TOP ROUND STEAKS COOKED IN CONVENTIONAL OR MICROWAVE OVENS BY DRY OR MOIST HEAT

by

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INTRODUCTION

Microwave ovens have been on the market over two decades. When first introduced, their high cost was a deterrent to their widespread use. A consumer microwave oven once cost as much as $1500. Better manufacturing techniques have reduced the cost to less than $500, resulting in increased sales (Van Zante, 1973). The sale of portable microwave ovens increased from 784,000 units in 1975 to 1,251,000 units in 1976 (Thomas, 1977). In the United States the number of households owning a microwave oven is expected to increase from 10% in 1976 to 20% by 1980 (Murray, 1977). One of the greatest advantages of microwave cooking is its time saving factor. With the microwave oven, cooking time of meat is four to five times faster than that of conventional cooking (Apgar et al., 1959; Bowers et al., 1974; Headley and Jacobson, 1960; Marshall, 1960; Wooldridge, 1974).

The effects of heat treatment on the palatability of meat should be considered in selecting a cooking method. Marshall (1960) and Law et al. (1967) compared microwave cookery to conventional roasting of beef top round and found that some portions of the microwave cooked beef were dry, hard and unpalatable. Apgar et al. (1959), Kylen et al. (1964) and Deethardt et al. (1973) compared microwave cookery to conventional roasting of pork. Headley and Jacobson (1960) compared conventional roasting and microwaves for cooking lamb. All of those authors found higher total cooking losses and lower palatability scores for the meat cooked by microwaves. Wooldridge (1974) compared microwave and conventional cooking of pork slices and patties from the frozen state in plastic film pouches and found no significant differences in palatability scores for meat cooked by the two methods.

Meats cooked by microwaves have a less attractive surface (grayed-brown) than the surface (brown) of conventionally cooked meats (Berger, 1958a; Kylen et al., 1964; Deethardt et al., 1973; Korschgen et al., 1976). To overcome this, some microwave oven manufacturers have included browning units in their ovens. No research reports were found on microwave cooking of beef with a browning unit, but Apgar et al. (1959) and Deethardt et al. (1973) cooked pork using browning units. Apgar et al. (1959) found that using the browning unit in the microwave oven increased total cooking time, surface browning, aroma and over-all acceptability; whereas, Deethardt et al. (1973) found the browning unit had little effect on the appearance of the pork and decreased flavor scores.

Uneven heating of foods during microwave cooking has been recognized as a problem. Berger (1958a) and Marshall (1960) found that when roasts were cooked to the rare stage in the center, the outer circle of the meat was well-done. Uneven heating also was observed when turkey roasts were cooked by microwaves (Bowers and Heier, 1970). One manufacturer attempted to alleviate this problem by developing a microwave oven with a carousel (rotary hearth). In the studies reviewed, microwave ovens with a stationary rack were used. Objectives of this project were: (1) to compare uniformity of doneness of beef top round steaks cooked in conventional or microwave ovens equipped with rotary hearths by dry (modified roasting) or moist (oven film bag) heat, and (2) to assess effects of four oven-heat treatment combinations on cooking losses, sensory characteristics and related objective measurements.

REVIEW OF LITERATURE

Definition of microwave

A microwave is a short electromagnetic wave that falls between ultra short radio waves and infrared waves in frequency. Microwaves are about 12.7 cm in length or about 1/700th the length of radio waves (Fenton, 1957). These waves are generated by a magnetron tube, which is capable of converting electrical power into microwaves. The waves generated by the magnetron in microwave ovens may have a frequency of 915 megacycles or megahertz (MHz) or 2,450 MHz. The commonly used wavelength for domestic microwave ovens is 2,450 MHz (Van Zante, 1973).

Microwaves are sources of energy, not heat. Only when the waves are absorbed is heat produced. In microwave cookery, the microwaves penetrate the food causing oscillation of the polar molecules, which converts the electrical energy into molecular motion. It is the intermolecular friction that is converted to heat and that results in cooking of the food (Fenton, 1957; Goldblith, 1966; Van Zante, 1966, 1973).

Differences between conventional and microwave cooking

The principle of heating food in the microwave oven is different from the principle of conventional cooking. With conventional methods of cooking, heat is applied to the outside of the food and the interior receives heat principally by conduction; i.e. heat is transmitted from the surface of the food to the interior along a temperature gradient (Rosen, 1972).

In microwave cooking, the food is cooked primarily by generation of heat within the food itself and not by applying heat to the surface. Microwave heating is referred to as volume heating, because its effect is throughout the product (Decareau, 1968; Copson, 1975). The air in the oven and the container the food is in are warmed only as they receive heat from the food. Microwaves are capable of penetrating food from 6.3 to 7.6 cm; therefore, when food products are thicker than that, microwave cooking of the food relies on the flow of heat from a hot region to a cold region (Napleton, 1967).

Factors influencing microwave heating of foods

Initial temperature. The higher the initial temperature of the food, the faster it will be heated by microwaves. Cooking foods from the frozen state in a microwave oven creates problems. Microwave absorption rate is much higher for water than for ice, so portions that become thawed absorb more energy and are overcooked while the unthawed parts absorb less energy and are undercooked (Napleton, 1967).

The initial temperature of food also is related to the depth of penetration of microwaves. Microwaves penetrate deeper into ice than they do into water (Van Zante, 1973). Considering the effect of temperature on microwave penetration in food, one might expect that cooking food from the frozen state would be preferable to cooking thawed food. However, differences in microwave absorption between ice and water and the effects of cooking from the frozen state on the food must be considered. When it is necessary to cook a food from the frozen state the effect of large differences in microwave absorption can be minimized by interrupting microwave thawing with short resting periods so that heat conduction can equalize the temperature difference (Napleton, 1967; Copson, 1975). Shielding the corners and edges of the food with aluminum foil also helps to prevent overheating in these areas (Van Zante, 1973).

Density and homogeneity. Generally, the denser a food, the longer it takes to cook by microwaves. Also, the more homogeneous the composition, the greater and more even the absorption of microwaves by the food and the less time required for cooking. Ground meat is homogeneous in terms of distribution of lean, fat and connective tissue; whereas, intact muscle such as a steak is heterogeneous with an uneven distribution of lean, fat and connective tissue, which absorb microwaves at different rates. Because of the uneven distribution of those components, when a steak is cooked by microwaves, the surface may become shrivelled and overcooked before the center is the desired degree of doneness (Napleton, 1967).

Presence of bone. The presence of bone affects the uniformity of microwave heating of meats. Bollman et al. (1948) reported difficulty in obtaining even doneness when meat with bone was cooked by microwaves. According to Van Zante (1968, 1973) the internal doneness of meat is hastened by the presence of bone. She suggested that calcium and other minerals in the bone cause a reflection of the microwaves. As microwaves penetrate the muscle they are turned back by the bone causing rapid heating of the meat near the bone, because the bone-reflected waves exspend most of their energy near the bone.

Van Zante (1968) recommended that meat containing bone be repositioned in the microwave oven occasionally during cooking. Repositioning aids in preventing overcooking on one side that is attributable to microwave reflectance.

Shape. Uniformly shaped pieces of meat heat more evenly than irregular-shaped pieces. If a steak or roast is of varying thickness, the thinner portions may become overheated before the desired degree of doneness is obtained in the thicker portions. Here again, aluminum foil may be used to shield the thinner portions to prevent overcooking in those areas. Copson (1975) suggested that roasts be twice as long as they are wide. Dungan (1969) suggested that a roast cooked in a microwave oven be such that the smallest dimension (thickness) is no greater than 10.1 cm. At greater thicknesses, the microwaves overcook the outer portions of the roasts before the interior is cooked.

Quantity. The quantity or amount of food to be heated in a microwave oven also influences the heating time. Increasing the mass increases the heating time. Napleton (1967) stated that for every additional item or increase in weight, approximately one-half the recognized time for one item is added to the heating time. Copson (1975) stated that generally there is a linear relationship between the quantity of food to be prepared and the total cooking time. For example, if one hamburger patty requires two min to cook, four patties will take eight min. Rhee and Drew (1977) reported that one 115 g patty cooks in two min, whereas four patties require five min to cook in a microwave oven.

Post-oven temperature rise. Cooking continues and the temperature of the food rises after foods cooked by microwaves are withdrawn from the oven. The post-oven temperature rise should be taken into account when cooking meats in the microwave oven. Application of microwave energy to the meat should not continue until the desired internal temperature is reached, because internal temperatures can rise considerably after removal from the oven resulting in overdoneness (Decareau, 1968).

Copson (1975) stated that the use of a standing time after roasts are removed from the microwave oven is an important part of cooking meat by microwaves. The purpose of the standby time is to allow heat to distribute itself throughout the roast, thereby helping to produce an even pattern of doneness. Use of standby time in meat cookery is important because it increases the yield of the meat and minimizes microwave oven time (Copson, 1975). He recommended that beef roasts weighing 2.3 kg or more be removed from the oven at 32° to 38°C, 60°C or 70°C to result in rare, medium or well done stages with 30 to 50 min standby time. Berger (1958b) reported that with pork roasts, the higher the internal temperature upon removal from the oven, the smaller the post-oven temperature rise. The temperature at which meat should be removed from the oven varies with the weight and shape of the piece of meat.

Utensils. Microwaves may be reflected, transmitted or absorbed. Heat-resistant glassware and ceramics are excellent utensils for microwave cookery because they transmit 95% or more of the microwave energy to the food. Paper and various types of plastic also transmit microwaves so they can be used in microwave cookery. Paper should have a moisture-resistant finish and plastics should be hard enough to resist distortion by the heat from foods. Metals reflect microwaves; therefore, they are unsuitable for use in microwave cookery (Fenton, 1957; Van Zante, 1973). Some utensils compete with the food for microwave energy, especially when small quantities of food are cooked in large containers; therefore, care should be taken to select a properly shaped and sized utensil (Copson, 1975). Van Zante (1969) showed round pans are superior to square pans because there are no corners where microwaves can become over concentrated.

Energy distribution. Distribution of energy in the cavity of a microwave oven may be uneven. The kind of food being heated, its shape and mass affect an oven's heating pattern. Chemical and physical changes in food during cooking also may cause shifting heat patterns (Van Zante, 1973). Katz (1977) compared energy distribution patterns of nine microwave oven models and found that heating patterns varied among brands of ovens for the same power setting, and at times, within a given oven for different preparations of the same food. Characteristic heating patterns in a microwave oven can be determined by various tests using water, frankfurters, eggs, chickens, muffins, cakes or potatoes (Napleton, 1967; Van Zante, 1973; Copson, 1975).

Effects of microwave cookery on meat quality

According to Murray (1977), 26% of microwave oven owners cook meats frequently in the microwave oven. Early research showed that meat cooked in microwave ovens was less palatable than that cooked in conventional ovens; however, some recent research has demonstrated that meat cooked by microwaves can compare favorably with conventionally cooked meat (Ruyack and Paul, 1972; Wooldridge, 1974; Korschgen et al., 1976). Baldwin (1977) presented an excellent summary of the literature on microwave cookery of meats. Care should be taken when cooking meats in a microwave oven to prevent overheating and to protect the tenderness of meat. The proteins in meat are denatured easily by high heat with toughening of the meat resulting. Kalafat and Kroger (1973) explained the toughening of meats cooked in the microwave oven as a function of the amount of heat energy applied to the proteins. At very high power levels meat will cook rapidly, but it will be extremely tough.

According to Van Zante (1973), tender cuts of meat will retain their natural juices and have good flavor when properly cooked in the microwave oven. Less tender cuts of meat will not become tender, because the long, slow cooking process in the presence of moisture needed to breakdown the connective tissue is not produced by microwave cookery. That was demonstrated with arm roasts by Ream et al. (1974). Some contemporary ovens (1978) have a slow cook cycle. Research is needed to determine if the use of this cycle along with the use of some means to provide a moist atmosphere will enhance tenderization of less tender cuts of meat cooked by microwaves.

Higher total cooking losses for meat cooked by microwaves than for that conventionally roasted were reported by Headley and Jacobson (1960), lamb roasts; Marshall (1960), beef roasts; Kylen et al. (1964), pork and beef roasts; Moore et al. (1966), Bowers et al. (1974), pork roasts and Korschgen et al. (1976) beef, pork and lamb roasts. Apgar et al. (1959) reported that pork chops had less cooking losses when cooked by microwaves than by conventional roasting; however, no significant difference was noted in cooking losses for pork patties or roasts cooked by the two methods. Nobel and Gomez (1962) and Deethardt et al. (1973) reported total cooking losses were about the same for lamb and pork roasts cooked by microwaves or conventionally. Generally, in those studies where sensory characteristics were evaluated, conventionally roasted meat had higher palatability scores than meat cooked by microwaves.

Comparing the effect of dry and moist heat treatments on the quality of beef roasts cooked conventionally or by microwaves, Ruyack and Paul (1972) and Ream et al. (1974) found that cooking losses were higher for roasts cooked by microwaves than for roasts cooked by conventional heating by both dry and moist heat. Ruyack and Paul (1972) reported that using plastic wrap to provide a moist atmosphere increased cooking losses for steaks cooked in either oven. Ream et al. (1974) reported that beef roasts cooked in the microwave oven were less juicy, tender and flavorful than conventionally cooked meat; whereas, Ruyack and Paul (1972) reported no difference in palatability. Wooldridge (1974) compared microwave and conventional cooking of pork slices and patties from the frozen state in plastic film pouches and found no significant differences in the palatability scores for meat cooked by the two methods. Taste panel scores indicated patties were juicier and tenderer than slices.

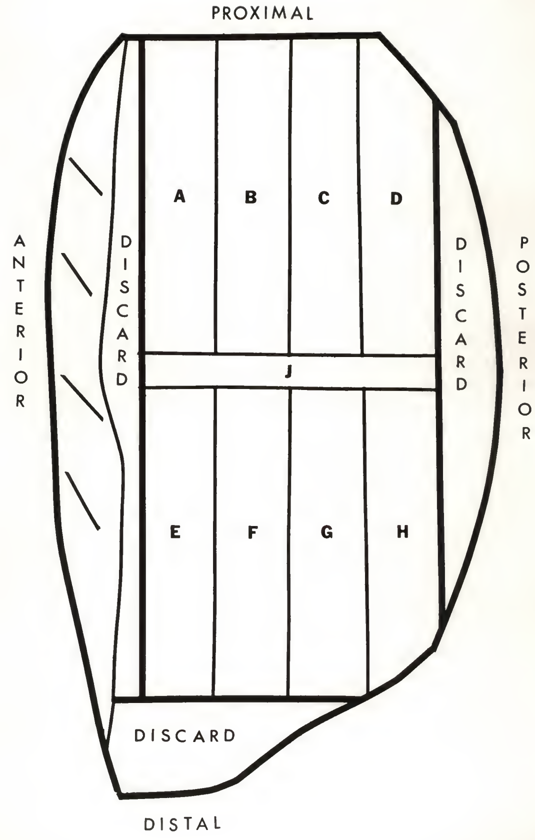
MATERIALS AND METHODS

Four U.S. Choice fresh, unfrozen beef top rounds, approximately 9 kg, were obtained from a local wholesale meat company. They were vacuum packed in a Cryovac B-620 "Barrier bag" using a Cryovac 8200 vacuum chamber 1 to 4 days after slaughter. The rounds were purchased 16 to 30 days after vacuum packaging. The external fat covering was removed, the semimembranosus (SM) and adductor (AD) muscles were squared off and divided into eight steaks, each 3.8 cm thick (Fig. 1). Steaks were assigned to treatments according to the position of the steak within the round (Fig. 2). Weight of the four inside steaks (B,C,F,G) ranged from 467 to 752 g; the four outside steaks (A,D,E,H) ranged in weight from 468 to 633 g.

Fig. 1--Photograph of trimmed top round cut into steaks.


A
B
C
D
E
F
G
H

Fig. 2--Sampling plan for beef top round (SM and AD muscles). Steaks A - H were used for cooked sample analysis. Strip J was used for raw sample analysis.


PROXIMAL
A
B
C
D
ANTERIOR
DISCARD
J
DISCARD
POSTERIOR
E
F
G
H
DISCARD
DISTAL

Individual steaks (except steaks for the first cooking period from each round) were wrapped in aluminum foil (gauge 0.0015) and frozen in an upright household freezer at an average temperature of -23.5°C ± 2.5°C until used (3-10 days).

Experimental design and cooking

Treatment combinations studied were: conventional oven, dry heat (CD); conventional oven, moist heat (CM); microwave oven, dry heat (MD); microwave oven, moist heat (MM). The experimental design for the sensory and objective data (except shear values and Gardner color-difference) was a split plot with eight replications with the steak positions in the round as the main plots and the treatment combinations as the subplots. The experimental design for the Gardner color-difference and shear values and temperature data was a split, split plot with the steak positions in the round as the main plots, the treatment combinations as the subplots, and the position in the steak as the sub-subplots. There were 16 evaluation periods with two steaks cooked at each period. Each top round provided steaks for two replications of each treatment (Table 1).

Before each cooking period, except for the first period for each round, steaks designated by the experimental design were defrosted in the foil wrap four hours at approximately 25°C and 20 hours at approximately 4°C, then unwrapped and weighed. Steaks for the first cooking period were stored at 4°C for 20 hours, then unwrapped and weighed.

Thermometers (-20° to 105°C, 15 cm long) were inserted with the bulb (approximately 1.3 cm long) in the geometric center, and at positions 4.0 cm from the proximal and distal edges of each steak.

Table 1--Experimental design for cooking

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

[a]Steak positions are illustrated in Fig. 1.

[b]Treatments randomly assigned to the steaks. CD-Conventional, dry; CM-Conventional, moist; MD-Microwave, dry; MM-Microwave, moist.

Temperatures at the three positions were recorded initially, upon removal from the oven and after a post-oven temperature rise. Glass thermometers with mercury in the column indicating the temperature were used for conventionally cooked steaks, and glass thermometers with a nonpolar organic liquid in the column were used for microwave cooked steaks.

In preliminary work the weight and the cooking time required for steaks were plotted in a graph and a line that best fit points on the graph was drawn for each treatment. From that line, cooking time for steaks assigned to each treatment in the main study was estimated based on thawed weight of the steaks. The CM, MD and MM steaks were removed from the oven at a mean center temperature of 58°, 59° and 55°C, respectively, to achieve a final temperature of 65°C at the center of the steak. CD steaks were cooked to 65°C; preliminary work showed no post-oven temperature rise for that treatment.

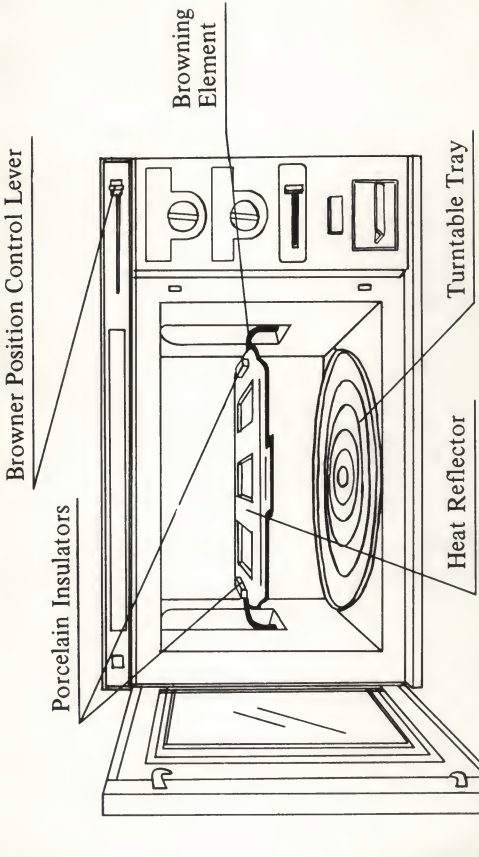
For conventional modified roasting (CD) each steak was placed on a wire rack 12.7 cm high set in a shallow pan (Fig. 3). Steaks were cooked in an electric rotary hearth oven at 177°C. For microwave roasting (MD), each steak was placed on a Pyrex casserole lid (diameter, 15.5 cm) in a 22.8-cm Pyrex pie plate (Fig. 3), placed in the center of the rotary hearth in the microwave oven (Sharp R-8200) and cooked at the roast setting (approximately 455 watts), Fig. 4.

For cooking in oven film bags, each steak was placed in an oven film bag (Cooking Magic) and closed with a twister tie or with masking tape for microwave cooked steaks. Six slits (approximately 1.5 cm long) were made in each bag to allow steam to escape and prevent the bag from breaking. The thermometers were inserted through the oven film bag in

Fig. 3--Raw steaks prepared for conventional and microwave dry heat treatments.


MICROWAVE, DRY
CONVENTIONAL, DRY

Fig. 4--Diagram of the interior view of the Sharp microwave oven, Model R-8200.


Browner Position Control Lever
Browning Element
Turntable Tray
Porcelain Insulators
Heat Reflector

the same three positions described for dry heat treatments. For CM, the entire system was placed on a low rack in a shallow roasting pan and cooked in an electric rotary hearth oven at 177°C (Fig. 5). For MM, the entire system was placed on a Pyrex casserole lid (diameter 15.5 cm) in a 22.8-cm Pyrex pie plate in the center of the rotary hearth in the microwave oven and cooked at the roast setting (Fig. 5).

Cooking time and losses, post-oven temperature rise

Total cooking time was recorded in minutes. Percentage total, drip and volatile (dry heat treatments only) cooking losses based on weight of the thawed raw steak were calculated. Drippings for steaks cooked by CM, MD or MM were collected in 250-ml graduated cylinders and allowed to stand 45 min. After the fat had stabilized at the top of the drippings, total volume of drippings, volume of fat and volume of coagulum were read and the percentage fat in the drippings was calculated. Post-oven temperatures were taken 10 min after removal of steaks from the oven; preliminary work indicated the temperature began to fall after 10 min standing. The steaks were covered with aluminum foil during standing.

Cooked steaks were sampled according to the plan illustrated in Fig. 6.

Sensory evaluation

Flavor, juiciness, texture and tenderness of 1.3 x 2-cm cores of cooked meat were evaluated by an 8-member laboratory panel using a 5 to 1 point intensity scale (Form I, Appendix, p. 59). Instructions for evaluation (Form II, Appendix, p. 60) were given to panel members during preliminary work.

Fig. 5--Raw steaks prepared for conventional and microwave moist heat treatments.

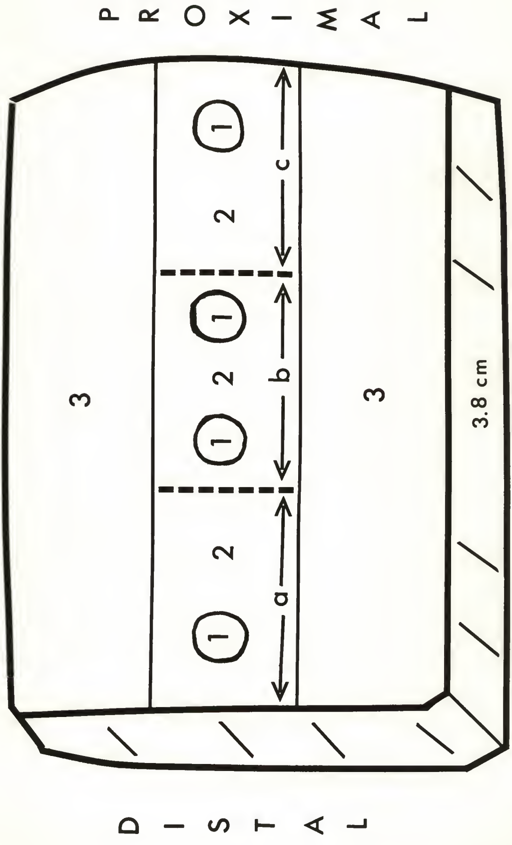

MICROWAVE,
MOIST
CONVENTIONAL,
MOIST

Fig. 6--Sampling plan for cooked top round steaks

1 Shear cores, water-holding capacity

2 Total moisture; ether extract; pH; Gardner color-difference; a) distal, b) center, c) proximal

3 Sensory evaluation.


PROXIMAL
DISTAL
3
3
1
2
1
2
1
2
1
a
b
c
3.8 cm

Cores were presented to panel members in the top of half-pint double boilers set over warm water (approximately 65°C) and the entire system was placed on an electric hot tray at low heat (approximately 35°C). All sensory evaluation took place within 15 min after preparation of samples.

pH

A slurry of cooked meat was prepared by blending 10 g ground muscle with 100 ml of distilled, deionized water in an electric blender for 2 min at high speed. The slurry was placed in a beaker and the temperature brought to 25°C. After the slurry was stirred 30 sec with a magnetic stirrer, the pH was measured with a digital pH meter standardized at 25°C against a buffer of pH 6.86. A second pH reading was made after the beaker was rotated 180° and stirred another 15 sec.

Shear value

Tenderness was measured on cooked samples cooled to room temperature by shearing 1.3-cm cores with a Warner-Bratzler shearing apparatus with a 11.25-kg dynamometer. Four cores were taken from the proximal (c), center (b) and distal (a) positions in each steak (Fig. 6). Duplicate measurements were made on each core and the over-all shear value was the average for the four shear cores.

Total moisture and ether extract

Percentage of total moisture and ether extract in samples of both raw and cooked meat were measured in triplicate by the analytical laboratory of the Department of Animal Science and Industry using a modified AOAC method (AOAC, 1975). Percentage total moisture also was measured on duplicate 10-g samples of cooked meat by drying in the C.W. Brabender Semi-automatic Moisture Tester at 121°C for 60 min.

Water-holding capacity

Water-holding capacity (WHC) of the cooked meat was measured as described by Miller and Harrison (1965) on 0.3-g samples taken from the center of cores used for Warner-Bratzler shear values. This is a press method; the ratio of the area of pressed muscle to the area of expressed liquid on the filter paper (Whatman 1) 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. Because the expressible-liquid-index is inversely related to the amount of liquid expressed from the sample, the larger the value of WHC, the greater the amount of liquid expressed.

Gardner color-difference

Color-difference values were measured with a Gardner Color-Difference Meter on the center (b) and end sections (a,c) of each cooked steak (Fig. 6). The instrument was standardized using a satin finished ceramic tile with calculated values of: Rd (reflectance), 37.8; a+ (redness), 5.8; and b+ (yellowness), 15.2. A sample of ground meat was packed into a plexiglass cell 5.5 cm in diameter so that light could not filter through the sample. After the first measurement, the cell was rotated 90° and duplicate measurements were made for each color-difference factor.

Analysis of data

The analysis of variance used to analyze data for sensory and objective measurements (except volatile cooking losses, shear values and Gardner color-difference) was:

Source of variation	D/F
Round	3
Position in round (a)	1
Error (A)	3
Type of oven (b)	1
Type of heat (c)	1
Interactions	
b x c	1
a x b	1
a x c	1
a x b x c	1
Error (B)	18
Total	31

The analysis of variance used to analyze data for volatile cooking losses was:

Source of variation	D/F
Round	3
Position in round (a)	1
Error (A)	3
Type of oven (b)	1
Interaction (a x b)	1
Error (B)	6
Total	15

The analysis of variance used to analyze data for shear values$^{(x)}$, Gardner color-difference values$^{(y)}$ and the final temperature values$^{(z)}$ was:

Source of variation	D/F^x	D/F^y	D/F^z
Round	3	3	3
Position in round (a)	1	1	1
Error (A)	3	3	3
Treatment (b)	3	3	2
Interaction (a x b)	3	3	2
Error (B)	18	18	12
Position in steak (c)	2	1	2
Interactions			
a x c	2	1	2
b x c	6	3	4
a x b x c	6	3	4
Error (C)	48	24	36
Total	95	63	71

RESULTS AND DISCUSSION

Initial weight of steaks, thaw loss

Analysis of variance indicated no significant differences between weights of steaks or thaw losses of steaks assigned to type of oven (Table 2), type of heat (Table 3) or to position in the round (Table 4). Although the differences between weights of steaks from the inside and outside position in the round were not significant, the inside steaks (B,C,F,G) averaged 67.75 g more than the outside steaks (A,D,E,H).

Table 2--Means and F-values for selected measurements by type of oven[a]

Measurement	Type of oven		F-value
	Conventional	Microwave	
Initial weight, g	588.88	567.50	1.302
Thaw loss, %	1.75	1.50	0.497
Cooking time, min	46.04	11.63	2112.244***
Cooking losses, %			
Total	24.03	29.73	52.855***
Drip	11.99	20.30	50.111***
Volatile[b]	18.74	12.86	105.416***
Ether extract, %	5.20	6.61	6.100*
Total moisture, %			
AOAC	65.92	63.02	10.413***
Brabender	64.28	61.88	18.648***
WHC[c]	0.70	0.69	3.189
pH	5.50	5.51	0.054
Shear value, kg/1.3-cm core	2.93	3.41	3.985
Sensory scores,[d]			
Flavor	3.0	3.0	0.006
Juiciness	3.4	2.5	17.141***
Texture	3.3	3.4	0.632
Tenderness,			
Initial	4.0	3.2	21.806***
Final	4.4	4.0	17.050***

[a]Dry and moist heat data combined.

[b]Dry heat data only.

[c]Water-holding capacity - 1.0 minus expressible-liquid-index; the larger the value, the greater the amount of liquid expressed.

[d]5-(intense beef flavor, juicy, mealy, tender) to 1-(no beef flavor, dry, chewy, tough).

***$P < 0.001$; *$P < 0.05$.

Table 3--Means and F-values for selected measurements by type of heat[a]

Measurement	Type of heat: Dry	Type of heat: Moist	F-value
Initial weight, g	567.69	588.69	1.257
Thaw loss, %	1.88	1.38	1.986
Cooking time, min	34.17	23.50	203.158***
Cooking losses, %			
Total	25.01	28.75	22.725***
Drip	10.01	22.28	109.273***
Ether extract, %	5.85	5.95	0.033
Total moisture, %			
AOAC	65.01	63.94	1.425
Brabender	63.43	62.74	1.533
WHC[b]	0.69	0.69	0.054
pH	5.49	5.52	0.596
Shear value, kg/1.3-cm core	2.93	3.41	4.220
Sensory scores,[c]			
Flavor	3.0	2.9	0.006
Juiciness	3.1	2.8	3.056
Texture	3.3	3.5	0.404
Tenderness,			
Initial	3.7	3.5	2.580
Final	4.2	4.1	0.977

[a]Conventional and microwave oven data combined.

[b]Water-holding capacity - 1.0 minus expressible-liquid-index; the larger the value, the greater the amount of liquid expressed.

[c]5-(intense beef flavor, juicy, mealy, tender) to 1-(no beef flavor, dry, chewy, tough).

***P < 0.001.

Table 4--Means and F-values for selected measurements by position in the top round[a]

Measurement	Position in round: Inside	Outside	F-value
Initial weight, g	612.06	544.31	9.537
Thaw loss, %	1.56	1.69	3.125
Cooking time, min	29.16	28.51	0.270
Cooking losses, %			
Total	26.57	27.19	0.970
Drip	15.93	16.36	0.748
Volatile	15.71	15.89	0.055
Volume of drip, ml[b]	110.58	102.17	1.400
% lipid	2.75	5.50	2.028
% coagulum	29.33	24.67	2.529
Ether extract	5.12	6.68	11.408*
Total moisture, %			
AOAC	65.68	63.26	8.964
Brabender	63.75	62.41	9.663
WHC[c]	0.70	0.69	0.973
pH	5.49	5.52	2.100
Shear value, kg/1.3-cm core	3.18	3.16	0.000
Sensory scores,[d]			
Flavor	3.0	2.9	0.029
Juiciness	3.1	2.8	12.273*
Texture	3.4	3.3	1.149
Tenderness,			
Initial	3.7	3.5	2.997
Final	4.3	4.0	32.827*

[a]Data combined for all treatments.

[b]Data combined for treatments CM, MD and MM.

[c]Water-holding capacity - 1.0 minus expressible-liquid-index; the larger the value, the greater the amount of liquid expressed.

[d]5-(intense beef flavor, juicy, mealy, tender) to 1-(no beef flavor, dry, chewy, tough).

*P < 0.05.

Data for the interaction between treatment and position in the round (Table 5) indicate that the weights of inside steaks (B,C,F,G) assigned to treatments CM, MD or MM were greater ($P < 0.05$) than the weights of the outside steaks (A,D,E,H) assigned to those treatments. No significant differences in weights of steaks assigned to CD were observed. The weights of steaks did not differ significantly between the treatments within the inside or outside position (Table 5).

Type of oven

Data for effects of type of oven on cooked steaks are presented in Table 2. Total cooking time, volatile cooking losses, total moisture and sensory juiciness and tenderness scores were greater ($P < 0.001$) for conventionally cooked steaks than for steaks cooked by microwaves. Total and drip cooking losses and ether extract were greater ($P < 0.001$ or 0.05) for steaks cooked by microwaves than for those cooked in the conventional oven. Drip losses for steaks cooked by CM, MM and MD can be observed in Fig. 7. The amount of coagulum in the drippings was greater for steaks cooked in the microwave oven than for those cooked in the conventional oven (Table 6).

Cooking steaks in the microwave oven was approximately four times faster than cooking in the conventional oven. Other researchers working with beef reported that a microwave oven cooks beef four to five times faster than various conventional methods (Berger, 1958a; Marshall, 1960; Korschgen et al., 1976).

The findings that total and drip cooking losses were higher ($P < 0.001$) for steaks cooked in the microwave oven agree with the work of Marshall (1960), Kylen et al. (1964), Ruyack and Paul (1972), Bowers

Table 5--Means and LSD's for significant type of heat[a] x position in the round interactions and treatment x position in the round interactions

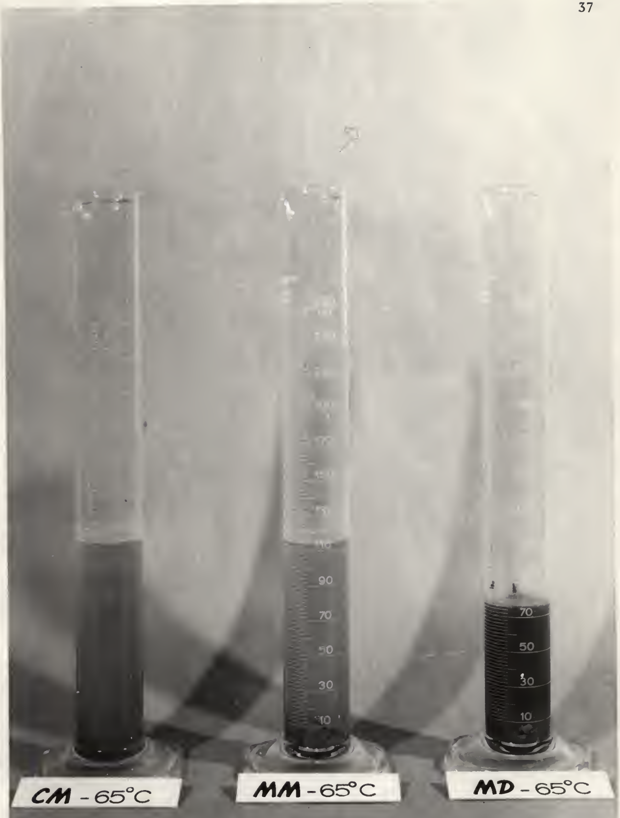
Measurement	Type of heat	Treatment[b]	Position in round		LSD[c] $_{0.05}$
			Inside	Outside	
Cooking losses, %					
Drip	Dry		e11.05d	e8.96d	3.49
	Moist		f20.81d	f23.75d	6.25
Initial weight, g		CD	f565.75d	f578.75d	55.65
		CM	f642.50d	f568.50e	95.56
		MD	f640.00d	f486.25e	
		MM	f600.00d	f543.75e	

[a]Conventional and microwave oven data combined.

[b]CD-Conventional, dry; CM-Conventional, moist; MD-Microwave, dry; MM-Microwave, moist.

[c]The first LSD listed is used to compare means between positions within a type of heat or treatment. Means within a type of heat or a treatment differ significantly when the letters to the right of the means are different. The second LSD is used to compare means between treatments within a position. Means between treatments within a position differ significantly when letters to the left of the means are different.

Fig. 7--Drip cooking losses from top round steaks cooked by CM-Conventional, moist; MM-Microwave, moist; MD-Microwave, dry.


CM - 65°C
MM - 65°C
MD - 65°C

et al. (1974), Korschgen et al. (1976) and Moody et al. (1978). Marshall (1960) working with 2.3 kg top round roasts found that with microwave cookery total cooking losses were higher and drip losses were approximately double those of conventionally roasted meat. Kylen et al. (1964) reported greater ($P < 0.01$) total cooking losses for beef roasts, beef loaves and ham loaves, and higher drip losses for beef and pork roasts cooked in a microwave oven than for those products cooked by conventional roasting.

Table 6--Means and LSD's for volume of drip, % lipid in drip and % coagulum in drip by treatment

Measurement	Treatment[a] CM	MD	MM	$LSD_{0.05}$
Volume of drip	126.13b	76.88c	116.13b	16.00
% lipid	2.75b	5.50c	3.13b	1.43
% coagulum	12.13b	50.13c	18.75b	10.16

[a]CM-Conventional, moist; MD-Microwave, dry; MM-Microwave, moist.

[b,c]Means for a measurement bearing different letters differ significantly.

Ruyack and Paul (1972) compared microwave and contentional cooking of uncovered beef roasts with roasts wrapped in plastic wrap and reported higher ($P < 0.01$) total and drip cooking losses for roasts cooked by microwaves than for those cooked conventionally. They suggested that the increase in drip losses for meat cooked by microwaves may be attributable to the effect of the oscillation of water molecules on the bonding of bound water, resulting in greater ease of moisture loss.

Cooking beef rib eye roasts, pork loin roasts and lamb roasts, Korschgen et al. (1976) reported higher ($P < 0.05$) drip losses with microwave cookery than with conventional roasting. Greater total cooking losses occurred with microwave heating of beef, but not with pork or lamb. Comparing conventional roasting of roasts thawed by several methods to microwave thawing and cooking, Moody et al. (1978) reported greater ($P < 0.025$) cooking and drip losses for microwave than for conventional roasting.

Wooldridge (1974) compared microwave and conventional cooking of pork slices and patties from the frozen state in plastic film pouches. She found that total cooking losses were about the same for both cooking methods, but higher drip losses were observed for the microwave method.

In this study, volatile cooking losses were greater ($P < 0.001$) for conventionally cooked steaks than for steaks cooked by microwaves (Table 2). The difference in volatile losses may be attributable to the longer cooking time in the conventional oven or to the effect of the oven temperature. In microwave cookery, the oven cavity remains cool; whereas, in conventional cookery the hot oven temperature may increase evaporation.

In contrast to this study, Marshall (1960), Ruyack and Paul (1972), Ream et al. (1974) and Moody et al. (1978) all observed that microwave cookery of beef roasts resulted in greater volatile cooking losses than conventional roasting. Headley and Jacobson (1960) worked with lamb roasts and reported similar findings. Korschgen et al. (1976) reported less evaporative cooking losses for conventionally roasted beef roasts than for roasts cooked in the microwave; however, the opposite was true for pork roasts.

Although volatile losses were greater ($P < 0.001$) for steaks cooked in the conventional oven than for those cooked by microwaves, total moisture in microwave cooked steaks was less ($P < 0.01$) than that in conventionally cooked steaks (Table 2). Kylen et al. (1964) and Bowers et al. (1974) also found less total moisture in microwave cooked beef roasts, beef and ham loaves or pork loin than when those products were cooked by conventional methods.

The AOAC and Brabender methods for determining total moisture gave similar percentages of total moisture for steaks cooked in both types of ovens, with the AOAC method giving slightly higher mean values (1.14 or 1.64%), Table 2. Ether extract was greater ($P < 0.05$) and total moisture was less ($P < 0.001$) for microwave cooked steaks than for conventionally cooked steaks. Although those differences were statistically significant, mean percentage differences were only 1.41 for ether extract and 2.40 or 2.90 for total moisture.

Total moisture is one factor that affects the juiciness of meat. Similar to values for total moisture, sensory juiciness scores were lower ($P < 0.001$) for steaks cooked in the microwave oven than for those cooked in the conventional oven. Headley and Jacobson (1960) and Ream et al. (1974) also reported that conventionally roasted lamb or beef roasts, respectively, were juicier than those cooked in a microwave oven.

Sensory tenderness scores indicated that steaks cooked in the conventional oven were tenderer ($P < 0.001$) than those cooked in the microwave oven. Differences in shear values attributable to the type of oven were not significant (Table 2). In earlier studies, conventional roasting of beef yielded more tender meat than that cooked in a microwave oven (Berger, 1958a; Marshall, 1960; Ream et al., 1974).

Final tenderness scores averaged 0.4 to 0.8 of a point higher than the initial tenderness scores. The initial score reflects the panelists' first impression of the sample's tenderness; whereas, the final score was based on a chew count scale devised by each individual panelist to standardize his scoring for intensity of tenderness from one evaluation period to another. A larger difference between initial and final tenderness scores was observed for steaks cooked in the microwave oven than for those cooked in the conventional oven (Table 2). Comments from panelists indicated that samples of meat cooked in the microwave oven initially seemed tougher than was indicated by the final tenderness scores (based on chew count), because those samples fell apart easily with chewing.

Measurements for which type of oven had no significant effect were: water-holding capacity, pH, Warner-Bratzler shear values and sensory scores for flavor and texture.

Generally, the present study confirmed reports in the literature concerning the effect of microwave cookery on the quality of red meat. Previous studies, though not in total agreement, tend to indicate that meat cooked by microwaves has greater total cooking losses and is less flavorful and tender than that cooked conventionally. The present study showed that the flavor and texture of meat cooked in the two ovens were similar; whereas, meat cooked in the microwave oven was less juicy and tender.

Type of heat

Data for effects of type of heat on cooked steaks are presented in Table 3. Total cooking time was greater ($P < 0.001$) for steaks cooked by dry heat than for steaks cooked by moist heat. Steaks cooked by moist heat had higher ($P < 0.001$) total and drip cooking losses than those cooked by dry heat. Similarly, Ruyack and Paul (1972) reported that beef semitendinosus roasts cooked by dry heat in conventional or microwave ovens required longer cooking time, but had less ($P < 0.05$) total and drip cooking losses than those covered with polyester wrap. Ream et al. (1974) also found that cooking arm roasts by top-of-the stove moist heat and moist heat in the microwave oven had greater ($P < 0.05$) drip losses than by conventional or microwave roasting.

Measurements for which type of heat had no significant effect were: ether extract, total moisture, water-holding capacity, pH, shear value and all sensory scores.

Few research reports on the effects of dry and moist heat treatments on meat cooked by microwaves were found in the literature. The findings in this study agree with those of earlier studies that cooking losses were greater for meat cooked by moist heat than for that cooked by dry heat and that sensory attributes of meat are similar for the two types of heat.

Type of oven x type of heat interactions

Data for significant type of oven x type of heat interactions are presented in Table 7. Total cooking time was less ($P < 0.05$) for steaks cooked by moist heat and for steaks cooked in the microwave oven than for those cooked by dry heat and in the conventional oven. Steaks cooked by moist heat required 18.40 min less time in the conventional oven and 2.94 min less time in the microwave oven than steaks cooked by dry heat in the conventional or microwave oven. Microwave cooking time

Table 7--Means and LSD's for significant type of oven x type of heat interactions

Measurement	Type of oven	Type of heat: Dry	Type of heat: Moist	$LSD_{0.05}$
Cooking time, min	Conventional	55.24a	36.84b	2.22
	Microwave	13.10c	10.16d	
Cooking losses, % Total	Conventional	20.59a	27.47b	2.33
	Microwave	29.44c	30.02c	
Drip	Conventional	1.65a	22.32b	3.49
	Microwave	18.36c	22.24b	
Shear value, kg/1.3-cm core	Conventional	2.44a	3.43b	0.71
	Microwave	3.41b	3.40b	
Sensory score,[e] Juiciness	Conventional	3.8a	2.9b	0.61
	Microwave	2.4b	2.6b	

[a-d]Means for a measurement bearing different letters differ significantly.

[e]5-(juicy) to 1-(dry).

was 42.14 min less for dry heat and 26.88 min less for moist heat than was conventional cooking time for dry or moist heat. These data suggest: 1) moist heat reduces cooking time more for conventional cookery than for microwave cookery and 2) microwave cookery reduces the cooking time more with dry heat than with moist heat when compared to conventional cooking by dry or moist heat.

For both types of heat, percentage total cooking losses were greater ($P < 0.05$) for steaks cooked in the microwave oven than for those cooked conventionally, with a greater difference for dry heat. With dry heat, the difference in total cooking losses between ovens was 9%, whereas with moist heat the difference, although statistically significant, was only 2.6%. Significant differences in total cooking losses between dry and moist heat (Table 3) are attributable to the differences of the conventional oven treatments (Table 7). For both types of ovens, drip cooking losses were greater ($P < 0.05$) for moist heat than for dry heat. With dry heat, but not with moist heat, drip losses were greater ($P < 0.05$) for steaks cooked in the microwave oven than for those cooked in the conventional oven. Data in Table 7 suggest that significant differences in total and drip cooking losses (Tables 2 and 3) are mainly attributable to the effect of the CD treatment.

Warner-Bratzler shear values were less ($P < 0.05$) for steaks cooked by dry heat than for those cooked by moist heat in the conventional oven. With microwave cookery, there was no difference in shear values for steaks cooked by dry or moist heat. More shear force was required for steaks cooked in the microwave oven by dry heat than for those cooked in the conventional oven by dry heat (Table 7). Those differences were not large enough to be detected when only type of oven (Table 2) or type of heat (Table 3) were considered.

Sensory juiciness scores were higher ($P < 0.05$) for steaks cooked by dry heat than for those cooked by moist heat in the conventional oven. Steaks cooked in the microwave oven by dry heat were less juicy than those cooked in the conventional oven by dry heat (Table 7). Significant differences in sensory juiciness scores between the conventional and microwave oven (Table 2) are attributable to the effects of dry heat (Table 7). Data for nonsignificant interactions for type of oven x type of heat are presented in Table 9, Appendix, p. 61.

Position of the steaks in the round

Only ether extract and sensory scores for juiciness and final tenderness were affected significantly by position of steaks in the round (Table 4). Outside steaks (A,D,E,H) had more ($P < 0.05$) ether extract and lower ($P < 0.05$) juiciness and final tenderness scores than inside steaks (B,C,F,G). No significant interactions occurred between type of oven and position in the round (Table 10, Appendix, p. 62). Drip cooking loss was the only measurement for which there was a significant interaction between type of heat and position in the round. For both positions in the round, drip cooking losses were greater ($P < 0.05$) for moist than for dry heat (Table 5). Data for nonsignificant interactions for type of heat x position in the round are presented in Table 11, Appendix, p. 64.

Position within steaks

Warner-Bratzler shear. Cores used for Warner-Bratzler shear measurements were taken from the proximal, center and distal positions of each steak (Fig. 6). Mean shear values for steaks given each treatment are in Table 8. Generally, less force was required to shear the center cores of steaks than to shear the proximal or distal cores. No significant differences attributable to position of cores were observed for steaks cooked by CD. More force (P < 0.05) was required to shear the proximal cores of steaks from treatments CM, MD or MM than to shear center cores. Shear force for distal cores of steaks from those treatments did not differ significantly from the proximal or center cores.

<u>Gardner color-difference</u>. Gardner color-difference measurements for RD (reflectance), a+ (redness) and b+ (yellowness) were taken on the center and end sections of each steak. The Gardner Rd values for the end sections were higher (P < 0.05), except for steaks cooked by CD, than for the center section; whereas, the a+ values for the end sections were lower (P < 0.05) than for the center section (Table 8). This indicates that the end sections of steaks were more done than the center section.

The internal color of the steaks demonstrated uneven heating throughout a steak. A "ring" effect was observed in steaks, particularly for those cooked by CM, MD or MM; the outer circle of the steaks appeared well-done, whereas the inner portion was rare. Berger (1958a) and Marshall (1960) working with 1.6 to 3.9 kg roasts found that when roasts were cooked in a microwave oven to the rare stage in the center, the outer circle of the meat was well-done.

On the basis of treatments, data for effects of positions within steaks (Table 8) indicate that steaks cooked by CD had a rarer appearance than steaks cooked by CM, MD or MM. Lower (P < 0.05) Rd (reflectance) values (end sections) and higher (P < 0.05) a+ (redness) values

Table 8--Means and LSD's for position effects within steaks for Warner-Bratzler shear, Gardner color-difference and final temperature measurements

Measurement	Treatment[b]	Position[a] 1	Position[a] 2	Position[a] 3	$LSD^{c}_{0.05}$
Shear value, kg/1.3-cm core	CD	f2.70d	g2.26d	g2.35d	1.15
	CM	g4.29d	g2.56e	g3.43de	1.18
	MD	g4.07d	g2.90e	g3.27de	
	MM	g4.29d	g2.60e	g3.31de	
Gardner color-difference, Rd (reflectance)	CD	f20.13d	f19.87d		0.61
	CM	f20.23d	g21.43e		1.03
	MD	f20.23d	g22.08e		
	MM	f20.45d	g21.33e		
a+ (redness)	CD	f7.94d	f5.59e		0.75
	CM	g5.43d	g2.51e		1.18
	MD	h3.91d	g1.81e		
	MM	g5.89d	g2.66e		
b+ (yellowness)	CD	f11.43d	f10.91e		0.20
	CM	g10.98d	f10.81d		0.24
	MD	g11.08d	f10.90d		
	MM	g10.98d	f10.81d		

Table 8--(concluded)

Measurement	Treatment[b]	Position[a] 1	Position[a] 2	Position[a] 3	$LSD^{c}_{0.05}$
Final temperature, °C	CD	f66.38d	f65.00d	f65.88d	2.05
	CM	g70.50d	f66.25e	fh67.50e	2.29
	MD	g72.00d	f66.38e	g73.75d	
	MM	g69.75d	f64.13e	h69.00d	

[a]Shear value and final temperature: 1=proximal, 2=center, 3=distal. Gardner color-difference: 1=center, 2=end.

[b]CD-Conventional, dry; CM-Conventional, moist; MD-Microwave, dry; MM-Microwave, moist.

[c]The first LSD listed is used to compare means between positions within a treatment. Means within a treatment differ significantly when the letters to the right of the means are different. The second LSD is used to compare means between treatments within a position. Means between treatments within a position differ significantly when letters to the left of the means are different.

(center and end sections) and b+ (yellowness) values (center section) were observed for steaks cooked by CD than for those cooked by CM, MD or MM. Comparing conventional roasting with cooking in oven film bags, Shaffer et al. (1973) found that beef roasts cooked by dry heat were redder (appeared less well-done) than roasts cooked by moist heat. In this study, Gardner a+ (redness) values for steaks cooked conventionally, but not those for steaks cooked by microwaves, supported the findings of Shaffer et al. (1973).

Final temperature. Immediately after removal of CD steaks from the oven or after a post-oven temperature rise for CM, MD or MM steaks temperature was recorded at three positions in each steak to study evenness of heating within a steak. Uneven heating was observed for steaks cooked by CM, MD or MM. Final temperatures for all treatments varied from 64°C at the center of the steaks to 72°C at the proximal position, or to 74°C at the distal position (Table 8). The final proximal and distal temperatures were higher ($P < 0.05$) than the center temperature for steaks cooked by MD or MM; however, the proximal temperature was higher ($P < 0.05$) than both center and distal temperatures for steaks cooked by CM. These data and Gardner Rd (reflectance) and a+ (redness) values explain why the "ring" was observed in those steaks. The data in this experiment demonstrated that more even heating throughout a steak is achieved with CD than with CM, MD or MM treatments.

Temperature differences between treatments within a position can be studied in Table 8. Final temperature at the proximal position was higher ($P < 0.05$) for steaks cooked by CM (70.5°C), MD (72°C) or MM (69.75°C) than for those cooked by CD (66.38°C). No significant differences occurred in center final temperatures that were attributable to treatment. Cooking procedures (p. 17) were planned so that the final temperature in the geometric center of all steaks would be approximately 65°C. Mean final center temperatures ranged from 64.13°C (MM) to 66.38°C (MD). The final temperature at the distal position was lower ($P < 0.05$) for steaks cooked by CD (65.88°C) than for those cooked by MD (73.75°C) or MM (69°C). Moreover, the final distal temperature for steaks cooked by MD (69°C) was higher ($P < 0.05$) than that for steaks cooked by CM (67.5°C) or MM (64.13°C), Table 8.

Differences between raw and cooked muscle

Percentage differences between values for selected characteristics of raw muscle and muscle subjected to each heat treatment were calculated; the data were not analyzed statistically. As expected, ether extract and total moisture values changed with each of the four cooking methods. Percentage ether extract increased from raw to cooked muscle: CD, +0.06; CM, +0.38; MD, +1.68; MM, +1.57; percentage total moisture decreased with all heat treatments: CD, -3.63; CM, -6.04; MD, -7.86; MM, -7.59. Microwave cookery changed the quantity of ether extract and total moisture in steaks more than did conventional cooking methods.

SUMMARY

Thirty-two beef top round steaks were cooked in conventional and microwave ovens equipped with rotary hearths by dry (modified roasting) and moist (oven film bag) heat to study 1) uniformity of doneness and 2) effects of four oven-heat treatment combinations on cooking losses, sensory characteristics and related objective measurements. Treatment

combinations studied were: conventional oven, dry heat (CD); conventional oven, moist heat (CM); microwave oven, dry heat (MD); microwave oven, moist heat (MM). Temperatures were recorded at the geometric center, and at positions 4.0 cm from the proximal and distal edges of each steak to study evenness of heating within a steak. The CM, MD and MM steaks were removed from the oven at a mean center temperature of 58°, 59° and 55°C, respectively, to achieve a final temperature of 65°C at the center of the steak. CD steaks were cooked to 65°C. Data for selected measurements were analyzed by a split plot or by a split, split plot analysis of variance.

Total cooking time, volatile cooking losses, total moisture and sensory juiciness and tenderness scores were greater ($P < 0.001$) for conventionally cooked steaks than for steaks cooked by microwaves. Total and drip cooking losses and ether extract were greater ($P < 0.001$ or 0.05) for steaks cooked by microwaves than for those cooked in the conventional oven. Cooking steaks in the microwave oven was four times faster than cooking in the conventional oven.

Total cooking time was greater ($P < 0.001$) for steaks cooked by dry heat than for steaks cooked by moist heat. Steaks cooked by moist heat had higher ($P < 0.001$) total and drip cooking losses than those cooked by dry heat. Sensory scores were not affected by type of heat.

Data for type of oven x type of heat interactions suggest: 1) moist heat reduces cooking time more for conventional cookery than for microwave cookery and 2) microwave cookery reduces cooking time more with dry heat than with moist heat when compared to conventional cooking by dry or moist heat. Interactions between type of oven and type of heat indicate that differences ($P < 0.05$) in total and drip cooking losses between dry and moist heat are attributable to the effect of the CD treatment. Significant differences ($P < 0.001$) in juiciness scores between steaks cooked in the conventional and microwave oven are attributable to the effect of dry heat.

Steaks designated as the outside position of the top round had more ($P < 0.05$) ether extract and lower ($P < 0.05$) juiciness and final tenderness scores than steaks designated as the inside position. No measurement was affected significantly by an interaction between type of oven and position in the round. For both positions in the round, drip cooking losses were greater ($P < 0.05$) for moist than for dry heat.

The effect of position within a steak on Warner-Bratzler shear and Gardner color-difference values and final internal temperatures were studied. Generally, less force was required to shear the center cores of steaks than to shear the proximal or distal cores.

Higher ($P < 0.05$) Gardner Rd (reflectance) values and lower ($P < 0.05$) a+ (redness) values for the end sections, except for steaks cooked by CD, than for the center section indicate that the end sections of steaks were more done than the center sections. A "ring" effect was observed in steaks, particularly for those cooked by CM, MD or MM; the outer circle of the steaks appeared well-done, whereas the inner portion was rare. Final temperature readings at three positions within a steak showed steaks cooked by CM, MD or MM heated unevenly with the temperature at the center of the steak being lower ($P < 0.05$) than that at the proximal or distal position. Those data and Gardner Rd and a+ values explain why the "ring" was observed in those steaks. Data for final temperatures also demonstrated that more even heating throughout a steak is achieved with CD than with CM, MD or MM treatments.

CONCLUSIONS

Under the conditions of this experiment, it was concluded that:

1) More even heating throughout a steak is achieved with CD than with CM, MD or MM treatments. The "ring" observed in steaks cooked by CM, MD or MM in which the outer circle appeared well-done, whereas the inner portion was rare results because the final temperature at the ends of steaks is significantly higher than that at the center.

2) Greater time savings are achieved with moist heat for conventional cookery than for microwave cookery when compared to cooking time with dry heat.

3) Compared to the cooking time of conventional cookery by dry or moist heat, greater time savings are achieved with microwave cookery by dry heat than by moist heat.

4) Position of steaks within the top round has little effect on cooking losses, sensory characteristics and the objective measurements studied.

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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	Texture	Initial Score	Tenderness (#of chews)	Final Score	Comments
A							
B							

Flavor

5 Intense beef flavor
4 Moderately intense beef flavor
3 Slightly intense 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.

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

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 texture

Mealiness is fragmentation of the meat resulting in tiny, dry 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.

Scoring for tenderness

Record a score describing your initial impression of tenderness at the beginning of the chewing process within a range of 5 to 1. Refer to the score card for descriptive terms for specific scores within the range of 5 to 1.

Count the number of times you chew the core of meat before swallowing. Chew until the core is masticated completely, then swallow. Record the number of chews required to masticate the core. Record a score from 5 to 1 that describes your impression of the tenderness of the core. 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 10-24 times, a score of 5; 25-34 times, a score of 4; 35-44 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.

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 9--Means and F-values for nonsignificant type of oven x type of heat interactions

Measurement	Type of oven	Type of heat: Dry	Type of heat: Moist	F-value
Initial weight, g	Conventional	572.25	605.50	0.428
	Microwave	563.13	571.88	
Thaw loss, %	Conventional	2.13	1.38	0.497
	Microwave	1.63	1.38	
Ether extract, %	Conventional	5.04	5.36	0.140
	Microwave	6.66	6.55	
Total moisture, %				
AOAC	Conventional	67.13	64.71	2.234
	Microwave	62.89	63.16	
Brabender	Conventional	65.14	63.43	3.384
	Microwave	61.71	62.05	
WHC[a]	Conventional	0.71	0.70	1.356
	Microwave	0.68	0.69	
pH	Conventional	5.49	5.52	0.003
	Microwave	5.50	5.53	
Sensory scores,[b]				
Flavor	Conventional	3.0	2.9	0.093
	Microwave	2.9	3.0	
Texture	Conventional	3.3	3.4	0.404
	Microwave	3.3	3.6	
Tenderness,				
Initial	Conventional	4.2	3.8	0.738
	Microwave	3.3	3.1	
Final	Conventional	4.5	4.3	0.977
	Microwave	3.9	3.9	

[a]Water-holding capacity-1.0 minus expressible-liquid-index; the larger the value, the greater the amount of liquid expressed.

[b]5-(intense beef flavor, mealy, tender) to 1-(no beef flavor, chewy, tough).

Table 10--Means and F-values for nonsignificant type of oven[a] x position in the round interactions

Measurement	Type of oven	Position in round: Inside	Outside	F-value
Initial weight, g	Conventional	604.13	573.63	3.955
	Microwave	620.00	515.00	
Thaw loss, %	Conventional	1.75	1.75	0.124
	Microwave	1.38	1.63	
Cooking time, min	Conventional	45.91	46.17	1.475
	Microwave	12.41	10.85	
Cooking losses, %				
Total	Conventional	23.90	24.16	0.214
	Microwave	29.24	30.22	
Drip	Conventional	11.23	12.75	0.878
	Microwave	20.64	19.96	
Volatile	Conventional	18.85	18.63	0.489
	Microwave	12.58	13.15	
Ether extract, %	Conventional	4.67	5.72	0.775
	Microwave	5.58	7.63	
Total moisture, %				
AOAC	Conventional	66.79	65.05	0.582
	Microwave	64.58	61.47	
Brabender	Conventional	64.55	64.01	2.107
	Microwave	62.96	60.80	
WHC[b]	Conventional	0.71	0.69	2.658
	Microwave	0.69	0.69	
pH	Conventional	5.48	5.53	0.441
	Microwave	5.51	5.52	
Shear value, kg/1.3-cm core	Conventional	2.80	3.07	1.566
	Microwave	3.57	3.25	

Table 10--(concluded)

Measurement	Type of oven	Position in round		F-value
		Inside	Outside	
Sensory scores,[c]				
Flavor	Conventional	3.1	2.8	3.068
	Microwave	2.8	3.1	
Juiciness	Conventional	3.5	3.3	0.129
	Microwave	2.7	2.4	
Texture	Conventional	3.5	3.1	3.640
	Microwave	3.3	3.6	
Tenderness,				
Initial	Conventional	4.2	3.8	0.169
	Microwave	3.3	3.1	
Final	Conventional	4.5	4.3	0.030
	Microwave	4.1	3.8	

[a]Dry and moist heat data combined.

[b]Water-holding capacity-1.0 minus expressible-liquid-index; the larger the value, the greater the amount of liquid expressed.

[c]5-(intense beef flavor, juicy, mealy, tender) to 1-(no beef flavor, dry, chewy, tough).

Table 11--Means and F-values for nonsignificant type of heat[a] x position in the round interactions

Measurement	Type of heat	Position in round: Inside	Outside	F-value
Initial weight, g	Dry	602.88	532.50	0.020
	Moist	621.25	556.13	
Thaw loss, %	Dry	1.88	1.88	0.124
	Moist	1.25	1.50	
Cooking time, min	Dry	34.08	34.26	1.216
	Moist	24.24	22.76	
Cooking losses, % Total	Dry	24.64	25.39	0.025
	Moist	28.50	29.00	
Ether extract, %	Dry	4.77	6.93	1.109
	Moist	5.48	6.43	
Total moisture, % AOAC	Dry	66.56	64.81	0.574
	Moist	63.46	63.06	
Brabender	Dry	64.41	62.44	1.248
	Moist	63.10	62.37	
WHC[c]	Dry	0.70	0.69	0.151
	Moist	0.70	0.69	
pH	Dry	5.50	5.49	1.718
	Moist	5.48	5.56	
Shear value, kg/1.3-cm core	Dry	3.09	2.76	1.880
	Moist	3.27	3.55	
Sensory scores,[c] Flavor	Dry	2.9	3.0	0.702
	Moist	3.0	2.9	
Juiciness	Dry	3.3	3.0	0.046
	Moist	2.9	2.7	

Table 11--(concluded)

Measurement	Type of heat	Position in round: Inside	Outside	F-value
Texture	Dry	3.3	3.3	0.228
	Moist	3.5	3.4	
Tenderness, Initial	Dry	3.9	3.6	0.001
	Moist	3.6	3.3	
Final	Dry	4.3	4.1	0.166
	Moist	4.3	4.0	

[a]Conventional and microwave oven data combined.

[b]Water-holding capacity-1.0 minus expressible-liquid-index; the larger the value, the greater the amount of liquid expressed.

[c]5-(intense beef flavor, juicy, mealy, tender) to 1-(no beef flavor, dry, chewy, tough).

Table 12--Means and F-values for nonsignificant treatment x position in the round interactions

Measurement	Treatment[a]	Position in round: Inside	Outside	F-value
Thaw loss, %	CD	2.00	2.25	1.117
	CM	1.50	1.25	
	MD	1.75	1.50	
	MM	1.00	1.75	
Cooking time, min	CD	54.05	56.44	3.059
	CM	37.78	35.90	
	MD	14.13	12.08	
	MM	10.70	9.63	
Cooking losses, % Total	CD	20.83	20.35	1.210
	CM	26.98	27.98	
	MD	28.45	30.43	
	MM	30.03	30.03	
Drip	CD	1.80	1.50	0.343
	CM	20.65	24.00	
	MD	20.30	16.43	
	MM	20.98	23.50	
Volatile	CD	18.85	18.63	0.489
	MD	12.58	13.15	
Ether extract, %	CD	4.68	5.40	2.690
	CM	4.66	6.05	
	MD	4.87	8.46	
	MM	6.29	6.81	
Total moisture, % AOAC	CD	67.73	66.52	1.837
	CM	65.85	63.58	
	MD	65.39	60.39	
	MM	63.77	62.55	

Table 12--(continued)

Measurement	Treatment[a]	Position in round		F-value
		Inside	Outside	
Brabender	CD	65.19	65.10	3.705
	CM	63.92	62.93	
	MD	63.64	59.78	
	MM	62.28	61.82	
WHC[b]	CD	0.71	0.70	3.189
	CM	0.71	0.68	
	MD	0.69	0.68	
	MM	0.68	0.70	
pH	CD	5.48	5.50	0.201
	CM	5.48	5.56	
	MD	5.53	5.47	
	MM	5.49	5.56	
Shear value, kg/1.3-cm core	CD	2.46	2.42	0.000
	CM	3.13	3.72	
	MD	3.72	3.11	
	MM	3.42	3.39	
Sensory scores,[c] Flavor	CD	3.0	3.0	2.320
	CM	3.3	2.6	
	MD	2.9	3.0	
	MM	2.8	3.2	
Juiciness	CD	3.9	3.8	0.588
	CM	3.1	2.7	
	MD	2.7	2.2	
	MM	2.7	2.6	
Texture	CD	3.4	3.2	0.101
	CM	3.6	3.1	
	MD	3.2	3.4	
	MM	3.5	3.7	

Table 12--(concluded)

Measurement	Treatment[a]	Position in round: Inside	Outside	F-value
Tenderness, Initial	CD	4.3	4.1	0.504
	CM	4.0	3.6	
	MD	3.4	3.1	
	MM	3.2	3.1	
Final	CD	4.6	4.4	0.761
	CM	4.5	4.1	
	MD	4.1	3.8	
	MM	4.1	3.9	

[a]CD-Conventional, dry; CM-Conventional, moist; MD-Microwave, dry; MM-Microwave, moist.

[b]Water-holding capacity-1.0 minus expressible-liquid-index; the larger the value, the greater the amount of liquid expressed.

[c]5-(intense beef flavor, juicy, mealy, tender) to 1-(no beef flavor, dry, chewy, tough).

Table 13--Initial weight, total cooking time and pH

Measurement	Heat treatments: Conventional Dry	Conventional Moist	Microwave Dry	Microwave Moist
Initial weight, g	573	513	517	570
	508	511	468	518
	562	689	506	618
	633	556	710	605
	653	595	490	578
	672	752	700	745
	502	616	481	474
	475	612	633	467
Mean	572.3	605.5	563.1	571.9
Total cooking time, min	52.80	37.83	13.00	10.25
	56.38	35.23	12.50	10.00
	57.07	41.70	12.50	11.30
	56.25	34.75	15.00	11.00
	52.63	30.60	11.00	9.00
	55.72	37.58	14.50	12.00
	57.40	34.00	12.33	8.50
	53.67	43.03	14.00	9.25
Mean	55.240	36.840	13.104	10.163
pH	5.52	5.50	5.40	5.44
	5.56	5.48	5.37	5.41
	5.48	5.51	5.48	5.48
	5.60	5.56	5.62	5.79
	5.42	5.68	5.41	5.56
	5.35	5.38	5.50	5.58
	5.50	5.51	5.62	5.48
	5.50	5.51	5.58	5.47
Mean	5.491	5.516	5.498	5.526

Table 14--Percentage total, drip and volatile cooking losses

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
Total	20.1	25.7	30.9	30.4
	23.6	30.3	30.8	31.7
	21.4	29.3	31.6	31.1
	17.5	30.0	27.0	32.7
	20.1	22.2	29.8	27.9
	19.2	27.4	25.9	25.4
	21.1	25.5	29.5	27.8
	21.7	29.4	30.0	33.2
Mean	20.59	27.48	29.44	30.03
Drip	1.4	20.9	17.8	22.5
	1.8	26.0	15.6	24.3
	1.6	25.1	18.2	24.3
	1.3	26.8	15.5	25.5
	2.5	18.5	17.1	22.0
	1.5	22.6	12.4	19.5
	1.4	14.0	14.8	22.2
	1.7	24.7	17.2	17.6
Mean	1.65	22.33	16.08	22.24
Volatile	18.3	---	12.8	---
	21.3	---	13.9	---
	19.6	---	12.8	---
	16.3	---	11.5	---
	17.9	---	11.6	---
	17.6	---	13.4	---
	19.3	---	14.3	---
	19.6	---	12.6	---
Mean	18.74	---	12.86	---

Table 15--Volume of drip, percentage of lipids and coagulum in drip, and ether extract

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
Volume of drip, ml	---	91	74	110
	---	123	64	111
	---	152	82	131
	---	138	94	136
	---	98	74	104
	---	153	72	132
	---	114	61	95
	---	140	94	110
Mean	---	126.1	76.9	116.1
Lipids in drip, %	---	1	3	3
	---	2	8	4
	---	3	5	4
	---	3	4	2
	---	4	4	4
	---	2	7	3
	---	3	8	3
	---	4	5	2
Mean	---	2.8	5.5	3.1
Coagulum in drip, %	---	9	41	8
	---	9	28	9
	---	21	70	24
	---	12	52	22
	---	13	51	37
	---	16	72	28
	---	6	25	9
	---	11	62	13
Mean	---	12.1	50.1	18.8

Table 15--(concluded)

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
Ether extract	3.41	5.29	8.31	6.92
	8.56	7.22	9.74	6.71
	5.88	6.50	8.75	7.25
	5.98	6.66	3.34	7.14
	4.26	5.26	3.84	5.39
	2.06	3.44	3.56	3.97
	4.98	3.42	11.50	8.00
	5.17	5.05	4.25	7.03
Mean	5.038	5.355	6.661	6.551

Table 16--Percentage total moisture and water-holding capacity (WHC)

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
Total moisture, % AOAC	73.90	67.23	61.64	62.17
	63.77	61.36	58.93	61.87
	65.27	62.23	59.47	62.88
	67.26	64.00	66.66	62.07
	65.90	66.39	63.72	64.17
	69.35	67.30	70.07	69.18
	65.71	66.65	59.43	62.10
	65.84	62.55	63.20	60.84
Mean	67.125	64.714	62.890	63.160
Total moisture, % Brabender	66.85	64.50	60.15	61.05
	62.80	60.53	58.50	61.20
	64.20	61.73	58.83	61.05
	65.30	62.15	65.55	61.20
	65.20	65.50	63.05	63.83
	66.65	63.75	65.45	65.70
	65.63	65.70	58.75	61.03
	64.50	63.55	63.40	61.30
Mean	65.141	63.426	61.710	62.045
WHC[a]	0.69	0.70	0.64	0.67
	0.72	0.67	0.68	0.70
	0.75	0.70	0.67	0.70
	0.71	0.74	0.71	0.72
	0.71	0.67	0.69	0.68
	0.68	0.72	0.73	0.67
	0.69	0.73	0.66	0.70
	0.70	0.63	0.68	0.68
Mean	0.706	0.695	0.683	0.690

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

Table 17--Warner-Bratzler shear values, kg/1.3-cm core

Heat treatment	Overall	Core position: Proximal	Center	Distal
Conventional, dry	2.47	2.39	2.54	2.48
	2.09	1.55	2.11	2.61
	2.75	3.43	2.13	2.68
	2.52	2.95	2.36	2.25
	2.58	3.41	2.34	2.00
	2.67	3.20	2.02	2.80
	2.38	2.36	2.36	2.43
	2.03	2.32	2.20	1.57
Mean	2.437	2.701	2.258	2.353
Conventional, moist	2.81	3.73	2.23	2.48
	2.83	2.39	2.42	3.68
	4.43	5.50	3.01	4.77
	2.91	2.89	2.27	3.57
	5.22	9.80	3.35	2.52
	2.18	1.34	2.52	2.68
	3.11	4.09	2.14	3.11
	3.92	4.59	2.52	4.66
Mean	3.427	4.291	2.558	3.434
Microwave, dry	3.12	3.93	2.58	2.86
	2.93	2.57	2.81	3.41
	2.87	4.36	2.16	1.93
	5.09	7.41	3.57	4.30
	3.28	5.27	2.73	1.84
	4.01	2.68	4.23	5.11
	3.39	3.34	2.59	4.25
	2.67	3.00	2.55	2.45
Mean	3.414	4.070	2.903	3.269

Table 17--(concluded)

Heat treatment	Overall	Core position		
		Proximal	Center	Distal
Microwave, moist	3.10	3.45	2.77	3.07
	3.86	3.89	4.55	3.14
	3.32	4.59	2.76	2.61
	3.53	4.11	2.74	3.75
	3.92	4.27	2.76	4.73
	4.36	5.75	1.91	5.41
	2.24	3.25	1.35	2.11
	2.89	5.05	1.95	1.66
Mean	3.401	4.295	2.599	3.310

Table 18--Sensory evaluation scores

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
Flavor[a]	2.3	3.9	3.4	2.1
	3.4	2.1	3.1	3.1
	2.5	3.0	2.6	2.8
	3.0	2.4	2.6	3.1
	3.6	2.5	3.0	3.4
	2.3	3.1	2.9	3.3
	3.4	3.1	3.3	3.0
	3.4	3.3	2.5	2.9
Mean	2.99	2.93	2.60	2.96
Juiciness[a]	3.8	3.9	2.3	2.4
	4.1	2.1	2.0	2.5
	3.6	2.3	2.1	1.8
	3.6	1.9	2.6	2.0
	3.9	3.6	1.7	3.0
	3.4	2.3	2.9	3.9
	4.0	3.8	2.9	2.9
	4.3	3.3	2.8	2.6
Mean	3.84	2.90	2.41	2.64
Texture[a]	3.0	3.3	3.1	3.7
	3.1	3.4	3.5	3.3
	3.3	3.4	3.6	3.0
	2.8	2.6	3.0	3.6
	3.9	3.0	3.7	3.8
	3.4	4.4	3.0	2.8
	3.3	3.3	2.9	4.0
	3.4	3.4	3.6	4.4
Mean	3.28	3.35	3.30	3.58

Table 18--(concluded)

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
Tenderness,[a] initial	4.5	4.6	2.8	2.9
	4.3	3.3	3.4	2.9
	3.4	3.3	3.6	2.6
	3.6	2.9	2.8	2.6
	4.6	3.9	2.6	3.0
	4.4	3.8	3.8	3.9
	4.0	4.3	2.8	3.9
	4.7	4.1	4.3	3.3
Mean	4.19	3.78	3.26	3.14
Tenderness,[a] final	4.8	4.4	3.4	3.7
	4.4	3.8	3.6	3.5
	3.8	4.1	4.1	4.0
	4.1	3.8	4.0	3.4
	4.9	4.3	3.7	4.1
	4.5	4.6	4.1	4.1
	4.7	4.8	3.8	4.4
	4.7	4.4	4.8	4.3
Mean	4.49	4.28	3.94	3.94

[a]5-(intense beef flavor, juicy, mealy, tender) to 1-(no beef flavor, dry, chewy, tough).

Table 19--Gardner color-difference values[a]

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
Rd (reflectance), center	18.40	19.10	20.60	20.80
	18.45	20.40	22.45	22.55
	18.90	18.80	20.95	19.05
	19.95	20.50	19.00	18.60
	22.20	20.30	22.80	21.80
	22.65	22.40	20.45	20.20
	20.05	20.35	21.10	20.60
	20.45	19.95	20.50	20.00
Mean	20.131	20.225	20.981	20.450
Rd (reflectance), end	17.55	20.00	21.85	21.35
	17.70	21.40	20.75	22.00
	18.85	19.70	21.90	19.55
	19.40	22.15	22.70	20.65
	21.75	22.20	24.10	22.25
	23.35	23.30	22.25	21.40
	19.45	20.70	20.60	21.90
	20.95	21.95	22.45	21.50
Mean	19.875	21.425	22.075	21.325
a+ (redness), center	8.80	5.95	3.75	4.95
	7.60	3.35	2.40	3.85
	8.60	4.70	2.80	5.85
	9.20	5.85	6.70	5.10
	5.85	9.50	2.80	6.05
	5.90	3.85	5.90	8.50
	7.60	5.55	2.45	5.90
	10.00	4.70	4.45	6.95
Mean	7.994	5.431	3.906	5.894

Table 19--(concluded)

	Heat treatments			
	Conventional		Microwave	
Measurement	Dry	Moist	Dry	Moist
a+ (redness), end	6.70	3.20	1.80	2.20
	5.25	2.10	1.10	2.45
	5.65	2.40	1.80	2.30
	7.25	1.45	2.70	2.30
	4.25	3.80	1.35	2.40
	3.85	1.85	2.35	2.80
	5.20	3.20	1.55	2.60
	6.60	2.10	1.80	4.20
Mean	5.594	2.513	1.806	2.656
b+ (yellowness), center	11.25	10.65	11.00	10.70
	11.10	10.35	11.20	10.80
	11.40	11.00	10.75	11.10
	11.90	10.90	11.80	10.80
	11.25	11.60	11.00	11.15
	11.75	11.10	11.10	11.45
	11.40	11.15	10.65	11.00
	11.35	11.05	11.10	10.80
Mean	11.425	10.975	11.075	10.975
b+ (yellowness), end	10.50	10.55	10.75	10.95
	10.35	10.70	10.60	10.55
	10.90	10.75	10.90	11.00
	11.20	11.00	11.60	10.55
	11.00	10.90	11.15	10.70
	11.40	10.90	10.80	10.90
	10.85	10.75	10.65	10.95
	11.10	10.95	10.75	10.90
Mean	10.913	10.813	10.900	10.813

[a]Calculated values for standard tile: (Rd) 37.8, (a+) 5.8, (b+) 15.2.

Table 20--Initial, endpoint, and post-oven temperatures of steaks cooked in the conventional oven

Heat treatment	Temperature, °C								
	Initial			Removed from oven			Post-oven		
	proximal	center	distal	proximal	center	distal	proximal	center	distal
Conventional, dry	5	5	4	66	65	64	---	---	---
	4	4	4	67	65	67	---	---	---
	6	7	5	68	65	67	---	---	---
	4	4	4	67	65	67	---	---	---
	5	5	5	65	65	65	---	---	---
	6	6	6	66	65	65	---	---	---
	3	3	3	66	65	65	---	---	---
	6	5	4	66	65	67	---	---	---
Mean	4.9	4.9	4.4	66.4	65.0	65.9	---	---	---
Conventional, moist	5	6	6	63	61	67	68	66	68
	7	6	5	72	60	60	75	68	67
	2	2	1	71	62	64	67	68	66
	1	1	3	62	59	62	71	67	69
	6	2	3	60	55	60	68	64	68
	6	6	6	67	57	58	72	65	66
	5	5	5	64	57	62	69	65	66
	1	1	1	78	58	63	74	67	70
Mean	4.1	3.6	3.8	67.1	58.6	62.0	70.5	66.3	67.5

Table 21--Initial, endpoint, and post-oven temperatures of steaks cooked in the microwave oven

Heat treatment	Temperature, °C								
	Initial			Removed from oven			Post-oven		
	proximal	center	distal	proximal	center	distal	proximal	center	distal
Microwave, dry	7	7	7	66	62	65	71	68	75
	4	4	5	76	60	78	74	69	76
	4	4	4	68	55	79	73	68	79
	4	4	4	71	56	74	72	65	76
	6	6	6	54	57	59	71	64	69
	5	5	5	75	55	62	68	64	67
	5	4	4	87	57	65	71	67	73
	1	1	1	67	58	66	76	66	75
Mean	4.5	4.4	4.5	70.5	57.5	68.5	72.0	66.4	73.8
Microwave, moist	8	8	8	60	56	69	73	63	70
	5	5	6	48	54	57	67	66	71
	5	5	5	59	54	62	72	64	72
	4	4	6	81	55	62	72	65	72
	10	10	10	67	57	55	67	64	62
	6	6	7	67	56	50	72	63	67
	4	3	4	59	55	65	63	65	67
	5	5	5	62	55	62	72	63	71
Mean	5.9	5.8	6.4	62.9	55.3	60.3	69.8	64.1	69.0

Table 22-Mean squares of initial weight, thaw loss, cooking time, ether extract, pH and over-all shear data

Source of variation	D/F	Initial weight	Thaw loss	Cooking time	Ether extract	pH	Shear, over-all
Round	3	29631.21	2.25**	6.13	14.22	0.01669	3.033
Position in round (a)	1	36720.50	0.13	3.37	19.28*	0.00690	0.014
Error (A)	3	3850.42	0.04	12.49	1.69	0.00329	2.489
Type of oven (b)	1	3655.13	0.50	9470.64***	15.90*	0.00053	5.420
Type of heat (c)	1	3528.00	2.00	910.90***	0.09	0.00578	5.738
Interactions (bxc)	1	1200.50	0.50	477.95***	0.37	0.00003	6.035*
(axb)	1	11100.50	0.13	6.62	2.02	0.00428	2.133
(axc)	1	55.13	0.13	5.45	2.89	0.01665	2.230
(axbxc)	1	17020.13*	1.13	13.72	7.01	0.00195	0.002
Error (B)	18	2806.67	1.01	4.48	2.61	0.00970	1.361

***P < 0.001; **P < 0.01; *P < 0.05.

Table 23-Mean squares of total and drip cooking losses, total moisture and water-holding capacity data

		Cooking losses		Total moisture		
Source of variation	D/F	Total	Drip	AOAC	Brabender	WHC
Round	3	16.93*	14.77	23.37	13.09	0.00147
Position in round (a)	1	3.13	1.44	47.07	14.55	0.00090
Error (A)	3	3.22	19.32	5.25	1.51	0.00093
Type of oven (b)	1	259.92***	552.78***	67.02***	46.32***	0.00165
Type of heat (c)	1	111.75***	1205.40***	9.17	3.81	0.00003
Interactions (bxc)	1	79.38***	564.48***	14.38	8.40	0.00070
(axb)	1	1.05	9.68	3.75	5.23	0.00138
(axc)	1	0.13	50.50*	3.69	3.12	0.00008
(axbxc)	1	5.95	3.78	11.82	9.20	0.00165
Error (B)	18	4.92	11.03	6.44	2.48	0.00052

***P < 0.001; *P < 0.05.

Table 24-Mean squares of sensory data

					Tenderness	
Source of variation	D/F	Flavor	Juiciness	Texture	Initial	Final
Round	3	0.1892	1.0061*	0.2475	1.0078	0.6103**
Position in round (a)	1	0.0050	0.5253*	0.0450	0.5778	0.4753*
Error (A)	3	0.1708	0.0428	0.0392	0.1928	0.0145
Type of oven (b)	1	0.0013	5.6953***	0.1250	4.8828***	1.5753***
Type of heat (c)	1	0.0013	1.0153	0.2450	0.5778	0.0903
Interactions (bxc)	1	0.0200	2.7028*	0.0800	0.1653	0.0903
(axb)	1	0.6613	0.0028	0.7200	0.0378	0.0028
(axc)	1	0.1513	0.0153	0.0450	0.0003	0.0153
(axbxc)	1	0.5000	0.1953	0.0200	0.1128	0.0703
Error (B)	18	0.2156	0.3323	0.1978	0.2239	0.0924

***P < 0.001; **P < 0.01; *P < 0.05.

Table 25-Mean sqaures of volatile cooking losses, volume of drip and percentage of lipids and coagulum in drip

Source of variation	D/F	Volatile loss	Source of variation	D/F	Volume of drip	Lipid	Coagulum
Round	3	2.72	Round	3	769.48	0.71	511.44*
Position in round (a)	1	0.12	Position in round (a)	1	425.05	5.04	130.67
Error (A)	3	2.22	Error (A)	3	303.60	2.49	51.67
Type of oven (b)	1	138.06***	Treatment (b)	2	5421.50**	17.79**	3296.37***
Interaction (axb)	1	0.64	Interaction (axb)	2	56.17	0.79	114.29
Error (B)	6	1.31	Error (B)	12	232.00	1.85	93.56

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.

Table 26-Mean squares of Warner-Bratzler shear and Gardner color-difference values

Source of variation	D/F	Warner-Bratzler shear	D/F	Gardner color-difference Rd (reflectance)	a+ (redness)	b+ (yellowness)
Round	3	3.0335	3	13.0719*	1.2083	0.4830
Position in round (a)	1	0.0143	1	4.9505	8.0869	0.0351
Error (A)	3	2.4892	3	0.9653	1.6584	0.0794
Treatment (b)	3	5.7309*	3	6.2559	43.5977***	0.2689
Interaction (axb)	3	1.4550	3	0.2212	8.0869	0.1443
Error (B)	18	1.3613	18	2.1998	2.7798	0.0885
Position in steak (c)	2	12.8555***	1	8.4825***	112.4918***	1.0251***
Interactions (axc)	2	0.0232	1	0.5625	0.9628	0.0002
(bxc)	6	0.7500	3	1.7959**	1.0798	0.1197**
(axbxc)	6	0.6723	3	1.6342**	1.5874	0.0385
Error (C)	48	1.3059	24	0.3495	0.5295	0.0366

***P < 0.001; **P < 0.01; *P < 0.05.

Table 27-Mean squares of initial, removal from oven and post-oven temperature data

Source of variation	D/F	Initial	Removal from oven	D/F	Post-oven
Round	3	37.2499	67.3430	3	38.1665
Position in round (a)	1	7.0417	3.7606	1	2.0001
Error (A)	3	5.7361	20.8155	3	6.7778
Treatment (b)	3	19.9166	208.8962**	2	66.4317**
Interaction (axb)	3	4.2361	3.6493	2	20.7915
Error (B)	18	6.7893	33.2465	12	6.2778
Position in steak (c)	2	0.2813	481.7913***	2	189.5557***
Interactions (axc)	2	1.0104	6.1667	2	4.1666
(bxc)	6	0.6146	60.2221	4	21.0139**
(axbxc)	6	0.3715	4.0972	4	11.0833*
Error (C)	48	0.3507	29.3093	36	4.0786

***P < 0.001; **P < 0.01; *P < 0.05.

TOP ROUND STEAKS COOKED IN CONVENTIONAL OR MICROWAVE OVENS BY DRY OR MOIST HEAT

by

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ABSTRACT

The sale of portable microwave ovens is rising rapidly. One of the greatest advantages of microwave cooking is its timesaving factor. With the microwave oven, cooking time of meat is four to five times faster than that of conventional cooking. Early research showed that meat cooked in microwave ovens had greater cooking losses and was less palatable than that cooked in conventional ovens. However, some recent research has demonstrated that meat cooked by microwaves can compare favorably in flavor, juiciness and tenderness with conventionally cooked meat.

Thirty-two beef top round steaks were cooked in conventional and microwave ovens equipped with rotary hearths by dry (modified roasting) and moist (oven film bag) heat to study the effects of four oven-heat treatment combinations on cooking losses, sensory characteristics and related objective measurements. Treatment combinations studied were: conventional oven, dry heat (CD); conventional oven, moist heat (CM); microwave oven, dry heat (MD); microwave oven, moist heat (MM). Temperatures were recorded at the geometric center, and at positions 4.0 cm from the proximal and distal edges of each steak to study evenness of heating within a steak. The CM, MD and MM steaks were removed from the oven at a mean center temperature of 58°, 59° and 55°C, respectively, to achieve a final temperature of 65°C at the center of the steak. Data for selected measurements were analyzed by a split plot or by a split, split plot analysis of variance.

Total cooking time, volatile cooking losses, total moisture and sensory juiciness and tenderness scores were greater ($P < 0.001$) for

conventionally cooked steaks than for steaks cooked by microwaves. Total and drip cooking losses and ether extract were greater ($P < 0.001$ or 0.05) for steaks cooked by microwaves than for those cooked in the conventional oven. Cooking steaks in the microwave oven was four times faster than cooking in the conventional oven.

Total cooking time was greater ($P < 0.001$) for steaks cooked by dry heat than for steaks cooked by moist heat. Steaks cooked by moist heat had higher ($P < 0.001$) total and drip cooking losses than those cooked by dry heat. Sensory scores were not affected by type of heat.

Data for type of oven x type of heat interactions suggest: 1) moist heat reduces cooking time more for conventional cookery than for microwave cookery and 2) microwave cookery reduces cooking time more with dry heat than with moist heat when compared to conventional cooking by dry or moist heat. Interactions between type of oven and type of heat indicate that differences ($P < 0.05$) in total and drip cooking losses between dry and moist heat are attributable to the effect of the CD treatment. Significant differences ($P < 0.001$) in juiciness scores between steaks cooked in the conventional and microwave oven are attributable to the effect of dry heat.

Steaks designated as the outside position of the top round had more ($P < 0.05$) ether extract and lower ($P < 0.05$) juiciness and final tenderness scores than steaks designated as the inside position. No measurement was affected significantly by an interaction between type of oven and position in the round. For both positions in the round, drip cooking losses were greater ($P < 0.05$) for moist than for dry heat.

The effect of position within a steak on Warner-Bratzler shear and Gardner color-difference values and final internal temperatures were studied. Generally, less force was required to shear the center cores of steaks than to shear the proximal or distal cores.

Higher ($P < 0.05$) Gardner Rd (reflectance) values and lower ($P < 0.05$) a+ (redness) values for the end sections, except for steaks cooked by CD, than for the center sections indicate that the end sections of steaks were more done than the center sections. A "ring" effect was observed in steaks, particularly for those cooked by CM, MD or MM; the outer circle of the steaks appeared well-done, whereas the inner portion was rare. Final temperature readings at three positions within a steak showed steaks cooked by CM, MD or MM heated unevenly with the temperature at the center of the steak being lower ($P < 0.05$) than that at the proximal or distal position. Those data and Gardner Rd and a+ values explain why the "ring" was observed in those steaks. Data for final temperatures also demonstrated that more even heating throughout a steak is achieved with CD than with CM, MD or MM treatments.