenderness. Satorius and Child (1938) and Hiner et al. (1953) noted that the smaller the diameter of the fibers, the greater the number of fibers per bundle resulting in a finer texture and greater tenderness. Ramsbottom et al. (1945) found the psoas major muscle with small, indistinct bundles had a smooth, fine texture, was more tender and had a lower shear reading than the superficial pectoral muscle with large bundles.

Some workers have established a relationship between tenderness and sarcomere length. Herring et al. (1965) found as sarcomere length decreased, fiber diameter increased; thus, decreasing tenderness. Unlike Herring et al. (1965), Paul (1962a) found no such relationship.

The relationship of collagenous and elastic tissues to tenderness has been studied extensively (Ramsbottom et al., 1945; Hiner et al., 1945; Harrison et al., 1959; Sanderson and Vail, 1963; Cross et al., 1973). Connective tissue softens on heating, but the muscle fibers become firmer. Thus, if connective tissue is high, cooking increases tenderness; whereas, with little connective tissue present, cooking may decrease tenderness by denaturing myofibrillar proteins.

Although reticular fibers and the ground substance in which the connective tissue fibers are embedded have not been studied extensively for their effect on tenderness, Cover et al. (1962a) suggested they may play an important role in determining tenderness.

Harrison et al. (1953) reported that an increase in proportion of fat resulted in more tender meat. However, Wang et al. (1954) asserted that the total amount of fat in the muscle was less important than its distribution. Others have reported poor correlations between marbling and tenderness scores (Cover et al., 1956; Parrish, 1974).

Heat induced changes in muscle tissue

The primary objective in cooking meat is to produce a palatable product and one of the most important aspects of palatability is tenderness. When meat is heated, physical and chemical changes occur in the connective tissue, muscle fiber proteins, and moisture and fat content. The rate at which the meat is heated and the amount of time the meat is exposed to heating also plays an important role in meat tenderization.

Changes in connective tissue. Machlik and Draudt (1963), Sanderson and Vail (1963) and Tuomy et al. (1963) studied the effects of heat on various muscle tissues in relation to tenderness. Macklik and Draudt (1963), working with beef semitendinosus, found little change in tenderness below 50°C, a marked increase in tenderness between 50° and 60°C, a tenderness decrease between 60° and 70°C and some increase in tenderness above 75°C. They attributed the initial increase in tenderness to collagen shrinkage, the tenderness decrease between 60° and 70°C to hardening of the muscle fibers and the subsequent increase above 75°C to the transformation of collagen to gelatin.

Sanderson and Vail (1963) investigated the effects of heating beef longissimus dorsi (LD), semimembranosus (SM) and semitendinosus (ST) muscles to 60°, 70° and 77°C. They found that increasing internal temperature in the LD did not change the tenderness, but the SM and ST muscles increased in tenderness with increasing internal temperature. They attributed the difference in response among muscles to the higher connective tissue content of the two muscles from the round (SM and ST).

Tuomy et al. (1963) heated strips of beef semimembranosus in a water bath and reported an initial toughening of the meat, which was attributed to protein denaturation. As temperature increased, tenderness increased gradually. They suggested, as did Machlik and Draudt (1963), that this tenderization is a result of the collagen-gelatin transformation.

Changes in muscle fiber proteins and moisture content. When meat is heated, the most obvious change is loss of water-holding capacity brought about by denaturation of the sarcoplasmic and myofibrillar proteins. According to Hamm (1966), the proteins lose much of their water-holding capacity because of heat coagulation. This begins at 35°C but occurs primarily between 40° and 50°C. Coagulation and subsequent release of juice are not yet complete at 60°C and continue to a lesser extent with increasing temperatures. The influence of heat treatments on water-holding capacity of meat mainly concerns "free" water. During coagulation, a major portion of this water becomes mobilized and is released from the meat (Laakkonen, 1973).

Cooking losses are a moisture related change brought about by heating of the muscle. Cooking losses can be separated into drip losses and evaporation or volatile losses. Drip losses often are said to contain largely fat and volatile losses largely water. However, when heating is in a closed container, drip losses will contain a good deal of water.

The degree of water-holding capacity primarily influences juiciness and the softness component of tenderness. As more moisture is lost, the meat becomes increasingly harder thus influencing tenderness and palatability.

Changes in fat content. In proximate analysis of raw muscle tissue, a highly significant negative correlation between total moisture content and ether-extractable materials usually is found. Also it was found that muscle tissue has a higher percentage of ether-extractable material after heating than does the raw muscle. Paul (1964) suggested that ether-extractable material increases in cooked meat because fat infiltrates into the muscle tissue during heating. Another possible explanation is that heat alters the muscle structure so that fat is more excessible to extraction. According to Kendall et al. (1974), percentage total moisture in cooked products increased as lipid decreased indicating that moisture is related inversely to lipid content.

The role of fat in muscle tenderness is undecided. Harrison et al. (1953) and Wang et al. (1954) agreed that fat influences tenderness; whereas, Cover et al. (1956) and Parrish (1974) concluded that little relationship exists between fat and tenderness.

Rate of heat penetration in skeltal muscle

The rate at which the interior of a piece of meat will heat is influenced by the rate at which energy is supplied, the rate at which it is transmitted to the meat, the size and shape of the sample, the amount of lean, fat and connective tissue, and the changes induced in the meat by heat including protein denaturation, loss of water and melting of fat (Paul, 1972).

Numerous authors (Bramblett et al., 1959; Bramblett and Vail, 1964; Bayne et al., 1969; Laakkonen, 1973) have reported that cooking at low temperatures for long periods of time produce more tender meat than their counterparts cooked at higher temperatures for shorter periods of time. McCrae and Paul (1974), though, found little difference in tenderness of meat when heated at both rapid and slower rates.

Methods of heating muscle tissue

Methods of meat cookery have been classified traditionally as either "dry" or "moist" heat, referring to the atmosphere surrounding the meat. The rate at which heat energy is supplied to the external surface of the meat influences the cooking process. Because water vapor is a more efficient conductor of heat than is dry air, moist heat methods often are preferred over dry heat methods. The microwave oven, still another cooking medium, supplies a rapid transmission of energy and is an even faster method of meat cookery than moist heat methods.

Moist heat cookery. Traditionally, moist heat methods have been recommended for cuts of meat high in connective tissue. Some examples of moist heat methods include braising, steaming, stewing, braising under pressure, wrapping in aluminum foil, oven film bags and slow-cookers.

In the moist heat method of braising, heat transfer is by convection from the moist atmosphere and by conduction from the pan surface or rack. Because the atmosphere is water-vapor saturated, heat is transferred rapidly allowing the meat to cook evenly and quite fast (Paul, 1972).

Clark et al. (1955) compared oven and pressure braising. They found beef semimembranosus and biceps femoris steaks required longer to cook, but had similar total cooking losses and palatability scores when braised to 80°C in a 300°F oven as when cooked under 10 and 15 p.s.i.g. to 80°C.

Clark and Van Duyne (1949) found significantly higher total cooking losses for top round beef roasts cooked in a pressure saucepan under 15 p.s.i.g. than for meat roasted in an oven. Roasts cooked in the pressure saucepan were rated drier and less palatable than the corresponding roasts cooked in the oven.

Griswold (1955) concluded that meat braised in a covered pan in the oven to an internal temperature of 85°C was more palatable than when braised under 5, 10 or 15 pounds of pressure to an internal temperature of 85°C.

Shock et al. (1970) reported shorter cooking time and increased cooking losses for pressure braised (10 p.s.i.g.) beef than for beef cooked by oven-roasting, oven-braising and deep-fat frying. Sensory scores for flavor, tenderness and overall acceptability did not differ significantly for meat cooked by the four methods; whereas, juiciness scores for the beef cooked under pressure were significantly lower than beef cooked by oven-roasting, oven-braising or deep-fat frying.

Dry heat cookery. Dry heat methods usually are recommended for tender cuts of meat, containing little connective tissue. These include roasting, broiling, pan broiling, baking and deep-fat frying.

In roasting, the principal form of energy is transmitted largely by air convection. Increasing the oven temperature decreases cooking time, increases total cooking losses, and decreases the uniformity of doneness.

Frying in deep fat is considered a dry heat method because the meat is surrounded by liquid fat rather than moisture vapor. Heat is transferred by conduction from the hot fat to the surface of the meat. Because the rate of heat transfer is rapid, careful regulation of the frying medium is required (Paul, 1972).

Broiling involves heating meat primarily by radiant energy from the heat source. It is a rapid method, but the cooking temperature is difficult to control for experimental work. A modified broiling or roasting method employs the use of racks with 4 to 8-in. legs that allow the meat to cook on all sides at the same time (Paul, 1972).

Microwave cookery. Microwave ovens have a dry atmosphere, but the heating principal is entirely different from the dry heat methods. The energy is supplied as short electromagnetic waves that fall between light and radio waves in frequency. These waves are generated by a power tube called the magnetron, located in the top of the oven. The energy wave frequencies are measured in terms of megacycles or megahertz (MHz) per second. The Federal Communications Commission has assigned frequencies of 915 MHz or 2,450 MHz for commercial and domestic uses, with 2,450 MHz being the more common (Van Zante, 1973).

Microwaves cause oscillation of the polar molecules, converting electrical energy into molecular motion which results in heating. Since heat is produced within the food, there is no time lapse during which heat must pass from an external source to the interior of the food. Cooking time is therefore affected by, and to an extent controlled by many factors such as: initial temperature of the food, desired degree of doneness, size and shape of the food item, dipolar molecular action and vapor pressure in the oven, moisture loss by evaporation and depth of penetration of the microwaves (Van Zante, 1973).

According to Van Zante (1973), tender cuts of meat, when cooked properly in the microwave oven, retain their natural juices and have a good flavor. Less tender cuts will not become tender, though, because the long, slow cooking process exposing connective tissue to moisture is not a condition produced by microwave cookery.

Studies dealing with microwave cookery of meat indicate much shorter cooking time, increased cooking losses and decreased palatability scores for microwave cooked samples when compared to conventional oven cooking (Marshall, 1960; Headley and Jacobson, 1960; Pollak and Foil, 1960; Kylen et al., 1964; Ream et al., 1974).

Law et al. (1967) found that conventional oven roasting resulted in fewer cooking losses than microwave cooking, which resulted in less cooking losses than did conventional broiling.

Decareau (1967) pointed out that conventional cooking standards and techniques are not always applicable to microwave cookery, but when the product heating performance has been analyzed thoroughly, a system involving microwave energy may yield better quality than conventional methods.

## MATERIALS AND METHODS

U.S. Choice grade beef top rounds (approximately 9 kg; 20 lb), semimembranous (SM) and adductor (AD) muscles, were purchased from a local wholesale meat company. The external fat covering was removed, the muscle squared off, and eight steaks cut from each round (Fig. 1). Weights of the steak ranged from approximately 400 to 800 g. Approximate dimensions of the steaks in cm were: length, 13 to 15; thickness, 5; and depth, 8 to 12.

Raw samples were analyzed at the time of cutting. Gardner color-difference values, percentage total moisture, and ether extracts were the measurements made.

Two rounds, comprising four replications, were purchased at one time, cut, wrapped, frozen and cooked according to the experimental design before meat for the next replications was purchased, processed and cooked. Each steak was wrapped in aluminum foil (gauge 0.0015), frozen in an upright freezer at -26°C (-15°F) and stored in the same freezer for 2 weeks. A record was kept of the freezer temperature during storage.

Twenty-four hours before cooking, steaks were removed from the freezer and thawed overnight at 4°C (40°F). The temperature at the center of the thawed steak was 2°C ± 4°C (36°F ± 7°F). The steaks were cooked in a microwave oven (Amana Radarange, model RR-2) or pressure braised in a pressure

Fig. 1-Sampling plan for beef top round (SM and AD muscles).
A-H Steaks cut from SM and AD muscles.


A
C
E
G
B
D
F
H

saucepan equipped with both a thermocouple and a thermometer (Figs. 2 and 3).

All steaks were cooked to an end point temperature such that the center of the steak was approximately 70° (158°F, medium) or 80°C (176°F, well-done) after the post cooking temperature rise. Preliminary work indicated that for pressure braising (PB), post cooking temperature rise averaged 3°C for 400 to 650 g steaks and 5°C for 650 to 800 g steaks. Microwave (MW) post cooking temperature rise averaged 2°C for 400 to 650 g steaks or 5°C for 650 to 800 g steaks. The post cooking temperatures were taken 5 min after removal from the heat. These corrections were used to calculate when to remove heat to achieve final temperatures of 70° or 80°C.

PB steaks were cooked with 30 ml water in the pressure saucepan at 10 p.s.i.g. (115°C, 240°F) to the appropriate internal temperature as measured by an iron-copper thermocouple. Cooking time was recorded. MW steaks were cooked to the appropriate temperature as measured at the center of the steak by a glass thermometer with non-polar liquid in the column indicating temperature. Steaks were cooked on an inverted ceramic saucer placed in a 9-in. pyrex glass pie plate in the center of the oven. Power supply in the oven was checked periodically (Van Zante, 1973) and was approximately 30% below oven specifications (Table 22).

Experimental design and analysis of data

The experimental design was a randomized complete block with 12 replications. One block (replication) consisted of

Fig. 2-Thermocouple inserted into center of steak in pressure saucepan and connected to a pententiometer.

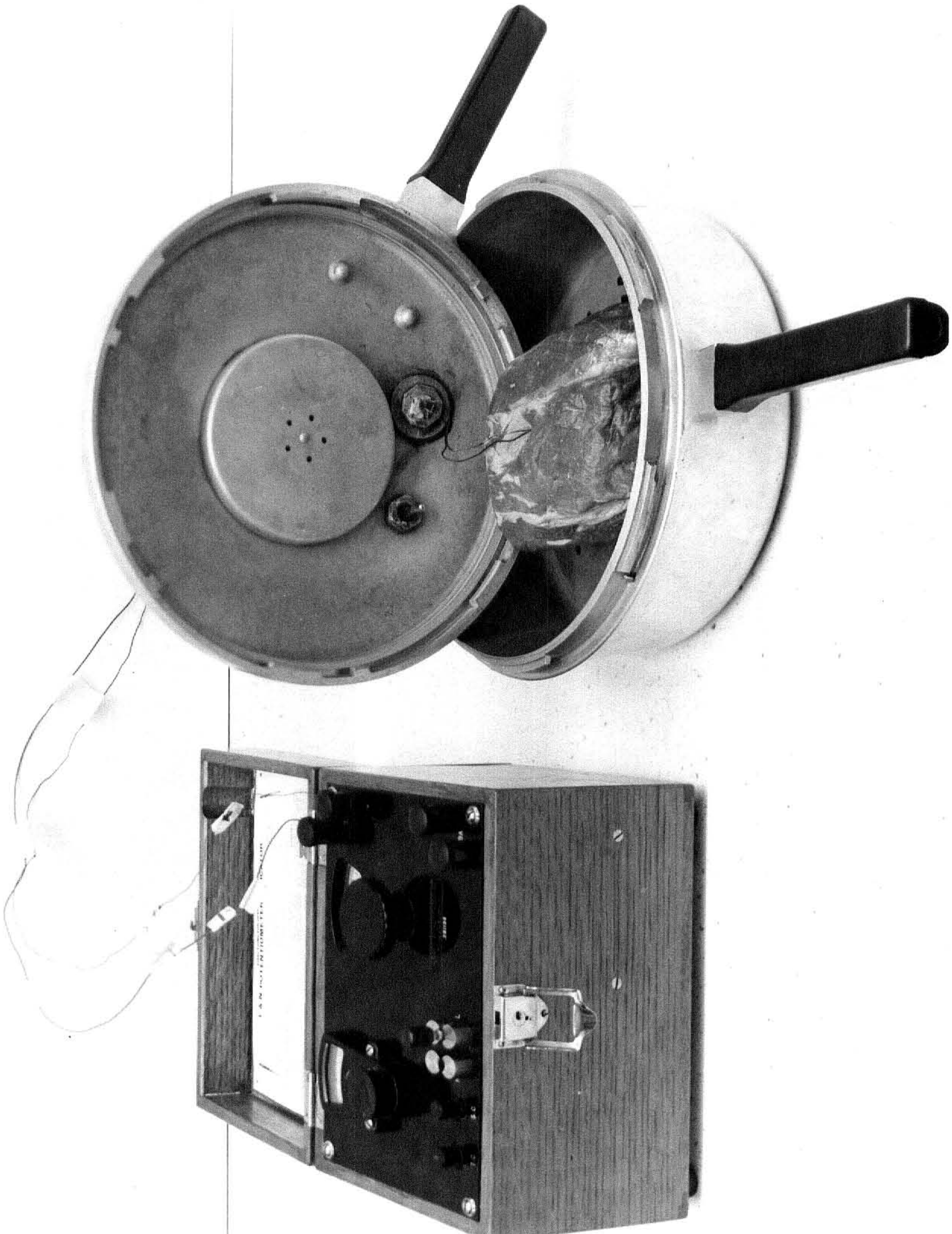
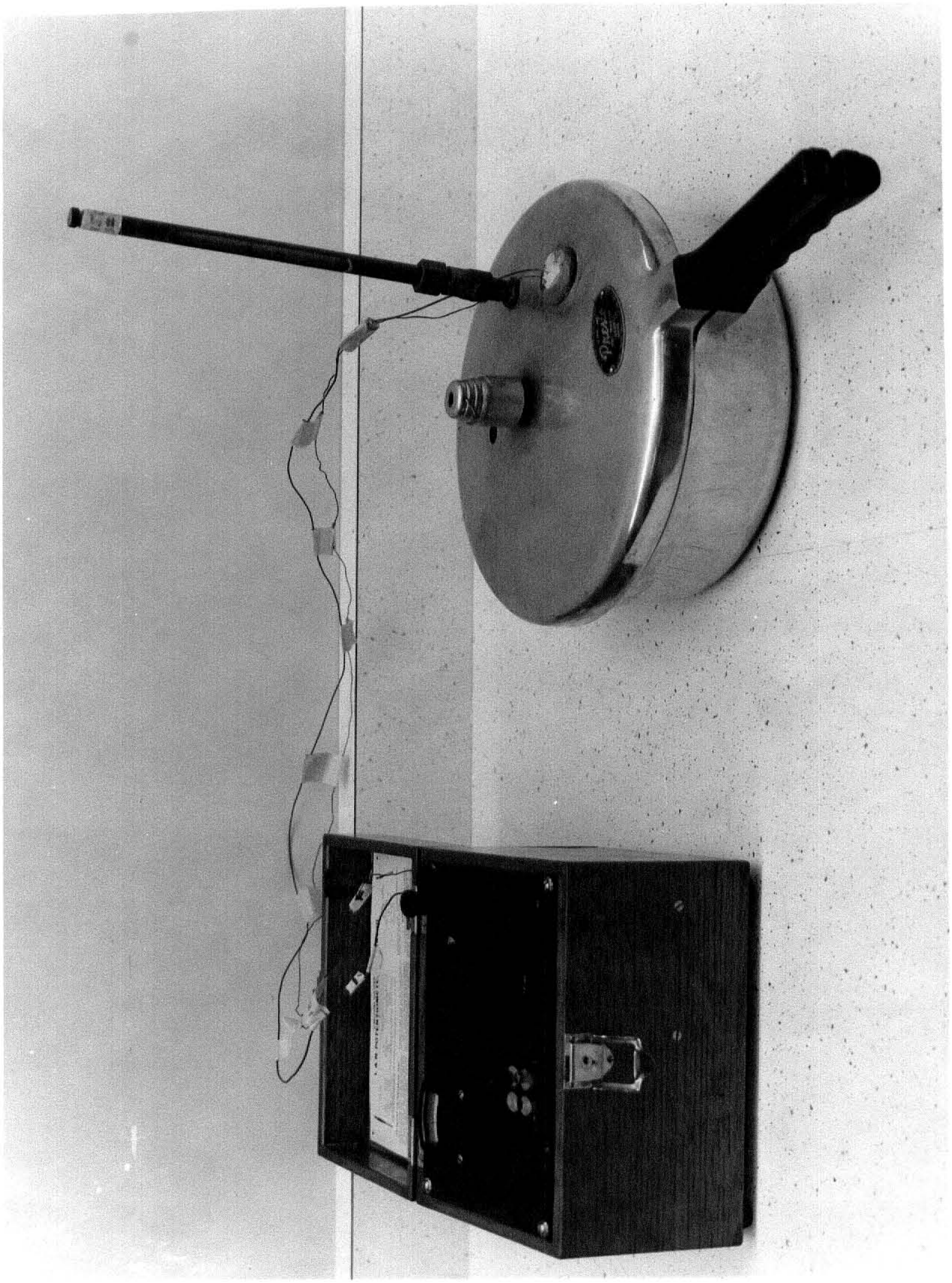


Fig. 3-Pressure saucepan with thermocouple connected to pententiometer to record internal temperature of steak.



four cooking method-end point temperature combinations (Table 1). Steaks were assigned to replications by position of steak (Fig. 1) with the odd replications comprised of steaks C, D, E, F weighing 450-750 g and the even replications composed of steaks A, B, G, H weighing 400-775 g. There were 24 evaluation periods with two steaks cooked at each period.

Data were analyzed by analysis of variance:

| Source of variation | D/F |
|---|---|
| Replication (steak weight) | 11 |
| Treatment combinations | |
| Method of cooking (a) (MW vs PB) | 1 |
| End point temperature (b) (70° vs 80°C) | 1 |
| Interaction (a x b) | 1 |
| Error | 33 |
| Total | 47 |

Rate of heat penetration and cooking losses

Rate of heat penetration was observed in PB steaks by recording the initial temperature and the time required for each 10°C rise from the initial temperature to 40°C and for each 5°C increase until the specific end point temperature was reached. For PB steaks, percentage total and drip cooking losses and for MW steaks, percentage total, volatile and drip cooking losses, based on the weight of the thawed steak, were calculated.

Table 1-Experimental design for cooking and position of raw sample

| Cooking period | Replication | Round | Steak position | Treatment[a] |
|---|---|---|---|---|
| 1 | 1 | 1 | C | I |
| | | | D | III |
| 2 | 1 | 1 | E | II |
| | | | F | IV |
| 3 | 2 | 1 | A | III |
| | | | B | I |
| 4 | 2 | 1 | G | IV |
| | | | H | II |
| 5 | 3 | 2 | C | II |
| | | | E | IV |
| 6 | 3 | 2 | D | III |
| | | | F | I |
| 7 | 4 | 2 | A | III |
| | | | H | I |
| 8 | 4 | 2 | G | II |
| | | | B | IV |
| 9 | 5 | 3 | D | IV |
| | | | E | II |
| 10 | 5 | 3 | C | I |
| | | | F | III |
| 11 | 6 | 3 | A | II |
| | | | G | IV |
| 12 | 6 | 3 | H | III |
| | | | B | I |
| 13 | 7 | 4 | D | III |
| | | | F | I |
| 14 | 7 | 4 | E | IV |
| | | | C | II |
| 15 | 8 | 4 | A | II |
| | | | H | IV |
| 16 | 8 | 4 | G | III |
| | | | B | I |

Table 1-concluded

| Cooking period | Replication | Round | Steak position | Treatment[a] |
|---|---|---|---|---|
| 17 | 9 | 5 | D | IV |
| | | | E | II |
| 18 | 9 | 5 | C | III |
| | | | F | I |
| 19 | 10 | 5 | A | III |
| | | | G | I |
| 20 | 10 | 5 | H | IV |
| | | | B | II |
| 21 | 11 | 6 | C | I |
| | | | D | III |
| 22 | 11 | 6 | F | II |
| | | | E | IV |
| 23 | 12 | 6 | A | III |
| | | | B | I |
| 24 | 12 | 6 | G | II |
| | | | H | IV |

[a] Treatments:

I Pressure braised, 70°C

II Pressure braised, 80°C

III Microwave oven, 70°C

IV Microwave oven, 80°C

Sensory evaluation

A 7-member laboratory panel selected at random and evaluated 1.3-cm cubes of cooked meat for tenderness, texture, juiciness and flavor (Form I, Appendix, p. 54). Instructions for evaluation were provided (Form II, Appendix, p. 55). Evaluation was made on an intensity scale of 5-to-1 for tenderness, juiciness and flavor. A scale of 5-to-1 for degree of mealiness was used to evaluate texture. Samples were presented to the judges in the top of half pint double boilers set over hot water. The entire system was placed on an electric hot tray at low heat (65°C ± 6°C, 150°F ± 10°F). All sensory evaluation took place within 30 min after preparation of the samples. Cooked steaks were sampled according to Fig. 4.

Gardner color-difference

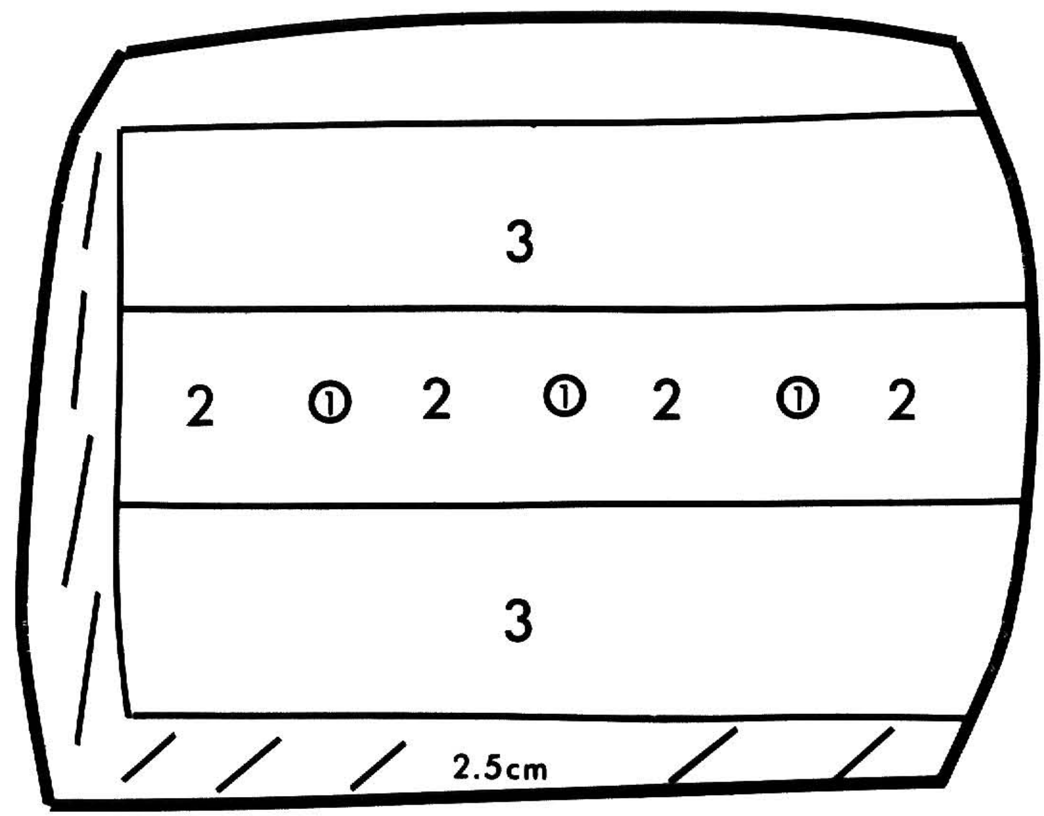
Color-difference values for both raw and cooked samples were measured with a Gardner Color Difference Meter. The instrument was standardized for the raw sample using a satin finished ceramic tile with calculated values of: Rd (reflectance), 5.9; a+ (redness), 24.7; and b+ (yellowness), 7.3. For the cooked samples, the standard calculated values were: Rd (reflectance), 38.1; a+ (redness), 6.4; and b+ (yellowness), 15.2. A sample of ground meat was packed into a plexiglass cell of 5.5-cm in diameter so that no light filtered through the sample. Duplicate readings were made for each color-difference factor; the cell was rotated 90° between readings.

Fig. 4-Sampling plan for cooked steaks.

1--Shear cores, water-holding capacity

2--Total moisture, Gardner color-difference, ether extract

3--Sensory evaluation samples


3
2
①
2
①
2
①
2
3
2.5cm

### Shear values

Tenderness was measured on cooked samples by shearing 1.3-cm cores on a Warner-Bratzler shearing apparatus with a 25-lb dynamometer. Cores were taken from the proximal, center and distal position in each steak (Fig. 4). Three measurements were made on each core and the overall shear value was the average of the three cores.

### Water-holding capacity

Water-holding capacity (WHC) of the cooked meat was measured as reported by Miller and Harrison (1965) on 0.3-g samples taken from the center of cores used for shear values. The ratio of the area of pressed muscle to the area of expressed liquid on the filter paper on which the sample is pressed was designated as the expressible liquid-index. WHC values were obtained by subtracting the expressible liquid-index from 1.0, arbitrarily chosen as the maximum expressible-liquid index. The expressible-liquid index is related inversely to the amount of liquid expressed from the sample; thus, the larger the value of WHC, the greater amount of liquid expressed.

### Total moisture

Percentage total moisture was measured on duplicate 10-g samples of raw or cooked meat by drying the C.W. Brabender Semi-automatic Moisture Tester at 121°C. Raw samples were dried for 90 min and cooked samples for 60 min as determined in preliminary work.

Ether extract analysis

Percentages of ether extract in both raw and cooked meats were measured by a modified AOAC method (AOAC, 1970). Samples dried in the C.W. Brabender Semi-automatic Moisture Tester for total moisture measurements were used for ether extract analyses. Dried samples, 1-1.5 g, were rolled in Whatman No. 1 filter paper and transferred to extraction thimbles. Pans used for drying were rinsed with petroleum ether used in the extraction process to include any lipid lost during drying. Duplicate dried samples were subjected to extraction with petroleum ether for 16 hr on the Goldfisch Extraction apparatus, the ether evaporated and the percentage ether extract calculated.

## RESULTS AND DISCUSSION

Weight of steak--replications

Analysis of variance indicated no significant differences among weights of the steaks assigned to cooking method (Table 2) or to end point temperature (Table 3). However, significant ($P \leq 0.05$) differences in weight of steak attributable to replication did occur (Table 4).

Steaks were assigned to replications according to the position of the steak in the round with the four inside steaks (C, D, E, F) (Fig. 1) weighing 450-700 g, comprising the odd replication. The four outside steaks (A, B, G, H) (Fig. 1) weighed 400-775 g, comprising the even replications. Preliminary work had shown steaks A, B, G, H weighed from 400 to 650 g

Table 2-Means and F-values for cooking method[a]

| Measurement | Pressure braised | Microwave | Difference | F-value |
|---|---|---|---|---|
| Initial weight, g | 541.0 | 576.3 | 35.3 | 1.92ns |
| Total cooking time, min | 30.0 | 14.6 | 15.4 | 100.92*** |
| Post cooking temp rise | | | | |
| °C | 2.0 | 3.5 | 1.5 | 12.5*** |
| % | 2.8 | 5.0 | 2.2 | 12.1** |
| Cooking losses, % | | | | |
| Total | 33.9 | 33.8 | 0.1 | 0.01ns |
| Drip | 23.3 | 9.1 | 14.2 | 229.12*** |
| Volatile | | 23.9 | | |
| Total moisture, % | 59.9 | 59.3 | 0.6 | 1.63ns |
| Water-holding capacity[b] | 0.71 | 0.70 | 0.01 | 0.19ns |
| Shear value, kg/1.3-cm core | 6.9 | 6.7 | 0.2 | 0.29ns |
| Ether extract, % | 13.0 | 13.1 | 0.1 | 0.01ns |
| Color-difference, Gardner | | | | |
| Rd (reflectance) | 20.6 | 20.0 | 0.6 | 1.83ns |
| a+ (redness) | 2.5 | 2.8 | 0.3 | 4.16* |
| b+ (yellowness) | 11.0 | 10.8 | 0.2 | 3.05ns |

Table 2-concluded

| Measurement | Pressure braised | Microwave | Difference | F-value |
|---|---|---|---|---|
| Sensory scores[c] | | | | |
| Flavor | 3.3 | 3.5 | 0.2 | 2.12ns |
| Juiciness | 2.9 | 3.3 | 0.4 | 3.64ns |
| Tenderness | 3.6 | 3.5 | 0.1 | 0.27ns |
| Texture | 3.3 | 3.0 | 0.3 | 1.88ns |

[a] End point temperature data combined

[b] 1.0-(expressible liquid index); the larger the value, the greater the amount of liquid expressed

[c] 5-(rich, beef flavor, juicy, tender, mealy); 1-(no beef flavor, dry, tough, chewy)

*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$; ns, not significant

Table 3-Means and F-values for end point temperature[a]

| Measurement | End point temp, °C 70° | 80° | Difference | F-value |
|---|---|---|---|---|
| Initial weight, g | 555.4 | 562.0 | 6.6 | 0.07ns |
| Total cooking time, min | 19.7 | 25.0 | 5.3 | 11.52** |
| Post cooking temp rise | | | | |
| °C | 2.6 | 2.9 | 0.3 | 0.45ns |
| % | 3.9 | 3.8 | 0.1 | 0.01ns |
| Cooking losses, % | | | | |
| Total | 32.4 | 35.2 | 2.8 | 6.79** |
| Drip | 15.6 | 16.8 | 1.2 | 1.70ns |
| Volatile | 22.1 | 25.6 | 3.5 | 2.84ns |
| Total moisture, % | 60.1 | 59.1 | 1.0 | 3.78ns |
| Water holding capacity[b] | 0.75 | 0.67 | 0.08 | 12.03** |
| Shear value, kg/1.3-cm core | 6.6 | 7.0 | 0.4 | 0.71ns |
| Ether extract, % | 13.4 | 12.7 | 0.7 | 0.64ns |
| Color-difference, Gardner | | | | |
| Rd (reflectance) | 20.0 | 20.6 | 0.6 | 1.41ns |
| a+ (redness) | 2.8 | 2.5 | 0.3 | 3.77ns |

Table 3-concluded

| Measurement | End point temp, °C 70° | 80° | Difference | F-value |
|---|---|---|---|---|
| b+ yellowness) | 10.8 | 11.0 | 0.2 | 3.82ns |
| Sensory scores[c] | | | | |
| Flavor | 3.5 | 3.3 | 0.2 | 6.01* |
| Juiciness | 3.4 | 2.8 | 0.6 | 8.26** |
| Tenderness | 3.8 | 3.2 | 0.6 | 9.74** |
| Texture | 3.2 | 3.1 | 0.1 | 0.65ns |

[a] Cooking method data combined

[b] 1.0-(expressible liquid index); the larger the value, the greater the amount of liquid expressed

[c] 5-(rich beef flavor, juicy, tender, mealy); 1-(no beef flavor, dry, tough, chewy)

** $P \leq 0.01$; * $P \leq 0.05$; ns, not significant

Table 4-Means and LSDs for significant difference attributable to weight of steak (replication)

| Measurement | Replication 1 | 7 | 2 | 8 | 3 | 9 | 4 | 10 | 5 | 11 | 6 | 12 | LSD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial weight | 578.0 | 601.3 | 472.5 | 556.3 | 622.8 | 714.3 | 493.5 | 614.3 | 562.3 | 524.5 | 507.3 | 457.5 | 127.3 |
| Drip cooking losses, % | 19.9 | 14.4 | 13.9 | 13.6 | 18.1 | 19.6 | 16.1 | 16.9 | 16.5 | 18.5 | 12.9 | 13.7 | 4.7 |
| Total Moisture, % | 60.1 | 62.4 | 61.1 | 60.7 | 58.7 | 62.9 | 58.6 | 61.1 | 58.5 | 56.5 | 58.7 | 55.9 | 2.7 |
| Shear value, kg/1.3 cm-core | 10.3 | 5.7 | 9.7 | 5.7 | 6.2 | 6.4 | 6.4 | 4.8 | 5.0 | 8.6 | 4.9 | 8.1 | 2.2 |
| Ether extract, % | 12.8 | 13.4 | 12.3 | 9.1 | 18.5 | 7.6 | 18.3 | 7.0 | 11.8 | 15.2 | 15.9 | 14.3 | 4.6 |

Table 4-concluded

| Measurement | Replication 1 | 7 | 2 | 8 | 3 | 9 | 4 | 10 | 5 | 11 | 6 | 12 | LSD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Color-difference, Gardner | | | | | | | | | | | | | |
| Rd | 23.8 | 17.7 | 24.3 | 19.8 | 16.9 | 23.5 | 16.1 | 22.8 | 19.7 | 19.5 | 20.3 | 19.4 | 2.4 |
| a+ | 1.6 | 3.2 | 2.4 | 2.6 | 3.9 | 2.7 | 2.7 | 2.3 | 2.8 | 2.6 | 2.3 | 2.8 | 0.8 |
| b+ | 11.2 | 10.8 | 10.7 | 10.8 | 10.2 | 11.4 | 10.2 | 10.2 | 11.1 | 11.1 | 10.8 | 11.0 | 0.6 |

and steaks C, D, E, F weighed 650 to 800 g. However, that difference did not hold true for the steaks used in the main experiment.

Generally, as weight of the steak increased, drip losses increased. Percentage total moisture, shear values, percentage ether extract and Gardner color-difference values had no set pattern of increase or decrease as related to weight of the steaks, but significant differences attributable to steak weights were evident (Table 4).

Method of cooking

Measurements affected ($P \leq 0.001$) by method of cooking were: total cooking time in minutes, post cooking temperature rise in °C and drip cooking losses (Table 2). Total cooking time and drip cooking losses were greater for PB steaks than for MW cooked steaks. Although microwave cookery differs from the usual dry heat methods, these data support the idea of Paul (1972), who stated that an increase in cooking losses results when moist heat methods of meat cookery are used compared to dry heat methods.

The data presented in this study tend to agree with the work of Clark and Van Duyne (1949) and Schock et al. (1970). Clark and Van Duyne (1949) working with beef top round roasts found that although cooking time was less for pressure saucepan cooked samples, both total and drip cooking losses were significantly greater for pressure saucepan cooked roasts than for oven-roasted samples. Clark et al. (1955) reported almost no difference in total cooking losses of beef top round steaks when cooked to 80°C by oven braising and cooking under 10 and 15 p.s.i.g. Schock et al. (1970) cooked pieces of beef top round by four methods: deep-fat frying, oven-braising, oven roasting and pressure braising and found, as did Clark and Van Duyne (1949), that pressure braising decreased cooking time and increased cooking losses.

In this study, total cooking losses did not differ significantly for MW samples when compared to pressure braising. Kylen et al. (1964) reported higher ($P \leq 0.01$) total, drip and volatile cooking losses for microwave cooked samples of beef when compared to conventionally cooked samples. Headley and Jacobson (1960) working with lamb roasts reported similar findings.

The °C post cooking temperature rise was greater ($P \leq 0.0$[illegible]) for MW cooked steaks than for PB steaks. The percentage of post cooking temperature rise also was greater ($P \leq 0.01$) for MW steaks (Table [illegible]).

The Gardner color-difference a+ (redness) value was higher ($P \leq 0.05$) for MW cooked steaks than for PB steaks.

Cooking method did not affect total cooking losses, total moisture, water-holding capacity, Warner-Bratzler shear values, ether extract, Gardner Rd (reflectance) and b+ (yellowness) values and sensory scores of flavor, juiciness, tenderness and texture.

End point temperature

Data for effects of end point temperatures are presented in Table 3. Measurements affected at the $P \leq 0.01$ level are:

total cooking time in minutes, total cooking losses, water-holding capacity and juiciness and tenderness sensory scores. Flavor scores were affected at the $P \leq 0.05$ level.

Differences between the 70° and 80°C end point temperature were as would be expected. The total cooking time in minutes and total cooking losses are less ($P \leq 0.01$) for the lower end point temperature. As a higher end point temperature was reached, a decrease in water-holding capacity resulted. This supports the findings of Shaffer et al. (1973) who found that as temperature increased, ability of the meat sample to retain moisture decreased.

Effects of end point temperature, as reported in this study, agree with results of Hood et al. (1955) and Visser et al. (1960) in regard to juiciness. Hood et al. (1955) broiled biceps femoris steaks to 71.5° and 8[illegible]°C and found the steaks cooked to the lower end point temperature were juicier. Visser et al. (1960) cooked beef roasts in the oven and in deep fat to rare, medium and well-done. They reported that as degree of doneness or end point temperature increased, juiciness decreased. Unlike both of these authors who report no significant difference in tenderness or flavor attributable to end point temperature, the results of this study indicate a higher ($P \leq 0.01$) score for tenderness and a higher ($P \leq 0.05$) score for flavor for the lower end point temperature.

Measurements not significantly affected by end point temperature were: post cooking temperature rise in °C or percentage, drip and volatile cooking losses, total moisture, Warner-Bratzler shear values, ether extract, Gardner color-difference Rd (reflectance), a+ (redness) or b+ (yellowness) values, and texture sensory scores.

Relationship between selected measurements

Correlation coefficients were calculated between selected measurements for each cooking method and each end point temperature. Because relationships for the four treatments had a great deal of similarities, data from both cooking methods and both end point temperatures were pooled (Table 5). Data for relationships for each cooking method and end point temperature are presented in Tables 8-11, Appendix, pp. 56-62.

In this discussion, relationships will be discussed according to Shindell (1964) who stated that a coefficient between 0.00 and 0.39, irrespective of sign, was considered a low correlation; a coefficient between 0.40 and 0.79, a moderate correlation; and a coefficient above 0.80, a high correlation. Unless otherwise stated, a moderate correlation existed between the selected paired variates.

A positive correlation at the $P \leq 0.01$ level existed between total cooking time and total cooking losses, volatile losses and drip losses. As cooking losses increased, total moisture decreased; thus, as cooking time increased, cooking losses increased and the ability of the meat to retain moisture decreased. A negative correlation ($P \leq 0.01$) existed between total cooking time and flavor and juiciness scores. These data indicated that as cooking time increased, cooking losses

Table 5-Correlation coefficients for selected paired variates

| Paired variates d/f = 46 | r-values[a] |
| --- | --- |
| Total cooking time, min vs: | |
| Total cooking losses, % | 0.42** |
| Volatile losses, % | 0.63** |
| Drip losses, % | 0.88** |
| Flavor score | -0.47** |
| Juiciness score | -0.57** |
| Total cooking losses, % vs: | |
| Volatile losses, % | 0.80** |
| Total moisture, % | -0.60** |
| Flavor score | -0.51** |
| Juiciness score | -0.72** |
| Volatile losses, % vs: | |
| Drip losses, % | -0.66** |
| Total moisture, % | -0.61** |
| Flavor score | -0.44* |
| Juiciness score | -0.67** |
| Total moisture, % vs: | |
| Ether extract, % | -0.40** |
| Color-difference Rd value vs: | |
| a+ value | -0.69** |
| b+ value | 0.61** |
| Ether extract, % | -0.54** |

Table 5-concluded

| Paired variates d/f = 46 | r-values[a] |
|---|---|
| Color-difference b+ value vs: | |
| a+ value | -0.57** |
| Ether extract, % | -0.51** |
| Flavor score vs: | |
| a+ value | 0.41** |
| Juiciness score | 0.70** |
| Juiciness score vs: | |
| Drip losses, % | -0.42** |
| Tenderness score vs: | |
| Shear value, kg/1.3-cm core | -0.44** |
| Texture score | 0.75** |

[a] Levels of significance: * $P \leq 0.05$, $r = 0.288$; ** $P \leq 0.01$, $r = 0.372$

increased, but the intensity of beef flavor and juiciness decreased.

The negative correlation between volatile losses and drip losses indicated that as moisture in the meat was retained, fat was released. This is supported by the negative correlation between total moisture and percentage ether extract ($r = -0.40^{**}$).

Correlations occurred between Gardner color-difference values indicating that as Rd (reflectance) increased, a+ (redness) decreased and b+ (yellowness) increased. At the same time, juiciness scores decreased.

A negative correlation ($r = -0.44^{**}$) occurred between tenderness scores and Warner-Bratzler shear values as expected. Tenderness scores vs texture scores exhibited a positive correlation ($r = 0.75^{**}$). As tenderness increased, shear values decreased and the meat became increasingly mealy in texture.

Rate of heat penetration

Rate of heat penetration data were collected for both pressure braised treatments and are presented in Table 6. Additional details of mean heat penetration data can be observed in the rate of heat penetration curves presented in Fig. 5. For both pressure braised treatments (end points of 70° or 80°C), heat penetrated the muscle at a constant and rapid rate. The rate at which heat penetrated the steaks was not significantly different up to an internal temperature of 30°C. However, from 30°C to an end point temperature of 70° or 80°C,

Table 6-Means and F-values for rate of heat penetration

| Measurement | End point temperature, °C 70 | 80 | F-value |
|---|---|---|---|
| Initial temp, °C | 2.1 | 3.4 | 1.16ns |
| Initial temp to 10°C, min | 4.9 | 6.2 | 1.23ns |
| Min/10°C, 10°C to 20°C | 8.5 | 10.3 | 3.22ns |
| Min/10°C, 20°C to 30°C | 11.3 | 14.0 | 4.45ns |
| Min/10°C, 30°C to 40°C | 14.2 | 17.3 | 4.87* |
| Min/ 5°C, 40°C to 45°C | 16.1 | 19.9 | 5.71* |
| Min/ 5°C, 45°C to 50°C | 17.9 | 22.3 | 7.41* |
| Min/ 5°C, 50°C to 55°C | 19.8 | 24.3 | 7.60* |
| Min/ 5°C, 55°C to 60°C | 21.8 | 26.2 | 6.10* |
| Min/ 5°C, 60°C to 65°C | 23.6 | 28.2 | 6.18* |
| Min/ 5°C, 65°C to 70°C | 25.8 | 30.3 | 4.90* |
| Min/ 5°C, 70°C to 75°C | | 32.7 | |
| Min/ 5°C, 75°C to 80°C | | 35.1 | |

* $P \leq 0.05$

Fig. 5-Rate of heat penetration from initial temperature to 70°C and from initial temperature to 80°C for pressure briased steaks.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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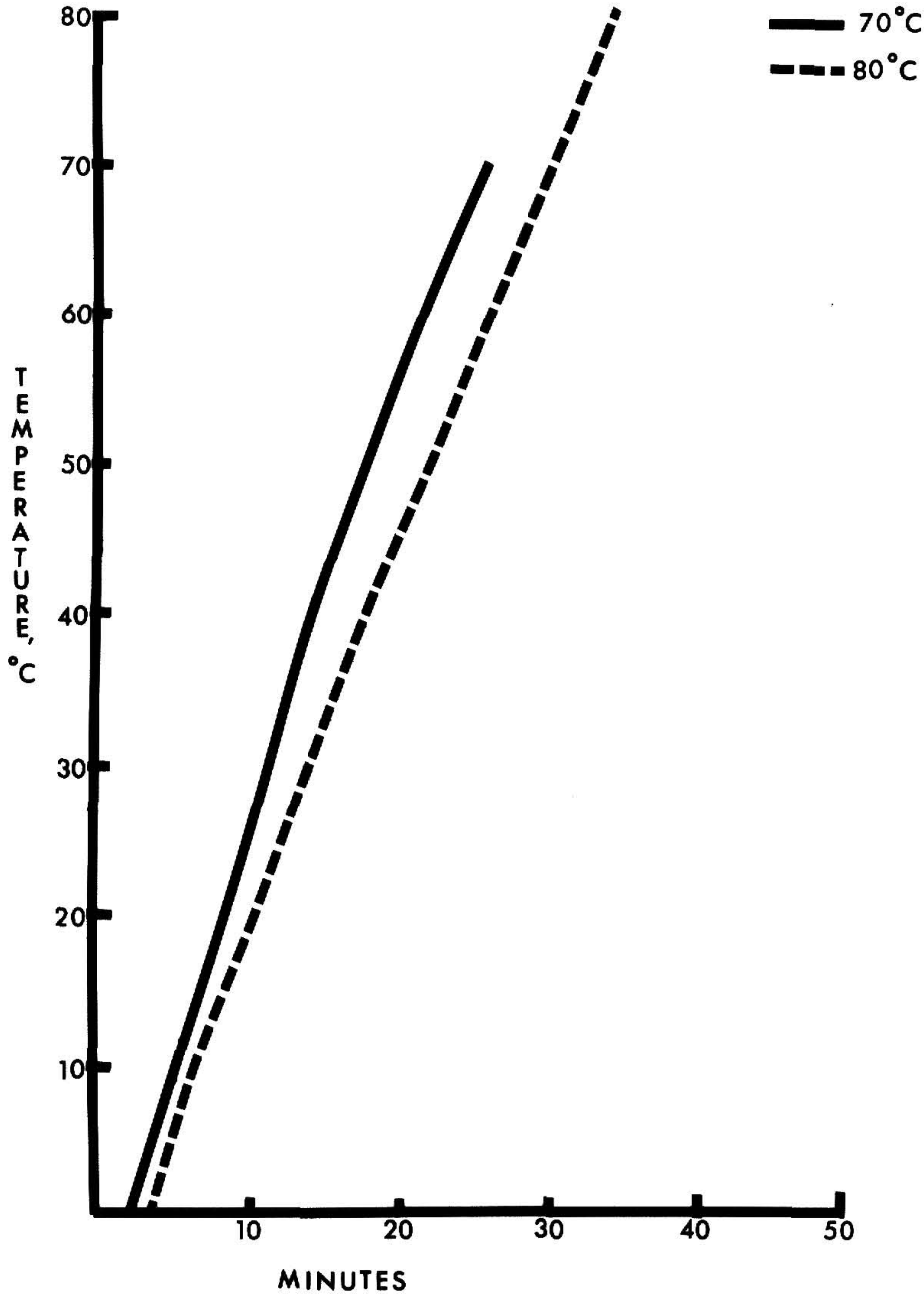
70°C
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the rate at which heat penetrated the steaks differed significantly ($P \leq 0.05$).

Method of cooking x end point temperature interactions

Data for the two significant method of cooking x end point temperature interactions are presented in Table 7. For total cooking time in minutes, a difference ($P \leq 0.01$) exists between pressure braising to 70°C and pressure braising to 80°C, but no significant difference occurred for microwave cooking to either 70°C or 80°C. Pressure braising to 80°C significantly ($P \leq 0.01$) increased drip cooking losses, but again, microwave cooking did not differ significantly for the two end point temperatures. Data for non-significant method of cooking x end point temperature interactions are presented in Table 12, Appendix, p. 63.

## SUMMARY

Top round beef steaks, semimembranosus and adductor muscles were cooked in a pressure saucepan (PB) (10 p.s.i.g.) or in a microwave oven (MW) to an internal temperature of 70° or 80°C. Data were analyzed by analysis of variance and correlation coefficients for selected paired variates were calculated for each of the four treatments.

There were no significant differences in weights of steaks assigned to the cooking methods or end point temperatures. However, significant ($P \leq 0.05$) differences in steak weights assigned to replications of the experiment occurred; there were differences ($P \leq 0.05$) attributable to replication for drip

Table 7-Means and F-values for significant cooking method x end point temperature interactions

| Measurement | Cooking method | End point temp, °C 70° | 80° | F-value |
|---|---|---|---|---|
| Total cooking time, min | Pressure braised | 25.4 | 34.6 | 6.65** |
| | Microwave | 14.0[a] | 15.2[a] | |
| Drip cooking losses, % | Pressure braised | 21.2 | 25.3 | 9.33** |
| | Microwave | 9.9[b] | 8.2[b] | |

[a,b] Means for a measurement bearing the same letter do not differ significantly ($P \leq 0.05$)

** $P \leq 0.01$

losses, total moisture, Warner-Bratzler shear values, ether extract, and Gardner color-difference values.

Total cooking time and drip losses were greater ($P \leq 0.001$) for PB steaks than for MW cooked steaks. Post cooking temperature rise in both °C and percentage was greater ($P \leq 0.001$) for MW cooked steaks than for PB steaks. The mean Gardner color-difference a+ value was higher ($P \leq 0.05$) for MW cooked steaks than for PB steaks, but other color-difference values were not affected significantly by cooking method.

Differences between the 70° and 80°C end point temperature were as expected. The total cooking time and total cooking losses were less ($P \leq 0.01$) for the 70°C end point temperature. As a higher end point temperature was reached a decrease in water-holding capacity occurred. Steaks cooked to 70°C were juicier, more tender and had more beef flavor than those cooked to 80°C.

As total cooking time increased, cooking losses increased and juiciness, total moisture, and flavor decreased. Correlations between Gardner color-difference values indicated that as Rd (reflectance) increased, a+ (redness) decreased and b+ (yellowness) increased. As tenderness increased, shear values decreased and mealiness increased.

Rate of heat penetration in both PB treatments was at a constant and rapid rate.

Method of cooking x end point temperature interactions data indicated that a significant ($P \leq 0.01$) difference existed between pressure braising to 70°C and pressure braising to 80°C for total cooking time and drip losses. No significant differences occurred between the two microwave treatments.

## CONCLUSION

Under the conditions of this study, little differences occurred in total cooking losses, sensory characteristics and related objective measurements of beef top round steaks cooked by pressure braising (10 p.s.i.g.) or microwave cookery to both internal temperatures of 70° or 80°C.

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# APPENDIX

Form I. SCORE CARD FOR SENSORY EVALUATION OF BEEF TOP ROUND STEAKS
(Semimembranosus and Adductor Muscles).

Panel member ____________________ Code __________ Date ________

| Sample | Flavor | Juiciness | Tenderness Chews | Tenderness Score | Texture | Comments |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |

Flavor

5 Rich beef flavor
4 Moderately rich beef flavor
3 Slightly rich beef flavor
2 Perceptible beef flavor
1 No beef flavor

Juiciness

5 Juicy
4 Moderately juicy
3 Neither juicy nor dry
2 Slightly dry
1 Dry

Tenderness

5 Tender
4 Moderately tender
3 Neither tender nor tough
2 Slightly tough
1 Tough

Texture

5 Mealy (fine, friable)
4 Moderately mealy
3 Neither mealy nor chewy
2 Slightly chewy
1 Chewy

Form II. Instructions to Judges for Sensory Evaluation of Beef Top Round

Semimembranosus and Adductor Muscles.

For scoring palatability characteristics, each judge is to select two cubes of meat at random from each double boiler. Use one cube for counting chews and evaluating tenderness, and one for assessing flavor, juiciness, and texture.

Scoring for flavor and juiciness

Record a score for flavor and another for juiciness within a range of 5 to 1 that describes your impression of the sample. Refer to the score card for descriptive terms for specific scores within the range of 5 to 1. Record the score describing your impression of flavor and juiciness at the beginning of the chewing process.

Scoring for tenderness

Count the number of times you chew the 1.3-cm cube of meat before swallowing. Chew until the cube is masticated completely, then swallow. Record the number of chews required to masticate the cube. Record a score from 5 to 1 that describes your impression of the tenderness of the cube. Refer to the score card for descriptive terms for specific scores within the range of 5 to 1.

Use the number of chews to help you standardize your tenderness scores from day to day. Set up for yourself a range of the number of chews for each score from 5 to 1. For example, if you chew 25 to 35 times, a score of 4; 35 to 45 times, a score of 3; continuing to reduce the score by a given number of increased chews. Each judge sets his own range of chews for a given score.

Texture

Mealiness is fragmentation of the meat resulting in tiny, dry and hard pieces of meat that cling to the cheek, gum and tongue. Record a score for mealiness within the range of 5 to 1 that describes your impression of the sample. Refer to the score card for descriptive terms for specific scores within the range of 5 to 1.

Comments

Comments about the samples and/or explaining your reason for giving a particular score are helpful.

Take your time to score each sample. Water is provided for rinsing your mouth between samples.

Table 8-Correlation coefficients for selected variates for pressure braised to 70°C cooked steaks

| Paired variates d/f = 11 | r-values[a] End point temperature, 70°C |
|---|---|
| Total cooking time, min vs: | |
| Initial weight, g | 0.74** |
| Total cooking loss, % | 0.58* |
| Drip loss, % | 0.78** |
| Juiciness score | -0.67* |
| Total cooking loss, % vs: | |
| Drip loss, % | 0.65* |
| Shear value, kg/1.3-cm core | 0.76** |
| b+ value | 0.64* |
| Juiciness score | -0.75** |
| Drip loss, % vs: | |
| Ether extract, % | -0.60* |
| Rd value | 0.67* |
| b+ value | 0.80** |
| Total moisture, % vs: | |
| Water-holding capacity | 0.61* |
| Color-difference a+ value vs: | |
| Ether extract, % | 0.60* |
| Rd value | -0.77** |
| Flavor score | 0.77** |

Table 8-concluded

| Paired variates d/f = 11 | r-values[a] End point temperature, 70°C |
|---|---|
| Color-difference b+ value vs: | |
| Rd value | 0.73** |
| a+ value | -0.74** |
| Juiciness score vs: | |
| Drip loss, % | -0.73** |
| Rd value | -0.58* |
| b+ value | -0.64* |
| Flavor score | 0.65* |

[a] Levels of significance: * $P \leq 0.05$, $r = 0.553$; ** $P \leq 0.01$, $r = 0.684$

Table 9-Correlation coefficients for selected paired variates for pressure braised to 80°C cooked steaks

| Paired variates d/f = 11 | r-values[a] End point temperature, 80°C |
|---|---|
| Total cooking time, min vs: | |
| Initial weight, g | 0.82** |
| Total cooking loss, % | 0.81** |
| Drip loss, % | 0.86** |
| Total moisture, % | -0.59* |
| Flavor score | -0.67* |
| Juiciness score | -0.66* |
| Total cooking loss, % vs: | |
| Initial weight, g | 0.66* |
| Drip loss, % | 0.95** |
| Total moisture, % | -0.73** |
| Juiciness score | -0.63* |
| Drip loss, % vs: | |
| Initial weight, g | 0.81** |
| Total moisture, % | -0.58* |
| Juiciness score | -0.64* |
| Color-difference a+ value vs: | |
| Rd value | -0.71* |
| b+ value | -0.64* |
| Color-difference b+ value vs: | |
| Rd value | 0.75** |

Table 9-concluded

| Paired variates d/f = 11 | r-values[a] End point temperature, 80°C |
|---|---|
| Flavor score vs: | |
| Initial weight, g | -0.70* |
| Juiciness score | 0.82** |
| Juiciness score vs: | |
| Initial weight, g | -0.73** |
| Tenderness score vs: | |
| Shear value, kg/1.3-cm core | -0.75** |
| Texture score | 0.92** |

[a] Levels of significance: * $P \leq 0.05$, $r = 0.553$; ** $P \leq 0.01$, $r = 0.684$

Table 10--Correlation coefficients for selected paired variates for microwaved to 70°C cooked steaks

| Paired variates d/f = 11 | r-values[a] End point temperature, 70°C |
|---|---|
| Initial weight, g vs: | |
| Total cooking time, min | 0.58* |
| Water-holding capacity | 0.67* |
| Total moisture, % | 0.63* |
| Total cooking losses, % vs: | |
| Volatile loss, % | 0.77** |
| a+ value | -0.75** |
| Flavor score | -0.66* |
| Juiciness score | -0.88** |
| Color-difference a+ value vs: | |
| Volatile loss, % | -0.77** |
| Rd value | -0.65* |
| b+ value | -0.61* |
| Juiciness score | 0.66* |
| Color-difference b+ value vs: | |
| Ether extract, % | -0.63* |
| Flavor score vs: | |
| Total cooking time, min | -0.61* |
| Juiciness score | 0.66* |

Table 10-concluded

| Paired variates d/f = 11 | r-values[a] End point temperature, 70°C |
|---|---|
| Juiciness score vs: | |
| Volatile loss, % | -0.71* |
| Total moisture, % | 0.59* |
| Texture score vs: | |
| Tenderness score | 0.75** |

[a] Levels of significance: * $P \leq 0.05$, $r = 0.553$; ** $P \leq 0.01$, $r = 0.684$

Table 11-Correlation coefficients for selected paired variates for microwaved to 80°C cooked steaks

| Paired variates d/f = 11 | r-values[a] End point temperature, 80°C |
|---|---|
| Total cooking loss, % vs: | |
| Total cooking time, min | 0.63* |
| Volatile loss, % | 0.81** |
| Total moisture, % | -0.58* |
| Juiciness score | -0.62* |
| Volatile loss, % vs: | |
| Total cooking time, min | 0.71* |
| Drip loss, % | -0.69* |
| Total moisture, % | -0.62* |
| Ether extract, % vs: | |
| Total moisture, % | -0.63* |
| Rd value | -0.62* |
| Color-difference Rd value vs: | |
| Shear value, kg/1.3-cm core | 0.59* |
| a+ value | -0.69* |
| Texture score vs: | |
| Tenderness score | 0.79** |

[a] Levels of significance: * $P \leq 0.05$, $r = 0.553$; ** $P \leq 0.01$, $r = 0.684$

Table 12-Means and F-values for non-significant cooking method x end point temperature interactions

| Measurement | Cooking method | End point temperature, °C 70 | 80 | F-value |
|---|---|---|---|---|
| Initial weight, g | Pressure braised | 528.4 | 553.7 | 0.54ns |
| | Microwave | 582.3 | 570.3 | |
| Post cooking temp rise | | | | |
| °C | Pressure braised | 2.3 | 1.8 | 3.30ns |
| | Microwave | 3.0 | 4.1 | |
| % | Pressure braised | 3.3 | 2.3 | 2.16ns |
| | Microwave | 4.6 | 5.4 | |
| Total cooking losses, % | Pressure braised | 31.9 | 35.8 | 1.08ns |
| | Microwave | 32.9 | 34.6 | |
| Total moisture, % | Pressure braised | 60.5 | 59.3 | 0.09ns |
| | Microwave | 59.7 | 58.8 | |
| Water-holding capacity[a] | Pressure braised | 0.75 | 0.67 | 0.05ns |
| | Microwave | 0.74 | 0.66 | |
| Shear value, kg/1.3-cm core | Pressure braised | 7.0 | 6.9 | 1.29ns |
| | Microwave | 6.3 | 7.1 | |
| Ether extract, % | Pressure braised | 14.1 | 11.8 | 2.89ns |
| | Microwave | 12.7 | 13.5 | |

Table 12-concluded

| Measurement | Cooking method | End point temperature, °C 70 | 80 | F-value |
|---|---|---|---|---|
| Color-difference, Gardner | | | | |
| Rd | Pressure braised | 20.2 | 21.1 | 0.34ns |
| | Microwave | 19.8 | 20.1 | |
| a+ | Pressure braised | 2.7 | 2.3 | 0.00ns |
| | Microwave | 3.0 | 2.7 | |
| b+ | Pressure braised | 10.9 | 11.1 | 0.00ns |
| | Microwave | 10.6 | 10.9 | |
| Sensory scores[b] | | | | |
| Flavor | Pressure braised | 3.5 | 3.2 | 0.05ns |
| | Microwave | 3.6 | 3.3 | |
| Juiciness | Pressure braised | 3.2 | 2.6 | 0.00ns |
| | Microwave | 3.6 | 3.0 | |
| Tenderness | Pressure braised | 3.8 | 3.3 | 0.06ns |
| | Microwave | 3.8 | 3.1 | |
| Texture | Pressure braised | 3.4 | 3.2 | 0.11ns |
| | Microwave | 3.1 | 3.0 | |

[a] 1.0-(expressible liquid index); the larger the value, the greater the amount of liquid expressed

[b] 5-(rich beef flavor, juicy, tender, mealy); 1-(no beef flavor, dry, tough, chewy)

ns, not significant

Table 13-Rate of heat penetration in minutes to increase by increments of 10°C to reach from initial temperature to 40° and by increments of 5°C from 40°C to 70°C or 80°C end point temperatures

| End point temp | Initial | 10° | 20° | 30° | 40° | 45° | 50° | 55° | 60° | 65° | 70° | 75° | 80° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 70°C | 1 | 6 | 8 | 11 | 14 | 16 | 18 | 20 | 23 | 25 | 27 | | |
| | 0 | 6 | 9 | 13 | 16 | 18 | 19 | 21 | 23 | 25 | 28 | | |
| | 4 | 5 | 8 | 10 | 12 | 13 | 15 | 16 | 17 | 19 | 21 | | |
| | 2 | 6 | 12 | 14 | 16 | 17 | 18 | 19 | 22 | 23 | 25 | | |
| | 5 | 7 | 13 | 15 | 19 | 21 | 24 | 26 | 28 | 31 | 33 | | |
| | 6 | 1 | 4 | 9 | 13 | 15 | 16 | 18 | 20 | 21 | 23 | | |
| | 2 | 5 | 6 | 7 | 11 | 14 | 16 | 19 | 22 | 26 | 28 | | |
| | 4 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 18 | 19 | 20 | | |
| | 0 | 4 | 10 | 12 | 17 | 20 | 22 | 23 | 26 | 27 | 31 | | |
| | 3 | 4 | 8 | 10 | 12 | 13 | 15 | 17 | 18 | 19 | 20 | | |
| | -3 | 7 | 10 | 15 | 17 | 19 | 22 | 24 | 26 | 27 | 30 | | |
| | 1 | 4 | 8 | 11 | 12 | 14 | 15 | 17 | 19 | 21 | 23 | | |
| Mean | 2.1 | 4.9 | 8.5 | 11.3 | 14.2 | 16.1 | 17.9 | 19.8 | 21.8 | 23.6 | 25.8 | | |

Table 13-concluded

| End point temp | Initial | 10° | 20° | 30° | 40° | 45° | 50° | 55° | 60° | 65° | 70° | 75° | 80° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80°C | 0 | 4 | 8 | 11 | 15 | 18 | 21 | 23 | 25 | 27 | 30 | 34 | 37 |
| | 7 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 19 | 21 | 22 | 23 | 19 |
| | -1 | 12 | 16 | 19 | 24 | 27 | 30 | 32 | 34 | 36 | 38 | 42 | 48 |
| | 5 | 7 | 12 | 15 | 17 | 19 | 20 | 22 | 24 | 26 | 28 | 30 | 32 |
| | -1 | 16 | 21 | 25 | 28 | 30 | 32 | 34 | 36 | 39 | 41 | 43 | 45 |
| | 5 | 5 | 7 | 10 | 13 | 15 | 16 | 18 | 20 | 21 | 22 | 23 | 25 |
| | 4 | 2 | 9 | 12 | 16 | 19 | 22 | 24 | 25 | 27 | 29 | 30 | 31 |
| | 5 | 5 | 9 | 12 | 14 | 16 | 20 | 22 | 24 | 25 | 26 | 28 | 31 |
| | 5 | 5 | 11 | 14 | 19 | 21 | 22 | 25 | 27 | 29 | 32 | 35 | 37 |
| | 3 | 6 | 10 | 17 | 21 | 25 | 27 | 30 | 31 | 34 | 37 | 40 | 42 |
| | 5 | 5 | 9 | 14 | 16 | 19 | 21 | 22 | 24 | 25 | 28 | 31 | 34 |
| | 4 | 5 | 7 | 12 | 15 | 18 | 21 | 23 | 25 | 28 | 30 | 33 | 35 |
| Mean | 3.4 | 6.2 | 10.3 | 14.0 | 17.3 | 19.9 | 22.3 | 24.3 | 26.2 | 28.2 | 30.3 | 32.7 | 34.7 |

Table 14-Post-cooking temperature rise, 5 min after removal from heat

| Method; end pt | Initial temp | Final temp | Difference | Percent |
|---|---|---|---|---|
| PB 70° | 65 | 70 | 5 | 7.7 |
| | 66 | 71 | 5 | 7.6 |
| | 70 | 70 | 0 | 0.0 |
| | 70 | 71 | 1 | 1.4 |
| | 65 | 70 | 5 | 7.7 |
| | 70 | 71 | 1 | 1.4 |
| | 65 | 70 | 5 | 7.7 |
| | 68 | 70 | 2 | 2.9 |
| | 65 | 70 | 5 | 7.7 |
| | 68 | 70 | 2 | 2.9 |
| | 70 | 70 | 0 | 0.0 |
| | 65 | 70 | 5 | 7.7 |
| Mean | 67.25 | 70.25 | 3.0 | 4.6 |
| PB 80° | 76 | 81 | 5 | 6.6 |
| | 79 | 80 | 1 | 1.3 |
| | 80 | 80 | 0 | 0.0 |
| | 75 | 80 | 5 | 6.7 |
| | 78 | 83 | 5 | 6.4 |
| | 75 | 80 | 5 | 6.7 |
| | 75 | 80 | 5 | 6.7 |
| | 75 | 80 | 5 | 6.7 |
| | 75 | 80 | 5 | 6.7 |
| | 75 | 80 | 5 | 6.7 |
| | 75 | 80 | 5 | 6.7 |
| | 78 | 81 | 3 | 3.9 |
| Mean | 76.33 | 80.42 | 4.1 | 5.4 |

Table 14-concluded

| Method; end pt | Initial temp | Final temp | Difference | Percent |
|---|---|---|---|---|
| MW 70° | 68 | 70 | 2 | 2.9 |
| | 68 | 70 | 2 | 2.9 |
| | 70 | 70 | 0 | 0.0 |
| | 70 | 73 | 3 | 4.3 |
| | 69 | 72 | 3 | 4.4 |
| | 70 | 72 | 2 | 2.9 |
| | 68 | 70 | 2 | 2.9 |
| | 68 | 71 | 3 | 4.4 |
| | 68 | 69 | 1 | 1.5 |
| | 69 | 71 | 2 | 2.9 |
| | 69 | 74 | 5 | 7.3 |
| | 70 | 72 | 2 | 2.9 |
| Mean | 68.92 | 71.17 | 2.25 | 3.3 |
| MW 80° | 79 | 81 | 2 | 2.5 |
| | 79 | 80 | 1 | 1.3 |
| | 80 | 80 | 0 | 0.0 |
| | 78 | 80 | 2 | 2.6 |
| | 80 | 85 | 5 | 6.3 |
| | 75 | 78 | 3 | 4.0 |
| | 79 | 80 | 1 | 1.3 |
| | 77 | 80 | 3 | 3.9 |
| | 78 | 79 | 1 | 1.3 |
| | 80 | 81 | 1 | 1.3 |
| | 79 | 80 | 1 | 1.3 |
| | 79 | 80 | 1 | 1.3 |
| Mean | 78.58 | 80.33 | 1.75 | 2.3 |

Table 15-Initial weight and total cooking time

| Measurement | Pressure braised 70° | Pressure braised 80° | Microwave 70° | Microwave 80° |
|---|---|---|---|---|
| Initial weight, g | 553 | 618 | 559 | 582 |
| | 495 | 383 | 587 | 425 |
| | 555 | 720 | 584 | 632 |
| | 422 | 469 | 502 | 581 |
| | 678 | 582 | 420 | 569 |
| | 416 | 440 | 487 | 686 |
| | 648 | 525 | 612 | 620 |
| | 387 | 500 | 678 | 660 |
| | 691 | 710 | 755 | 701 |
| | 480 | 705 | 774 | 498 |
| | 536 | 543 | 526 | 493 |
| | 480 | 449 | 504 | 397 |
| Mean | 528.42 | 553.67 | 583.33 | 570.33 |
| Total cooking time, min | 27 | 37 | 14.5 | 16 |
| | 28 | 19 | 17 | 11 |
| | 21 | 48 | 9.5 | 16.5 |
| | 23 | 32 | 11 | 18 |
| | 33 | 45 | 9 | 18.5 |
| | 23 | 25 | 15.5 | 14.5 |
| | 26 | 30 | 12.5 | 13 |
| | 20 | 31 | 20 | 20 |
| | 31 | 37 | 14 | 15 |
| | 20 | 42 | 18 | 14 |
| | 30 | 34 | 13 | 13 |
| | 23 | 35 | 13.5 | 13 |
| Mean | 25.42 | 34.58 | 13.96 | 15.21 |

Table 16-Percentage total, drip and volatile cooking losses

| | Heat treatments | | | |
|---|---|---|---|---|
| | Pressure braised | | Microwave | |
| Measurement | 70° | 80° | 70° | 80° |
| Total | 33.6 | 40.1 | 36.7 | 36.8 |
| | 38.0 | 25.6 | 36.8 | 32.2 |
| | 28.1 | 39.4 | 26.7 | 39.7 |
| | 31.7 | 37.5 | 34.6 | 36.6 |
| | 31.3 | 38.6 | 33.6 | 40.2 |
| | 32.0 | 31.8 | 35.7 | 30.5 |
| | 28.1 | 35.0 | 29.0 | 26.4 |
| | 30.2 | 31.6 | 35.2 | 36.2 |
| | 34.3 | 38.7 | 26.2 | 32.8 |
| | 28.8 | 36.0 | 31.1 | 34.7 |
| | 35.4 | 37.4 | 35.7 | 33.7 |
| | 31.3 | 37.9 | 33.9 | 35.5 |
| Mean | 31.90 | 35.80 | 32.93 | 34.61 |
| Drip | 23.9 | 30.6 | 13.9 | 11.2 |
| | 22.4 | 13.6 | 8.9 | 10.6 |
| | 16.6 | 31.9 | 11.6 | 12.2 |
| | 17.3 | 27.1 | 13.3 | 6.5 |
| | 23.2 | 29.2 | 10.0 | 3.7 |
| | 20.2 | 19.5 | 6.6 | 5.2 |
| | 19.7 | 22.3 | 6.5 | 9.2 |
| | 20.1 | 21.0 | 7.8 | 5.4 |
| | 26.5 | 31.5 | 9.0 | 11.4 |
| | 20.4 | 26.1 | 12.4 | 8.6 |
| | 26.3 | 26.9 | 10.5 | 10.1 |
| | 17.9 | 23.8 | 8.1 | 4.8 |
| Mean | 21.21 | 25.29 | 9.88 | 8.24 |

Table 16-concluded

| Measurement | Heat treatments | | | |
|---|---|---|---|---|
| | Pressure braised | | Microwave | |
| | 70° | 80° | 70° | 80° |
| Volatile | | | 21.3 | 24.4 |
| | | | 27.3 | 20.9 |
| | | | 14.2 | 26.7 |
| | | | 20.7 | 21.2 |
| | | | 19.3 | 35.7 |
| | | | 28.7 | 24.8 |
| | | | 21.9 | 16.4 |
| | | | 26.8 | 30.7 |
| | | | 16.9 | 20.8 |
| | | | 18.2 | 25.1 |
| | | | 24.9 | 22.7 |
| | | | 25.4 | 29.5 |
| Mean | | | 22.13 | 25.58 |

Table 17-Percentage total moisture and water-holding capacity (WHC)

| Measurement | Heat treatments: Pressure braised 70° | Pressure braised 80° | Microwave 70° | Microwave 80° |
|---|---|---|---|---|
| Total moisture | 60.75 | 57.60 | 60.95 | 60.90 |
| | 59.70 | 63.80 | 60.35 | 60.40 |
| | 60.60 | 58.45 | 60.30 | 55.40 |
| | 59.85 | 58.95 | 59.20 | 56.40 |
| | 60.00 | 56.40 | 60.60 | 57.17 |
| | 60.80 | 59.65 | 55.35 | 59.00 |
| | 62.35 | 62.60 | 62.05 | 62.70 |
| | 60.95 | 62.10 | 60.75 | 59.00 |
| | 61.60 | 60.95 | 64.40 | 64.70 |
| | 64.05 | 59.40 | 61.90 | 59.05 |
| | 56.00 | 56.50 | 57.80 | 55.70 |
| | 59.85 | 55.70 | 52.75 | 55.35 |
| Mean | 60.46 | 59.34 | 50.70 | 58.81 |
| WHC | .820 | .558 | .779 | .507 |
| | .731 | .611 | .805 | .693 |
| | .776 | .640 | .775 | .573 |
| | .718 | .793 | .624 | .748 |
| | .843 | .771 | .617 | .586 |
| | .740 | .608 | .662 | .522 |
| | .763 | .579 | .790 | .759 |
| | .694 | .770 | .736 | .729 |
| | .744 | .645 | .779 | .763 |
| | .835 | .699 | .807 | .672 |
| | .653 | .663 | .697 | .679 |
| | .718 | .692 | .774 | .741 |
| Mean | 0.752 | 0.669 | 0.737 | 0.664 |

Table 18-Warner-Bratzler shear values and percentage ether extract

| Measurement | Heat treatment: Pressure braised 70° | Heat treatment: Pressure braised 80° | Heat treatment: Microwave 70° | Heat treatment: Microwave 80° |
|---|---|---|---|---|
| Shear value, kg/1.3-cm core | 7.2 | 9.9 | 11.3 | 12.7 |
| | 10.1 | 9.9 | 6.5 | 12.1 |
| | 7.2 | 5.6 | 6.7 | 5.2 |
| | 8.2 | 6.1 | 7.6 | 3.8 |
| | 5.3 | 6.3 | 3.4 | 4.8 |
| | 6.9 | 4.2 | 3.1 | 5.3 |
| | 5.5 | 7.2 | 4.2 | 5.9 |
| | 6.3 | 4.0 | 5.9 | 6.5 |
| | 6.9 | 6.8 | 5.7 | 6.1 |
| | 5.8 | 3.8 | 4.1 | 5.3 |
| | 8.1 | 9.1 | 8.8 | 8.5 |
| | 6.2 | 9.3 | 7.8 | 9.1 |
| Mean | 6.98 | 6.85 | 6.26 | 7.11 |
| Ether extract, % | 12.50 | 12.05 | 15.15 | 11.30 |
| | 14.15 | 8.60 | 15.60 | 10.90 |
| | 24.15 | 13.20 | 21.25 | 15.45 |
| | 14.20 | 17.35 | 18.35 | 23.25 |
| | 14.90 | 12.50 | 7.60 | 12.25 |
| | 17.20 | 14.00 | 13.20 | 19.30 |
| | 20.80 | 10.40 | 12.50 | 9.80 |
| | 7.00 | 10.40 | 6.50 | 12.50 |
| | 8.05 | 9.35 | 4.65 | 8.20 |
| | 4.55 | 9.70 | 7.55 | 6.30 |
| | 15.15 | 12.65 | 15.40 | 17.80 |
| | 16.60 | 11.75 | 14.15 | 14.65 |
| Mean | 14.10 | 11.83 | 12.66 | 13.48 |

Table 19-Gardner color-difference factors

| Measurement | Heat treatments: Pressure braised 70° | Pressure braised 80° | Microwave 70° | Microwave 80° |
|---|---|---|---|---|
| Rd (reflectance) | 21.50 | 27.50 | 20.50 | 25.50 |
| | 24.00 | 24.10 | 24.05 | 24.85 |
| | 16.90 | 18.60 | 15.15 | 16.80 |
| | 15.90 | 16.50 | 16.15 | 15.70 |
| | 18.50 | 20.90 | 19.80 | 19.60 |
| | 21.90 | 19.20 | 21.25 | 18.95 |
| | 18.10 | 17.20 | 20.20 | 15.40 |
| | 22.25 | 21.20 | 17.75 | 18.10 |
| | 24.05 | 23.80 | 22.10 | 24.20 |
| | 21.60 | 22.60 | 22.30 | 24.55 |
| | 20.65 | 19.25 | 20.25 | 17.85 |
| | 17.15 | 21.80 | 18.60 | 20.05 |
| Mean | 20.21 | 21.05 | 19.84 | 20.13 |
| a+ (redness) | 2.30 | 0.60 | 2.50 | 1.15 |
| | 2.30 | 2.90 | 2.15 | 2.10 |
| | 4.20 | 2.40 | 5.40 | 3.70 |
| | 2.90 | 2.60 | 3.05 | 2.40 |
| | 2.75 | 2.55 | 3.00 | 2.75 |
| | 1.80 | 2.65 | 1.85 | 2.75 |
| | 2.85 | 2.90 | 2.95 | 4.10 |
| | 1.90 | 2.30 | 2.90 | 3.10 |
| | 2.05 | 2.25 | 3.55 | 3.10 |
| | 2.75 | 1.85 | 2.75 | 1.70 |
| | 2.70 | 2.55 | 2.65 | 2.45 |
| | 3.25 | 2.20 | 3.00 | 2.65 |
| Mean | 2.65 | 2.31 | 2.98 | 2.66 |

Table 19-concluded

| Measurement | Heat treatments | | | |
|---|---|---|---|---|
| | Pressure braised | | Microwave | |
| | 70° | 80° | 70° | 80° |
| b+ (yellowness) | 11.05 | 11.80 | 10.80 | 11.15 |
| | 11.15 | 10.95 | 10.20 | 10.35 |
| | 9.55 | 10.70 | 9.40 | 11.10 |
| | 10.15 | 10.30 | 10.25 | 10.05 |
| | 10.55 | 11.15 | 11.05 | 11.60 |
| | 11.00 | 10.75 | 10.85 | 10.70 |
| | 10.85 | 10.90 | 11.15 | 10.35 |
| | 11.05 | 10.75 | 10.55 | 10.75 |
| | 11.80 | 11.75 | 11.00 | 11.15 |
| | 10.60 | 11.70 | 10.70 | 11.60 |
| | 11.55 | 11.30 | 11.00 | 10.35 |
| | 10.90 | 10.95 | 10.70 | 11.35 |
| Mean | 10.85 | 11.08 | 10.64 | 10.88 |

Table 20-Sensory evaluation scores; range: 5.0-1.0

| Measurement | Heat treatments: Pressure braised 70° | Pressure braised 80° | Microwave 70° | Microwave 80° |
|---|---|---|---|---|
| Flavor | 3.7 | 3.3 | 3.1 | 3.6 |
| | 3.0 | 3.8 | 3.5 | 3.6 |
| | 4.1 | 3.2 | 4.0 | 3.6 |
| | 3.4 | 3.3 | 3.7 | 2.8 |
| | 3.4 | 2.8 | 3.7 | 3.1 |
| | 3.0 | 3.9 | 3.5 | 3.8 |
| | 3.4 | 2.9 | 4.1 | 3.3 |
| | 3.5 | 3.1 | 3.1 | 3.6 |
| | 3.2 | 3.0 | 4.3 | 3.1 |
| | 3.5 | 2.5 | 3.2 | 3.0 |
| | 3.5 | 3.2 | 4.0 | 3.8 |
| | 3.7 | 3.5 | 3.4 | 2.8 |
| Mean | 3.45 | 3.21 | 3.63 | 3.34 |
| Juiciness | 3.4 | 2.4 | 3.0 | 3.1 |
| | 2.5 | 4.0 | 3.3 | 4.0 |
| | 3.7 | 2.7 | 4.4 | 3.0 |
| | 3.4 | 2.6 | 3.6 | 2.3 |
| | 3.1 | 2.3 | 3.9 | 2.3 |
| | 2.5 | 3.8 | 2.7 | 3.6 |
| | 3.6 | 2.4 | 4.7 | 3.9 |
| | 3.6 | 2.7 | 3.2 | 2.9 |
| | 2.0 | 1.4 | 4.5 | 2.6 |
| | 4.0 | 1.2 | 3.5 | 2.5 |
| | 2.3 | 3.2 | 2.8 | 2.3 |
| | 4.0 | 2.3 | 3.3 | 3.2 |
| Mean | 3.18 | 2.58 | 3.58 | 2.98 |

Table 20-concluded

| Measurement | Heat treatments | | | |
|---|---|---|---|---|
| | Pressure braised | | Microwave | |
| | 70° | 80° | 70° | 80° |
| Tenderness | 3.4 | 2.9 | 2.9 | 2.9 |
| | 3.7 | 2.6 | 3.8 | 2.6 |
| | 4.1 | 3.4 | 3.6 | 3.3 |
| | 3.3 | 3.3 | 3.9 | 4.6 |
| | 4.0 | 2.7 | 3.0 | 2.6 |
| | 3.3 | 4.4 | 3.3 | 3.6 |
| | 3.8 | 1.9 | 4.0 | 2.7 |
| | 4.2 | 4.6 | 2.8 | 3.4 |
| | 4.3 | 3.0 | 4.5 | 3.4 |
| | 3.7 | 4.7 | 4.5 | 3.5 |
| | 3.8 | 3.2 | 4.2 | 2.8 |
| | 4.1 | 2.7 | 4.6 | 2.3 |
| Mean | 3.81 | 3.28 | 3.76 | 3.14 |
| Texture | 2.7 | 3.1 | 2.6 | 2.4 |
| | 4.5 | 2.0 | 3.5 | 2.8 |
| | 3.1 | 3.5 | 3.2 | 2.9 |
| | 3.0 | 3.2 | 3.1 | 4.3 |
| | 3.6 | 2.1 | 2.1 | 2.1 |
| | 2.5 | 3.8 | 3.2 | 3.4 |
| | 3.9 | 2.3 | 3.0 | 2.1 |
| | 3.4 | 4.3 | 2.6 | 3.1 |
| | 4.3 | 3.0 | 3.2 | 3.8 |
| | 3.2 | 5.0 | 3.3 | 2.8 |
| | 3.0 | 3.2 | 3.5 | 3.2 |
| | 3.4 | 2.5 | 3.4 | 2.7 |
| Mean | 3.83 | 3.17 | 3.06 | 2.97 |

Table 21-Selected measurements on raw muscle

| Round number | Total moisture | Ether extract, % | Gardner color-difference | | |
|---|---|---|---|---|---|
| | | | Rd | a+ | b+ |
| 1 | 75.20 | 7.05 | 6.80 | 23.10 | 9.50 |
| 2 | 72.80 | 11.40 | 5.45 | 15.30 | 7.45 |
| 3 | 71.80 | 19.00 | 6.80 | 18.70 | 7.50 |
| 4 | 73.55 | 15.15 | 6.40 | 22.25 | 9.10 |
| 5 | 72.65 | 8.75 | 9.20 | 29.70 | 12.40 |
| 6 | 71.65 | 12.25 | 8.30 | 30.25 | 12.35 |
| Mean | 72.94 | 12.27 | 7.16 | 23.22 | 9.72 |

Table 22-Power supply in MW oven

| Initial temperature | Final temperature | Watt output[a] |
|---|---|---|
| 81 | 111 | 525 |
| 79 | 106 | 472.5 |
| 72 | 102 | 525 |
| 79 | 104 | 437.5 |
| 77 | 102 | 437.5 |
| 80 | 112 | 560 |
| 75 | 110 | 612.5 |
| 72 | 102 | 525 |
| 74 | 106 | 560 |
| 72 | 102 | 525 |

[a] Wattage = Difference x 17.5

EFFECTS OF RAPID HEAT TREATMENTS
ON BEEF TOP ROUND STEAKS

by

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

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Time saving methods of cooking meat are popular. With the microwave oven, cooking time is decreased by 1/10 to 1/2 that of conventional cooking. An important consideration in the selection of any cooking method is the effect of heat treatment on the palatability of the final product. Rapid cooking methods such as braising under pressure and microwave cookery have been reported as acceptable methods for cooking beef.

Top round beef steaks, semimembranous and adductor muscles, were cooked in a pressure saucepan (PB) (10 p.s.i.g.) or in a microwave oven (MW) to an internal temperature of 70° or 80°C.

Significant differences attributable to the weight of the steak or replication occurred for drip losses, total moisture, shear values, ether extract and Gardner color-difference values.

Total cooking time and drip losses were greater for PB steaks than for MW cooked steaks. Post cooking temperature rise was greater for MW cooked steaks. Total cooking time and cooking losses were less for the 70°C end point temperature. As end point temperature increased, water-holding capacity decreased. Steaks were juicier, more tender and more intense in beef flavor when cooked to 70° than to 80°C.

As total cooking time increased, cooking losses increased, but total moisture, juiciness, and flavor decreased. As tenderness increased, shear values decreased and the samples became more mealy.