DIFFERENCES BETWEEN CONVENTIONALLY COOKED TOP ROUND ROASTS AND SEMIMEMBRANOSUS MUSCLE STRIPS COOKED IN A MODEL SYSTEM

by

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B.S., Virginia Polytechnic Institute & State University, 1975

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1981

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INTRODUCTION

Information on the characteristics of cooked meat is an important part of studies concerned with effects of production and processing treatments. Selecting a cooking (heating) method for samples from carcasses that have undergone different treatments is an important part of planning and conducting such research. Traditionally, roasts, steaks, or chops were cooked by conventional methods; also, model systems have been used to heat small pieces of meat in a water bath.

Machlik and Draudt (1963) stated that small samples are necessary to obtain conclusive information on effects of heating, because, in a roast, there is large variation in the time-temperature combinations from the surface to the center of the meat. Some investigators (Marsh et al., 1966; Howard and Judge, 1968; Laakkonen et al., 1970; Bouton et al., 1971) heated slices of muscle in sealed plastic bags; others (Machlik and Draudt, 1963; Paul et al., 1973; Penfield and Meyer, 1975; Penfield et al., 1976; Hearne et al., 1978 a, b; Brady and Penfield, 1981) used cores or strips of meat that were heated in test tubes in a water bath.

Precise time-temperature control was attempted in some model systems with the tacit assumption that if meat is cooked at the heat penetration rate that occurs with conventional methods, the "quality" characteristics of the meat would be the same as those of meat cooked by conventional methods. Researchers should know whether there are significant effects on the meat that are attributable to the method of heating (model system vs conventional cooking methods).

The only study found that compared meat cooked in a model system to meat cooked by conventional methods was that of Brady and Penfield (1981). They studied the effect of the heating system on the textural characteristics of beef and on solubilization of hydroxyproline for two end point temperatures at two rates of heating, but did no sensory evaluation. The slower rate of heating in the water bath resulted in greater total cooking losses and a higher percentage of hydroxyproline solubilized than was obtained with the conventional method, but no differences were found in those measurements with the fast heating rate. No differences between the model system and the conventional method were found with either heating rate in texture measurements of hardness, cohesiveness, chewiness, shear cohesiveness and shear firmness. They concluded that the method of heating had some influence on the final quality of the meat.

Also, with continual increase in the cost of producing and processing meat, researchers need to find economical, yet still reliable methods for conducting their experiments. One way of reducing the high cost of materials for meat cookery research is through the use of model systems.

In this study, top round roasts cooked by conventional methods (dry or moist heat) were compared to semimembranosus muscle strips cooked in test tubes in a water bath. In two experiments, data were collected for sensory characteristics, related objective measurements, and cooking losses.

REVIEW OF LITERATURE

Descriptions of some model systems used in meat research

To determine the effect of heating time and temperature on the shear value of beef semitendinosus muscle, Machlik and Draudt (1963) heated cores of muscle 1.3 cm in diameter by 5.1 cm long in test tubes covered with beakers in a constant temperature water bath at temperatures ranging from 50°-70° C for two hours and at temperatures of 70°-90°C for five hours. Small cores of meat were used to insure a rapid and uniform rise in temperature throughout the meat. Temperature of the cores came to within 10°C of the water bath temperature in 3.5 minutes and within 1°C of the bath temperature in 7 minutes after being placed in the water bath. They suggested that variation in tenderness due to cooking time-temperature differences in experimental meat cookery could be minimized by immersing samples in a plastic bag in a water bath held at 64°C for sufficient time to insure that the temperature of the slowest heating portion is held in the 60°-64°C range for one half hour or more.

To assess the correlation between sensory and objective measurements of tenderness in meat, Marsh et al. (1966) developed a model system for cooking small samples (80-200g) that simulated the time-temperature relationship of a roasting treatment. Samples of beef sternomandibularis muscle were put in polyethylene bags that were vacuum shrunk on the samples and sealed. The bags of samples were immersed in an 8-liter cylindrical glass tank and equilibrated for one hour at 30°C. The thermostat was raised to 80°C and the samples were removed one hour later, by which time the internal temperature of the meat reached 80°C. They recommended this "simple, reproducible procedure ... for any small scale cooking".

Howard and Judge (1968) compared sarcomere length to other predictors of beef tenderness using longissimus dorsi muscle.

Samples used for measuring shear values were sliced 5.1 cm thick, cut parallel to muscle fibers. Each slice was divided into medial and lateral halves and placed in a cryovac bag. After the thermocouple was inserted into the center of each sample, the bag was evacuated, sealed, and placed in a constant temperature water bath (60°, 64°, 68° or 72°C). The samples remained in the water bath 12 minutes after the internal temperature of the sample reached 1°C less than the bath temperature. Then, the samples were chilled at 4°C for 24 hours.

Laakkonen et al. (1970) used a model system to study the relationship between tenderness and water-holding copacity, pH, or water soluble components in beef cooked at low temperatures for long periods of time. They found that the center of a 15.7-kg round roast cooked in a 121°C institutional gas oven, increased in temperature at a rate of 0.1°C/min. They put vacuum sealed cryovac bags containing 2.5-cm slices (100-130g) of beef longissimus dorsi, rectus femoris, or semitendinosus muscle in a 30°C water bath. The temperature of the bath was increased at a rate of 0.1°C/min until it reached 60°C. The samples were held at 60°C for 10 hours. The control samples were tempered in a water bath at 30°C, heated to 80°C in one hour, and held at 80°C for one hour, a procedure similar to that used by Marsh et al. (1966).

Bouton et al. (1971) placed 130-g samples of ovine semimembranosus or biceps femoris muscle in polyethylene bags that were tightened around the samples with clips. The samples were immersed in a constant temperature water bath at 65° or 90°C for one hour. Because samples were about equal in weight, it was assumed that the time taken for any individual sample to reach the temperature of the bath was "sensibly constant".

To study the heat-induced changes in extractibility of collagen in beef, Paul et al. (1973) cut semitendinosus and biceps femoris muscle into strips 2x2x7 cm, with fibers running the length of the strip. Each strip was put in a 22-mm test tube with a thermocouple inserted lengthwise into the center of the strip. The tubes were put in a water bath programmed to reproduce a published time-temperature curve for a semitendinosus roast cooked in a 163°C oven. Samples were removed from the water bath and allowed to cool when the internal temperature was 58°, 67°, 75°, or 82°C.

In several studies (Penfield and Meyer, 1975; Penfield et al., 1976; Hearne et al., 1978a, b; and Brady and Penfield, 1981) researchers used a model system in which cores of beef semitendinosus muscle (2.5 cm in diameter x 5.7 cm long, with muscle fibers parallel to the length of the core) were heated in 50-ml glass tubes in a water bath. The temperature of one core of muscle was monitored by a thermocouple inserted lengthwise into the center of the core. The temperature control of the water bath was adjusted every 8 minutes so that the internal temperature of the monitored core approximated previously obtained heat penetration curves of 2-kg top round roasts oven roasted at 93° or 149°C.

Some model systems used slices of meat sealed in plastic bags; others used strips or cores of meat in test tubes. The rate of heat penetration was controlled to imitate conventional rates in some studies, whereas in others, the meat was heated as fast as possible to a certain end point, then held at that temperature for a specific time. Although details of the model systems varied, in all model systems, small pieces of meat were heated in a water bath.

Texture profile analysis of food

In her pioneering work on textural characteristics of food, Szczesniak (1963) defined primary measurements of hardness, cohesiveness, elasticity, adhesiveness, and viscosity and secondary measurements of brittleness, gumminess and chewiness. Those terms can be applied to both objective and sensory texture profile analysis (TPA). Friedman et al. (1963) used those basic terms to describe physical measurement of foods using the General Foods (GF) Texturometer in which a plunger was driven into the sample twice and the two cycles ("bites") were recorded on a strip chart. Szczesniak et al. (1963) described sensory texture profile analysis using a trained taste panel. Following are the basic definitions for each textural characteristic (Szczesniak, 1963) and the definitions as applied to objective measurement (Friedman et al., 1963) and to sensory measurement (Szczesniak et al., 1963).

"Hardness" was defined as the force required to obtain a given deformation. It was measured with the GF Texturometer as the peak height of the first bite. Organoleptically, hardness was the force required to penetrate a solid or semisolid substance with molar teeth.

"Cohesiveness" was defined as the strength of internal bonds making up the body of the product. Objectively, it was measured as the ratio of the area under the second curve to the area under the first curve on the strip chart. With sensory measurement, cohesiveness could not be perceived by itself.

"Elasticity" was described as the ratio at which a deformed material goes back to its original condition when force is removed. For objective measurement using the GF Texturometer, elasticity was specified as C - B, where B was the horizontal distance on the strip chart from the origin of the first curve to the origin of the second curve, and C was the same measurement on a completely inelastic material such as clay. Organoleptically, elasticity could not be measured directly.

"Adhesiveness" was defined as the work necessary to overcome attractive forces between the surface of the food and other surfaces. Objectively, it was measured as the area of the negative curve on the strip chart between the first and second bites, representing the work required to pull the plunger from the sample. With sensory measurement, it was considered the force required to remove the material that adheres to the mouth (generally the palate) during normal eating.

"Viscosity" was defined as the rate of flow per unit force. Using the GF Texturometer with the viscosity attachment (paddle and cup) it was recorded as a series of sinusoidal curves. In sensory TPA, it was specified as the force required to draw a liquid from a spoon over the tongue.

"Brittleness" was designated as the force with which a material fractures. Brittleness was related to hardness and cohesiveness; in brittle foods cohesiveness is low. Objectively, brittleness is measured as the height of the first significant break in the peak of a multipeak first curve. Organoleptically, brittleness is the force with which a sample crumbles, cracks or shatters. Brittleness and adhesiveness are not found in the same food product.

"Gumminess" was defined as the energy required to disintegrate a semisolid food to a state ready for swallowing. It was related to hardness and cohesiveness, with hardness being low in a semisolid food. With the GF Texturometer, gumminess was defined as the mathematical product of hardness x cohesiveness, multiplied by 100 to eliminate decimals. Organoleptically, it was interpreted as the deneseness present in semisolid foods that persists throughout mastication.

"Chewiness" was specified as the energy required to masticate a solid food to a state ready for swallowing. Objectively, chewiness was designated as the product of hardness x cohesiveness x elasticity. For sensory TPA, chewiness was defined as the length of time in seconds (one chew/second) required to masticate the sample until it was ready for swallowing.

Bourne (1968) was the first to use the Instron Universal Testing Machine for TPA of food. The Instron has largely replaced the Texturometer in textural analysis of foods (Breene, 1975). The GF Texturometer is driven by an eccentric, so the speed of the plunger moves in a sinusoidal pattern, but the strip chart speed is constant. This produces a force-time (stress-time) curve. The crosshead speed and chart speed on the Instron are constant and are driven synchronously. This produces a force-distance (stress-strain) curve. Because work is a force-distance integral, the area under the curve of the Instron is a true measure of work (Bourne, 1968). Mastication can be adequately described by a sinusoidal pattern, although the first bite to the point of maximum force is linear (Shama and Sherman, 1973). The rate at which force is applied in the mouth varies with the food; teeth move more slowly with hard foods. Because force varies with crosshead speed, different instrumental conditions are necessary with different foods if mastication patterns are to be simulated (Shama and Sherman, 1973).

Bourne's (1968) definitions for hardness, brittleness, gumminess, chewiness, and cohesiveness were similar to those of Friedman et al. (1963), except that he measured only the work attributable to compression in areas under the curves. Areas were defined by the upward sweep of the curve, the perpendicular line drawn from the peak to the baseline, and along the baseline to the origin. Because elasticity can be measured directly with the Instron, Bourne (1968) defined it as the horizontal distance from the origin of the second curve to the perpendicular dropped from the peak. He did not measure adhesiveness or viscosity.

Bouton et al. (1971) used a Warner-Bratzler shear attachment for the Instron to shear rectangular pieces of meat 0.66 x 1.5 cm, shearing perpendicular to the meat fibers. The mean of the peak shear force was used as an estimate of tenderness. A 0.63-cm diameter flat-ended cylindrical plunger was driven vertically 80% of the way through a 1.3-cm thick sample of meat with the meat fibers perpendicular to the direction of penetration. The plunger was driven into the meat twice at each location. Hardness and cohesiveness were defined according to Friedman et al. (1963). Chewiness was defined as the product of hardness x cohesiveness. Bouton et al. (1971) reported that in a private communication with Harris et al. (undated), sensory scores for tenderness were correlated highly with Instron measurements. Hardness was correlated highly (r=0.88) with initial impression of tenderness, whereas chewiness was correlated highly (r=0.90) with residual impression of tenderness. Bouton et al. (1971) reported correlation coefficients of r=0.80-0.86 between taste panel tenderness scores and Warner-Bratzler shear values or Instron hardness values. Larmond and Petrosavits (1972) investigated an alternative to correlation coefficients to study relationships between objective and sensory measurements of tenderness. Because the Warner-Bratzler shearing device deforms a sample of meat before the actual shearing begins, the first part of the curve produced represents compression and indicates the force required to produce a given deformation. They considered that deformation as a measure of firmness from a sensory point of view. "Firmness" was defined as the slope of the line from the origin to the peak of the curve and was recorded as g/sec. The peak force during shearing indicates rupturing of the sample and provides an index of cohesiveness. "Shear cohesiveness" was defined as the peak height in the shear deformation curve and was reported in grams. Larmond and Petrosavits (1972) found the sensory panel was influenced more by cohesiveness (height of the curve) than by firmness (slope of the curve) in determining the tenderness of meat.

In his review article on the application of texture profile analysis, Breene (1975) pointed out the lack of uniformity in reported conditions for obtaining GF TPA measurements. For example, the size of the compressing unit relative to sample size has varied, which must affect results. When the compression unit is larger than the sample, the force is mainly from compression, but when the compression unit is smaller than the sample, the force is from compression, shear, and flow. Breene (1975) observed that 75-80% deformation has been used by most workers for compression measurements, but crosshead speeds varied greatly. Some research has indicated that as the crosshead speed increased, the force required to achieve a given deformation increased (Shama and Sherman, 1973). Chart speed would not affect measurements of hardness, brittleness, or cohesiveness, but could affect the precision of elasticity measurements. Breene (1975) stressed that crosshead and chart speed must be specified for data to be meaningful and reproducible.

Some workers have been critical of measurement names and have substituted other terms. Breene (1975) suggested that a nomenclature committee be formed to establish and communicate standard terminology. He concluded that although instrumental TPA is not standardized, the usefulness and validity of multiple point food texture evaluation is not diminished.

MATERIALS AND METHODS

Twelve USDA Choice grade top rounds (approximately 9 kg), four for Expt. I and eight for Expt. II, were purchased, one at a time, from a local wholesale meat company. The outside fat covering was removed from each top round and the semimembranosus (SM) and adductor (AD) muscles were taken off in one piece and cut into three sections: two roasts and one section that was cut into strips (Fig. 1).

One roast was primarily AD muscle with some SM muscle, and the other roast was SM muscle. Roasts weighed 1.2-1.5 kg and the dimensions in cm were: length, 12-15; width, 10-14; depth, 4.5-9.5. Roasts were wrapped in medium weight aluminum foil, frozen at -25°C in an upright household freezer, and held until used (within 5 to 7 days).

The SM portion of the remaining section was partially frozen, then cut into strips, 2 x 2.3 x 7 cm, with the muscle fibers running the length of the strip. Individual strips were wrapped tightly in household plastic wrap to make them cyclindrical in shape. The group of strips from each round was wrapped in aluminum foil, frozen at -25°C, and stored until used (within 5 to 7 days).

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Fig. 1 - Sampling plan for beef top round (SM and AD muscles)

A- section to be cut into 2 x 2.3 x 7 cm strips (shown at left)

B- Muscle cut into two roasts of similar shape and weight (ca. 1.4 kg)

Remainder discarded.

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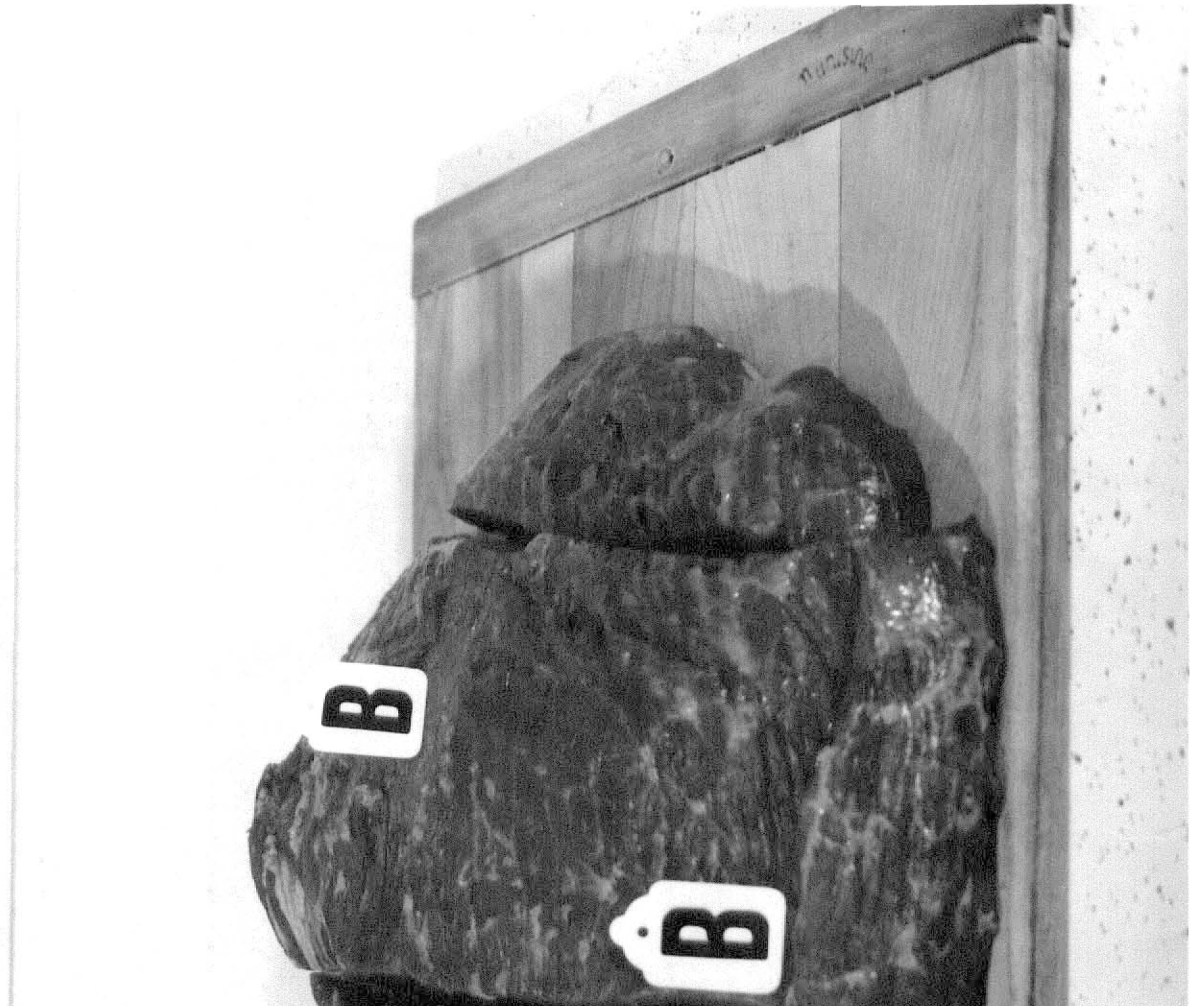
B
B
A

Heating

At the time of heating, the strips, eight for Expt. I and 10-11 for Expt. II, were unwrapped, thawed for 20-30 minutes at approximately 25°C, and put into 50 ml centrifuge tubes with a thermocouple inserted lengthwise into the center of each strip. The tubes were placed in an 18-liter circulating water bath (Fig. 2), and the bath temperature of the strips reproduced an average heating curve similar to that of a 1.2-1.4 kg top round roast cooked by dry heat in a 177°C oven. To accomplish this, the strips were tempered in 10°C water for 15 minutes, then the thermostat on the water bath was set at 100°C and the strips were heated for a total of 80-85 minutes. The temperature of the bath rose at a rate of 1°C/minute until about 45°-50°C, then rose at a rate of about 0.6°C/minute.

Roasts were defrosted at approximately 25°C for four hours, then at 4°C overnight. In Expt. I, roasts were cooked by dry heat oven roasting (OR); in Expt. II, they were cooked by OR or by moist heat in an oven film bag (OFB). A thermometer was inserted into the geometrical center of each roast, which was placed on a low rack in a shallow roasting pan. The oven film bag, which was closed with a twister tie, had 6 slits about 2 cm long over the top of the roast to allow steam to escape. All roasts were cooked in a rotary hearth electric oven at 177°C to an end point of 60°C. Roasts were sampled by a fixed position plan (Fig. 3).

Analysis of data

In Expt. I, the experimental design was a randomized complete block with subsampling, for two treatments and four replications.

Fig. 2 - Model system, left to right, centrifuge tubes in rack, 18-liter circulating water bath, muscle strips with thermocouples inserted into the center of six strips in centrifuge tubes in rack, recording potentiometer connected to thermocouples.


18 LITER
MODEL SYSTEM

Fig. 3 - Sampling plan for OR or OFB roasts (Expt. I and II)
Roasts were turned so that muscle fibers were oriented parallel to length of apparent doneness cores.

1 - Sensory cubes (1.3 cm)

2 - 2.5-cm apparent doneness core

3 - Instron sample

4 - Slice ground for HunterLab color measurement (Expt. II)

5 - Water-holding capacity

6 + remainder of 1, 3, and 4 - ground for pH, total moisture, and ether extract

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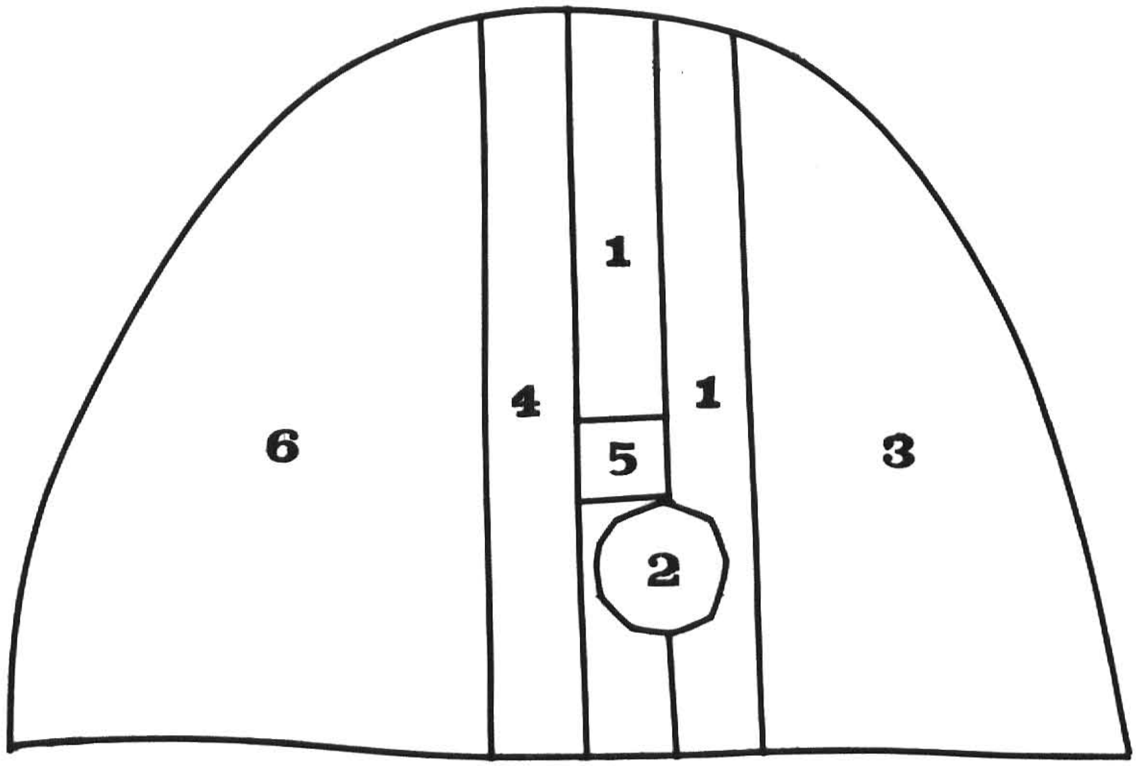
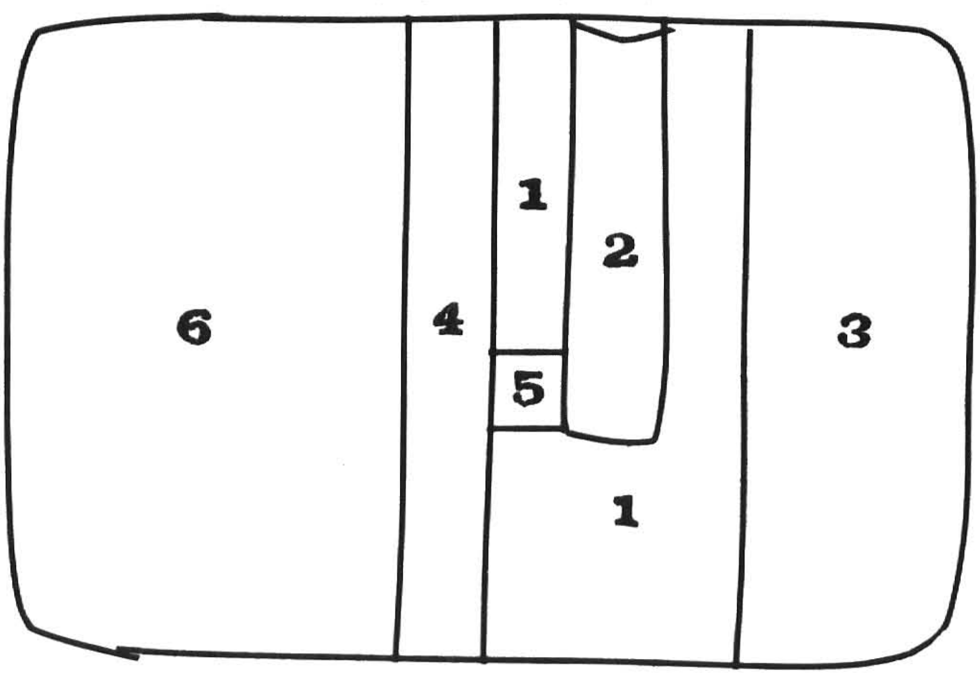
TOP VIEW



SIDE VIEW



Rounds were the blocks with two roasts within each round being subsampled. Data for each measurement were analyzed by the following analysis of variance:

Source of variation	D/F
Treatment	1
Rounds	3
Roasts/rounds	4
Error	7
Total	15

Because no significant differences were found between roasts within rounds, the subsampling data were pooled and the following randomized complete block design was used for analysis of variance:

Source of variation	D/F
Treatment	1
Rounds	3
Error	11
Total	15

In Expt. II, the experimental design was a randomized complete block for three treatments with eight replications, with rounds being blocked. Data for each measurement were analyzed by the following analysis of variance:

Source of variation	D/F
Treatment	2
Rounds	7
Error	14
Total	23

Correlation coefficients were used to study relationships between selected measurements. Sample variances were calculated to study variation among data for each conventional method of heating and for the model system.

Rate of heat penetration, cooking time, and cooking losses

The rate heat penetrated roasts was recorded as the time in minutes required for the internal temperature to reach 0°C and for each 5°C increase between 0° and 60°C. Cooking time was recorded as total minutes and as minutes cooking time between 0° and 60° after the temperature rose above 0°C. Percentages of total, volatile and drip losses based on precooked weights of the roasts or strips were calculated.

Sensory evaluation

Tenderness, juiciness, rare beef flavor, and apparent doneness were evaluated by a laboratory panel of 8-9 members, using an intensity scale of 5-1 (Forms IA, IB, and II; Appendix, pg. 46). Panelists first assessed the apparent doneness of a sliced strip and a sliced 2.5-cm core from a roast under a MacBeth Super Skylight, northern daylight setting. Panelists then selected randomly two samples of meat (1.3-cm cubes) from each treatment held over hot water in double boilers set on a warming tray held at approximately 35°C. The samples were scored within 15 minutes after the meat was prepared for evaluation.

Total moisture, ether extract, water-holding capacity, pH

Percentage of dry matter and ether extract were determined by A.O.A.C. methods (A.O.A.C., 1975) for samples of ground raw or cooked muscle by the Analytical Services Laboratory of the Department of Animal Science and Industry at Kansas State University. Percentage of total moisture (TM) was calculated by subtracting percentage of dry matter from 100.

For Expt. I, percentage of total moisture also was measured by drying duplicate 10-g samples of ground cooked muscle in a Brabender Semi-Automatic Rapid Moisture Tester for 60 minutes at 121°C.

Triplicate measurements for water-holding capacity (WHC) were made on samples (280-320 mg) of cooked muscle by the press method of Miller and Harrison (1965). The ratio of the meat area to juice area was designated as the expressible-liquid index (ELI). WHC values were obtained by subtracting the ELI from 1.0, arbitrarily chosen as the maximum ELI. The ELI is inversely related to the amount of liquid expressed from the sample, thus, the larger the WHC value, the more liquid expressed.

Duplicate pH readings were made on slurries of 100 ml distilled, deionized water and 10 g of ground cooked muscle according to the method of Rogers et al. (1967).

Texture measurements using the Instron Universal Testing Machine (Model 1122)

Penetration measurements. A flat-ended cylindrical puncture probe, 0.63 cm in diameter, was driven vertically about 80% of the way through a rectangular piece of cooked muscle (1.3 x 1.3 x 5 cm) with the fibers perpendicular to the direction of penetration (Bouton et al., 1971). The probe was driven into the sample twice at each of three locations (in the center and about one cm from each end). In Expt. I, a 50 kg load and Expt. II, a 20 kg load with a crosshead speed of 50 mm/min and a chart speed of 100 mm/min was used; the force distance curve for each cycle was recorded.

"Hardness" was the force, in kg, required to achieve the first penetration and was measured as the peak height of the curve from the first penetration. "Cohesiveness" was the ratio of work done during the second penetration to that done during the first. A compensating polar planimeter was used to trace the area of the curve defined by the baseline, the upward sweep of the curve, and perpendicular line drawn from the maximum point of the curve to the baseline. "Elasticity" was measured as the horizontal distance, in mm, from the origin to the perpendicular line dropped from the peak of the second penetration curve x (crosshead speed/ chart speed). "Chewiness" was defined as the product of hardness x cohesiveness x elasticity and was measured in kg-mm (Bourne, 1968).

Shear measurements. A strip of cooked muscle with a rectangular cross section of 1.3 cm was sheared in three places with a modified Warner-Bratzler shear attachment for the Instron, using the same load cell, crosshead, and chart speed as used for the penetration measurements. The force-distance curve was recorded and evaluated for shear cohesiveness and firmness. "Shear cohesiveness" was the peak force on the shear deformation curve measured in kg. "Firmness" was measured as the slope of the line drawn from the origin of the curve to the peak and expressed in kg/min (Larmond and Petrosavits, 1972).

Color measurements

HunterLab L (lightness), a (redness), and b (yellowness) values for a ground sample from a center slice of each roast and a ground strip were measured with the HunterLab Spectrophotometer (Model D54P-5). A white standard tile with calculated values of L (94.20), a (-1.01), and b (1.34) was used to standardize the instrument. Ground cooked muscle was packed tightly into a plexiglass cell to a depth of 1.3 cm. Duplicate L, a, and b measurements were taken, rotating the cell 90° for the second reading.

RESULTS AND DISCUSSION

Experiment I

Roasts were subsampled within rounds, because one roast was entirely SM muscle and the other one was composed of SM and AD muscles. Because no significant difference ($P < 0.05$) occurred between roasts for any measurement (Table 4, Appendix, pg. 49), data were pooled and treated as one variable. Analysis of variance showed differences ($P < 0.05$) among four rounds only for total cooking time and the Instron measurement of hardness (Table 5, Appendix, pg. 50).

<u>Oven roasting vs strips.</u> Few measurements differed ($P < 0.05$) between treatments other than Instron texture measurements (Table 1) and heat penetration rates (Table 6, Appendix, pg. 52). Strips had lower values than OR for hardness ($P < 0.0005$), chewiness ($P < 0.005$), shear cohesiveness ($P < 0.03$), and firmness ($P < 0.006$). Final tenderness scores were higher ($P < 0.06$), cooking time between 0^{o}-$60^{o}C$ was longer ($P < 0.007$), and percentage ether extract was greater ($P < 0.002$) for strips than for OR. Percentage total moisture (Brabender) was less ($P < 0.07$) and total cooking losses were less ($P < 0.06$) for strips than for OR. The rate that heat penetrated strips was slower than that for OR muscle in the

Table 1- Means, F-values, and probability levels for oven roasted (OR) beef roasts and beef muscle strips cooked in test tubes in a water bath (Expt. I).

Measurements	OR	Strips	F-value	P
Instron texture measurements				
Hardness,kg	6.2	5.0	23.51	0.0005
Cohesiveness	0.45	0.42	0.92	0.36
Elasticity,mm	5.7	5.2	1.91	0.19
Chewiness,kgmm	15.6	10.6	12.01	0.005
Shear cohesiveness,kg	7.0	5.6	6.58	0.03
Firmness,kg/min	39.8	19.5	11.24	0.006
Sensory scores				
Initial tenderness[a]	3.6	4.1	2.62	0.13
Final tenderness[a]	3.4	3.9	4.28	0.06
Juiciness[a]	3.8	4.0	0.82	0.39
Rare beef flavor[b]	3.5	3.6	0.25	0.63
Apparent doneness[c]	2.4	2.5	0.06	0.81
Cooking time 0^{o}-60^{o}C,min	72.4	81.5	10.72	0.007
Ether extract, %	3.7	6.0	19.03	0.002
Total moisture, %				
A.O.A.C.	66.1	64.9	1.65	0.23
Brabender	67.0	66.2	4.20	0.07
Total cooking losses, %	21.4	20.0	4.41	0.06
Water-holding capacity[d]	0.6624	0.6524	0.36	0.56
pH	5.53	5.51	0.30	0.60

[a]5-tender or juicy; 1-slightly tough or dry

[b]5-intense rare beef flavor; 1-no rare beef flavor

[c]5-well done; 1-rare

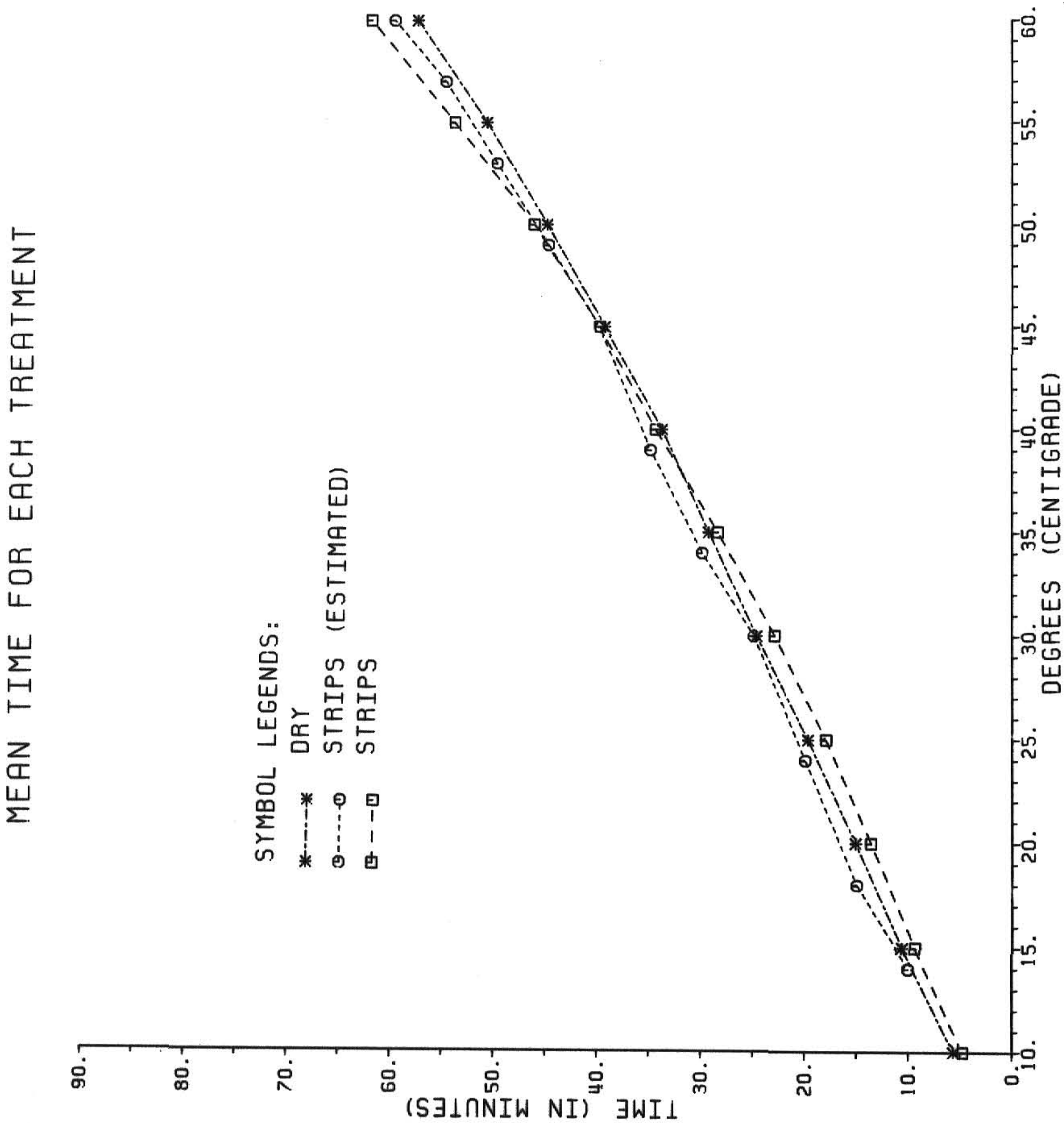
[d]1.0 minus (expressible liquid index); the greater the value the more liquid expressed.

intervals 35^{o}-40^{o} (P< 0.001), 50^{o}-55^{o} (P< 0.004), and 55^{o}-60^{o}C (P< 0.02). Paul (1963) suggested that slower rates of heating in the 57^{o}-60^{o}C range may promote softening of connective tissue without hardening muscle fibers, leading to increased tenderness. Machlik and Draudt (1963) observed a decrease in shear values in the 56^{o}-59^{o}C range, which they attributed to collagen shrinkage. Other researchers have reported a major decrease in shear values in the 50^{o}-60^{o}C range in meat heated slowly (Laakkonen et al., 1970; Penfield and Meyer, 1975).

Strips were in the 50^{o}-60^{o}C range 25% longer and in the 55^{o}-60^{o}C range 19% longer than OR roasts (Fig. 4), which could account for the lower hardness, chewiness, shear cohesiveness, and firmness values for strips. Ideally, the strips should not have been in the 50^{o}-60^{o}C range longer than OR roasts. The experiment was based on the premise that the strips could be cooked in the model system at the same rate that occurred with oven roasting. Preliminary work was done to obtain an "average" internal heating curve for 1.4-kg top round roasts. A procedure was developed so that by thawing the strips for 20-25 minutes and then manipulating the temperature of the water bath, the average internal temperature of six strips closely approximated the "average" heat curve determined during preliminary work (Fig. 4); but the roasts did not. On the average, OR roasts cooked in eight minutes less time than expected. Because of limitations in the maximum rate of heating in the water bath, the faster rate of heating of the roasts could not be matched using the procedure developed during preliminary work.

No differences (P< 0.07) between OR and strips occurred in sensory measurements for initial tenderness, juiciness, rare beef

Fig. 4 -Rate of heat penetration for 5^{o}-60^{o}C for OR roasts, strips, and "average" heat curve (strips estimated) that OR roasts and strips were expected to follow.


MEAN TIME FOR EACH TREATMENT
SYMBOL LEGENDS:
DRY
STRIPS (ESTIMATED)
STRIPS
TIME (IN MINUTES)
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
DEGREES (CENTIGRADE)
10.
15.
20.
25.
30.
35.
40.
45.
50.
55.
60.

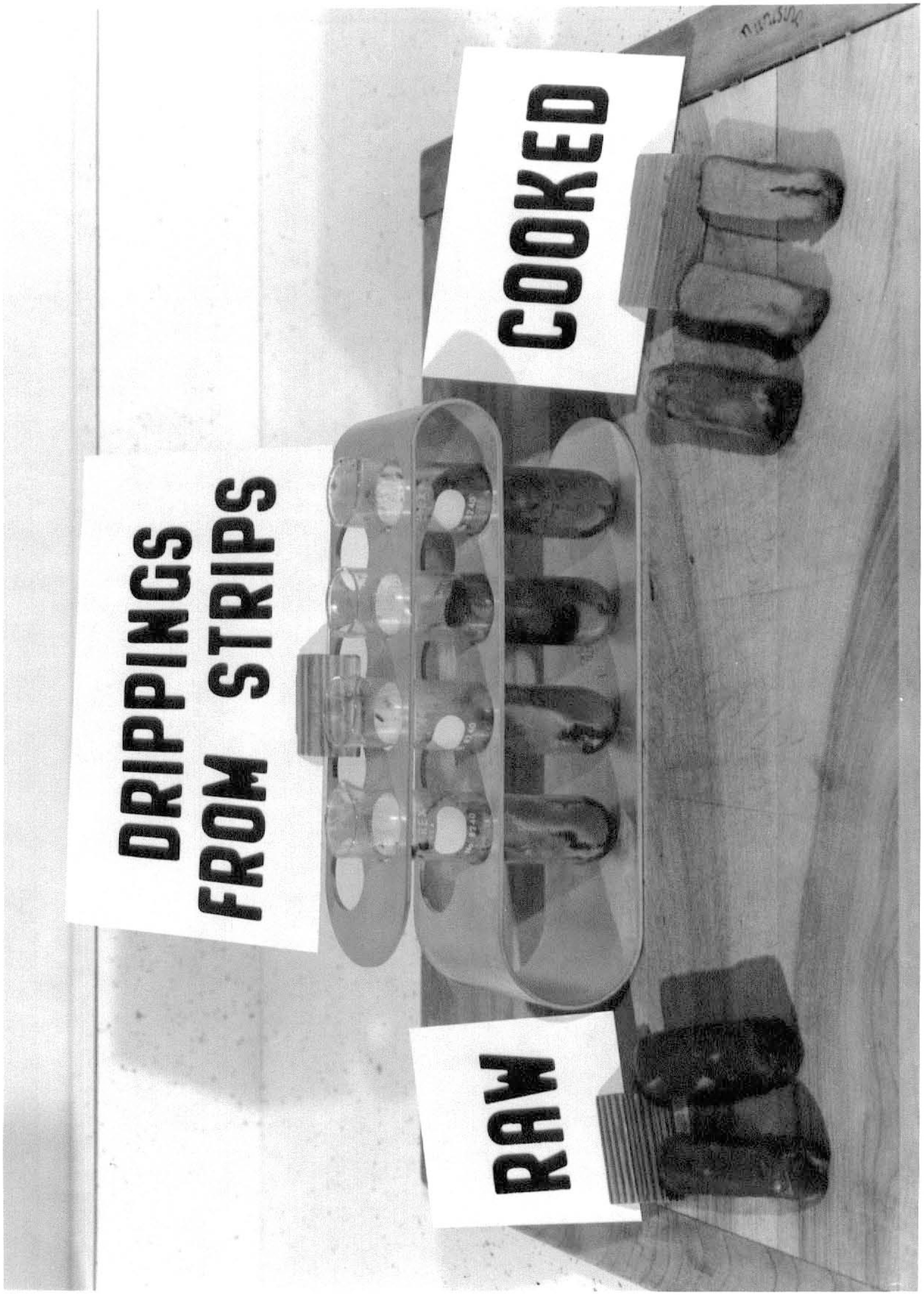
flavor, or apparent doneness; water-holding capacity; pH; total moisture (A.O.A.C. method); Instron measurements of cohesiveness or elasticity, (Table 1); and rates of heat penetration in the 5^{o}-35^{o} and 40^{o}-50^{o}C ranges (Table 6, Appendix, pg. 52).

Although data for objective measurements indicated that strips might be juicier (greater percentage ether extract, less total cooking loss) and tenderer than OR, sensory measurements indicated no significant difference in juiciness or initial tenderness, but possibly a difference ($P < 0.06$) in final tenderness between OR and strips (Table 1).

Because of the nature of the model system, no meaningful comparison can be made between roasts and strips for volatile or drip cooking loss and heat penetration in the 0^{o}-5^{o}C range. In roasts cooked by dry heat, most of the total cooking loss occurs as volatile loss, whereas with moist heat, drip loss accounts for most of the total cooking loss. In the model system, although the test tubes were not covered (Fig. 5), little moisture escaped as volatile loss, so drip loss accounted for almost all of the total loss. Thus, strips were cooked at a rate that occurred with dry heat, but in a moist atmosphere. The roasts had an initial temperature of 0^{o}C when put into a preheated oven. They remained at that temperature for an average of 25 minutes before the internal temperature started to rise, which is reflected by the long time the temperature at the center of the roasts was between 0^{o} and 5^{o}C (Table 6, Appendix, pg. 52). Because of the difficulty of holding strips at 0^{o}C in the water bath, no attempt was made to imitate that portion of the heat penetration curve. The strips imitated the heat curve after the temperature of OR roasts was above 0^{o}C. Therefore, no comparison of data for OR and strips should be made

Fig. 5 - Appearance of drippings from strips, after cooking to an end point of 60^{o}.

Appearance of raw and cooked strips.


DRIPPINGS
FROM STRIPS
COOKED
RAW

for the 0^{o}-5^{o}C heat penetration range.

Experiment II

For each replication, one round was divided into strips and two roasts that were assigned randomly to moist (OFB) or dry (OR) heat treatments. Analysis of variance showed differences among rounds for Instron texture measurements of elasticity ($P<0.02$), shear cohesiveness ($P<0.03$), total moisture ($P<0.02$), total cooking losses ($P<0.04$), pH ($P<0.002$), and HunterLab L-values ($P<0.0003$) (Table 7, Appendix, pg. 54). Differences in pH affect tenderness (Bouton et al., 1971), so differences ($P<0.002$) in pH among rounds used in this study may account for some of the differences between rounds in elasticity and shear cohesiveness. Differences in pH also affect color and may account for the difference among rounds in L-value.

Oven roasting vs oven film bag. OFB roasts were less tender, as assessed by both objective ($P<0.01$-0.05) and sensory ($P<0.04$-0.05) measurement, less juicy ($P<0.003$), had less rare beef flavor ($P<0.004$), had a shorter cooking time ($P<0.0001$), had greater total cooking losses ($P<0.0001$), had less red ($P<0.001$) and yellow ($P<0.01$) color than OR roasts (Table 2). Hood (1960) found that foil wrapped (moist heat) beef roasts cooked to 77^{o}C were less tender, less juicy, and had greater weight loss than oven roasted beef. Similar to data reported by Shaffer et al. (1973), OFB roasts in this study heated faster ($P<0.02$) above 25^{o}C than OR roasts (Table 6, Appendix, pg. 52), resulting in the shorter cooking time. A faster rate of heating, and thus, a shorter cooking time is expected, because steam conducts heat to the muscle surface faster than dry air (Paul, 1972).

Table 2- Means and probability that means are equal for beef roasts cooked in oven film bags (OFB) or oven roasted (OR) and beef muscle strips cooked in test tubes in a water bath (Expt. II).

Measurement	Means			Probability that means are equal		
	OFB	OR	Strips	OR=OFB	OR=Strips	OFB=Strips
Instron texture measurement						
Hardness,kg	7.8	7.1	5.5	0.23	0.01	0.001
Cohesiveness	0.46	0.45	0.41	0.60	0.21	0.09
Elasticity,mm	8.3	7.2	7.0	0.01	0.63	0.003
Chewiness,kg-mm	29.7	23.3	15.8	0.05	0.02	0.0003
Shear cohesiveness,kg	9.0	7.6	5.8	0.07	0.02	0.0005
Firmness,kg/min	33.0	24.3	17.6	0.008	0.03	0.0001
Sensory scores						
Initial tenderness[a]	3.4	4.0	4.3	0.05	0.48	0.01
Final tenderness[a]	3.5	4.0	4.2	0.04	0.29	0.004
Juiciness[a]	3.2	4.1	3.9	0.003	0.41	0.02
Rare beef flavor[b]	2.7	3.5	3.7	0.004	0.29	0.005
Apparent doneness[c]	3.3	2.8	2.2	0.19	0.19	0.02
Cooking time 0^o-60^o,min	53.9	68.3	83.0	0.0001	0.0001	0.0001
Ether extract,%	4.8	4.2	5.1	0.24	0.10	0.62
Total moisture, A.O.A.C.,%	62.6	65.4	65.9	0.0001	0.07	0.0001
Total cooking losses,%	29.7	22.5	21.2	0.0001	0.10	0.0001
Water-holding capacity[d]	0.6603	0.6238	0.6121	0.07	0.54	0.02
pH	5.48	5.48	5.46	0.97	0.69	0.66
HunterLab color measurements						
L-value (lightness)	47.2	47.9	47.4	0.15	0.29	0.74
a-value (redness)	4.3	6.9	9.6	0.001	0.001	0.0001
b-value (yellowness)	9.2	10.0	10.6	0.01	0.08	0.0004

[a]5- tender or juicy; 1- tough or dry

[b]5- intense rare beef flavor; 1- no rare beef flavor

[c]5- well done; 1- rare

[d]1.0 minus (expressible liquid index); the greater the value, the more liquid expressed

OFB roasts were less tender than OR roasts, as assessed by sensory measurements of initial tenderness ($P < 0.05$) and final tenderness ($P < 0.04$) and objective measurements of elasticity ($P < 0.01$), chewiness ($P < 0.05$), firmness ($P < 0.008$), and possibly shear cohesiveness ($P < 0.07$). Shaffer et al. (1973) found that roasts cooked in oven film bags were less tender than oven roasted beef. In this study, OFB roasts were less ($P < 0.003$) juicy than OR roasts, which agrees with results of other researchers (Ferger et al., 1972; Hood, 1960). OFB roasts had greater ($P < 0.0001$) total cooking losses and contained less ($P < 0.0001$) total moisture than OR roasts, which might have contributed to the lower juiciness scores for OFB roasts. Other researchers found greater total cooking losses with moist heat cooking (Hood, 1960; Schock et al., 1970; Shaffer et al., 1973).

Although OFB and OR roasts had similar scores for apparent doneness, OFB roasts had lower ($P < 0.001$) HunterLab a-values, indicating less red color. This difference can be explained by the sampling procedure. Roasts were compared with strips so apparent doneness samples consisted of 2.5-cm cores cut from the center of each roast. Because the core was taken from the center, little of the outer browner portion of the OFB roast was viewed by the sensory panel. To measure color objectively, a whole slice including the outer portions was ground up and color was measured spectrophotometrically. This explains why a color difference between roasts (OR vs OFB) was observed objectively, but not by sensory measurement. Other researchers found moist heating resulted in meat that appeared more done than meat cooked by dry heat to the same end point temperature (Schock et al., 1970; Ferger et al., 1972; Shaffer et al., 1973; Vollmar et al., 1976). Panelists commented that

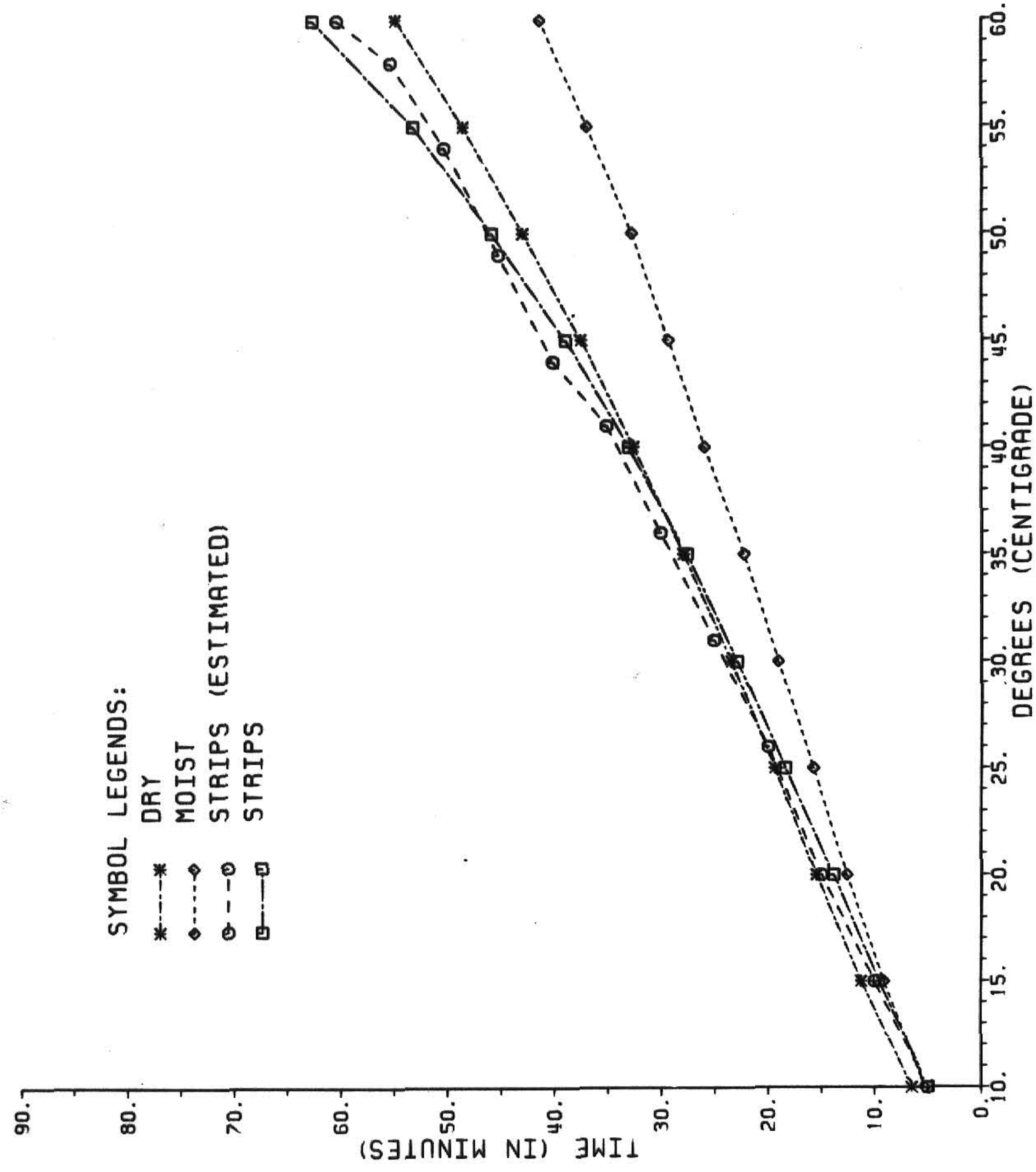
OR roasts had moderately intense rare beef flavor, but OFB roasts occasionally had a cooked beef flavor.

Measurements in which OFB and OR roasts did not differ significantly were initial weight and dimensions, pH, ether extract, hardness, cohesiveness, L-value, and rates of heat penetration between 5° and $25^{\circ}C$.

Oven roasting vs strips. Differences between OR roasts and strips in Expt. II were the same as those that occurred in Expt. I; namely, Instron texture measurements and heating rates (Table 2). Strips had lower values for Instron hardness ($P<0.01$), chewiness ($P<0.02$), shear cohesiveness ($P<0.02$), and firmness ($P<0.03$) than OR roasts, but differences did not occur in sensory tenderness measurements (Table 2). Strips had a longer ($P<0.0001$) cooking time and a slower ($P<0.01$) rate of heating above $40^{\circ}C$ than OR roasts (Fig. 6). The strips were in the 50°-$60^{\circ}C$ range 42% longer and in the 55°-$60^{\circ}C$ range 49% longer than were OR roasts, which may account for the lower Instron values for strips. Strips had more ($P<0.07$) total moisture than OR roasts, but were not significantly different in juiciness. HunterLab a-values indicated that strips were redder ($P<0.001$) than OR roasts, but that was not evident in apparent doneness scores. Measurements that were not significantly different between OR roasts and strips were: WHC, pH, ether extract, total cooking losses, Instron elasticity and cohesiveness measurements, HunterLab L and b-values and heating rates below $35^{\circ}C$.

Oven film bag vs strips. Differences between OFB roasts and strips were the same as those between OFB and OR roasts, plus OFB roasts were harder ($P<0.001$) than strips and appeared more ($P<0.05$) done (Table 2). Although strips and OFB roasts were

Fig. 6 - Rate of heat penetration from 5^{o}-60^{o}C for OR (dry) and OFB (moist) roasts, strips, and "average" heat curve (strips estimated) that OR roasts and strips were expected to follow, Expt. II.


SYMBOL LEGENDS:
DRY
MOIST
STRIPS (ESTIMATED)
STRIPS
TIME (IN MINUTES)
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
DEGREES (CENTIGRADE)
10.
15.
20.
25.
30.
35.
40.
45.
50.
55.
60.

both cooked in a moist atmosphere, strips were more like OR roasts than they were like OFB roasts. The question that arises is whether the strips would have been more like OFB than like OR roasts if they had been heated at a rate that occurred with moist heat cooking? Further research is needed to answer that question.

Correlation coefficients

Correlation coefficients were calculated to study the linear relationship between selected measurements (Table 8, Appendix, pg. 55). Shindell (1964) described correlation coefficients as low if $r \leq 0.39$, moderate if $0.40 \leq r \leq 0.79$, and high if $r \geq 0.80$, irrespective of sign. Because of the small sample size in this study, a large value for r was necessary to show significant correlation. Consequently, although r was in the upper half of the moderate range for many measurements, the coefficient was not significantly different from zero. Listed in Table 3 are selected measurements with significant correlation coefficients in the moderate or high range.

In Expt. I, initial tenderness of strips had a moderate negative correlation with firmness ($r=-0.77^{*}$) and with the 55°-60°C heat penetration rate ($r=-0.72^{*}$). Initial tenderness of strips was highly correlated with juiciness ($r=0.94^{**}$) and final tenderness ($r=0.87^{**}$). Final tenderness of OR roasts had a high negative correlation with elasticity ($r=-0.90^{**}$) and a moderate negative correlation with pH ($r=-0.79^{*}$). Final tenderness of strips was moderately correlated with juiciness ($r=0.77^{*}$) and had a high negative correlation with the 55°-60°C heat penetration rate ($r=-0.88^{**}$). Heat penetration rate in the 55°-60°C range of strips had moderate negative correlation with hardness ($r=-0.76^{*}$) and

Table 3- Significant correlation coefficients for selected measurements

Paired measurements	Treatment	r-value
	Expt. I	
Initial tenderness vs		
Firmness	Strips	-0.77*
55°-60° heat penetration rate	Strips	-0.72*
Juiciness	Strips	0.94**
Final tenderness	Strips	0.87**
Final tenderness vs		
Elasticity	OR	-0.90**
pH	OR	-0.79*
Juiciness	Strips	0.77*
55°-60° heat penetration rate	Strips	-0.88**
55°-60°C heat penetration rate vs		
Hardness	Strips	-0.76*
Firmness	Strips	-0.76*
Shear cohesiveness vs		
Hardness	Strips	-0.73*
	Expt. II	
Initial tenderness vs		
Final tenderness	Strips	0.72*
	OFB	0.83*
	OR	0.92**
Final tenderness vs		
Cohesiveness	Strips	-0.71*
0°-60°C cooking time	OR	0.81*
Juiciness vs		
Rare beef flavor	OFB	0.88**
Apparent doneness	Strips	-0.83*
Apparent doneness vs		
HunterLab a-value	Strips	-0.82*
0°-60°C cooking time	OR	0.84**
Shear cohesiveness vs		
Chewiness	OR	0.73*
Elasticity	OFB	-0.75*

D/F = 6.

*- significant at 5% level; $r \geq 0.707$

**- significant at 1% level; $r \geq 0.834$

firmness ($r=-0.76^*$). When Instron shear measurements were correlated to penetration measurements, only shear cohesiveness and hardness were linearly related ($r=-0.73^*$).

In Expt. II, initial tenderness had a moderate or high correlation with final tenderness for strips ($r=0.72^*$), OFB ($r=0.83^*$), and OR roasts ($r=0.92^{**}$). Final tenderness had a moderate negative correlation ($r=-0.71^*$) with cohesiveness of strips and a high correlation ($r=0.81^*$) with 0^o-60^oC cooking time of OR roasts. Juiciness had a high correlation ($r=0.88^{**}$) with rare beef flavor of OFB roasts and a high negative correlation ($r=-0.83^*$) with apparent doneness of strips. Apparent doneness had a high negative correlation ($r=-0.82^*$) with HunterLab a-values of strips and a high correlation ($r=0.84^{**}$) with 0^o-60^oC cooking time of OR roasts. When Instron shear and penetration measurements were correlated in Expt. II, shear had a moderate correlation with chewiness ($r=0.73^*$) for OR roasts and a moderate negative correlation ($r=-0.75^*$) with elasticity for OFB roasts.

Variance among data

To determine if precision in measurements differed between the model system and conventional methods, for each measurement, sample variances between treatments were tested for equality using an F-test. In Expt. I, only apparent doneness and 0^o-60^oC cooking time differed ($P< 0.01$) in sample variance between OR roasts and strips, with the roasts exhibiting the greater variation in both measurements (Table 9, Appendix, pg. 58).

In Expt. II (Table 10, Appendix, pg. 59), sample variance differed between OR and OFB roasts for HunterLab a-values ($P< 0.01$) and rate of heat penetration in the 5^o-10^o and 15^o-20^oC range

($P<0.05$). OR roasts had greater variation in HunterLab a-values and in the 5°-10°C heat penetration rate, but OFB roasts had greater variation in the 15°-20°C heat penetration rate. Sample variance differed ($P<0.05$) between OR roasts and strips for chewiness, and heat penetration rates in the 15°-20° and 30°-35°C range. OR roasts had greater variance for chewiness and 30°-35°C heat penetration rate, whereas strips had greater variance for 15°-20°C heat penetration rate. Differences ($P<0.01$) in sample variance between OFB roasts and strips occurred with HunterLab a-values and total cooking losses, with strips exhibiting the greater variation in both measurements. Sample variance differed ($P<0.05$) between OFB roasts and strips for firmness, with OFB roasts exhibiting the greater variation.

In general, variances for a given measurement were similar between meat cooked in a model system or by conventional methods.

SUMMARY

In two experiments, randomized complete block designs were used to evaluate differences between 1.4 kg top round roasts (SM and AD muscles) cooked by dry heat oven roasting (OR) or moist heat in oven film bags (OFB) and SM strips heated in test tubes in a water bath. Roasts were cooked in a 177°C rotary hearth electric oven to an end point temperature of 60°C. Strips were cooked to an end point of 60°C at an average heat penetration rate that occurred with oven roasting 1.4-kg top round roasts.

Roasts cooked by moist heat (OFB) cooked faster ($P<0.0001$), and were less tender ($P<0.05$), less juicy ($P<0.003$), had less rare beef flavor ($P<0.004$), less red ($P<0.001$) and yellow

($P<0.01$) color, and more total cooking losses ($P<0.0001$) than roasts cooked by dry heat (OR).

Strips had significantly lower values for Instron texture measurements of hardness, chewiness, shear cohesiveness, and firmness than roasts cooked by dry or moist heat. Strips had a longer cooking time ($P<0.0001$) and a slower rate of heating above $50^{o}C$ ($P<0.02$) than roasts. Although strips were cooked in a moist atmosphere at a rate that occurred with oven roasting, strips were more like roasts cooked by dry heat than they were like roasts cooked by moist heat.

Correlation coefficients showed no consistent trends between experiments or between treatments except moderate or high correlation between initial and final tenderness. Variance for a given measurement was similar between meat cooked in a model system or by conventional methods.

CONCLUSIONS

Under the conditions of these two experiments, it was concluded that a model system may be used in place of oven roasting when the data are to be used to evaluate treatment effects on measurements similar to those used in these experiments, except possibly Instron texture measurements.

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ACKNOWLEDGMENTS

The author thanks Dr. Dorothy L. Harrison, major professor and Professor of Foods and Nutrition for assigning the problem and for guidance in organizing the research project. Sincere appreciation is expressed to Dr. Harrison for her help in revising the manuscript, changing all the whiches to thats and unsplitting the infinitives. Thanks are given to Dr. Beth Fryer, Professor of Foods and Nutrition, for serving on the writer's advisory committee and to Dr. Arthur Dayton, Professor and Head of the Department of Statistics for serving on the advisory committee, for his assistance with the experimental design and for analyzing the data. Appreciation is expressed to Dr. Martha Stone, Assistant Professor of Foods and Nutrition for her suggestions for revising the texture profile analysis sections of the manuscript.

Special thanks are given to Carol Pacey for her very helpful suggestions on laboratory procedures. Appreciation is expressed to Ruth Vilander and Carol Pacey for their technical assistance and to members of the taste panel for evaluating the samples. Gratitude is expressed to the Department of Foods and Nutrition and to the Kansas Agricultural Experiment Station for financial support.

The writer gives special thanks to her husband, Jeff, for his many hours spent typing the manuscript and to her daughter, Reagan, for letting Mommy study.

APPENDIX

Score Card for Sensory Evaluation of Beef Top Round Roasts and Strips; Expt. I

Judge____________________ Date____________

Sample Code	Tenderness: Initial Score	Tenderness: Chews	Tenderness: Score	Juiciness	Flavor	Apparent Doneness	Comments:

Scoring Key:

Tenderness

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

Juiciness

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

Flavor

5-Intense rare beef flavor
4-Moderately intense rare beef flavor
3-Slightly intense rare beef flavor
2-Perceptible rare beef flavor
1-No rare beef flavor

Apparent Doneness[a]

5-Well done
4-Medium well done
3-Medium
2-Medium rare
1-Rare

Comments:

a-Viewed under the MacBeth skylight.

Score Card for Sensory Evaluation of Beef Top Round Roasts and Strips, Expt. II

Judge ______________________ Date ______________________

	Tenderness						
Sample Code	Initial Score	Chews	Score	Juiciness	Flavor	Apparent[a] Doneness	Comments:

Scoring Key:

<u>Tenderness</u>

5-Tender
4-Moderately tender
3-Slightly tender
2-Slightly tough
1-Tough

<u>Juiciness</u>

5-Juicy
4-Moderately juicy
3-Slightly juicy
2-Slightly dry
1-Dry

<u>Flavor</u>

5-Intense rare beef flavor
4- Moderately intense rare beef flavor
3-Slightly intense rare beef flavor
2-Perceptible rare beef flavor
1-No rare beef flavor

<u>Apparent Doneness</u>

5-Well done
4-Medium well done
3-Medium
2-Medium rare
1-Rare

a-viewed under the MacBeth skylight

Form II

INSTRUCTIONS TO JUDGES FOR SENSORY EVALUATION OF BEEF TOP ROUND

Each judge is to select two cubes of meat at random from each double boiler. Use one cube to score flavor and juiciness and one to score tenderness and count chews. If the two cubes within one sample are different, use an average score.

TAKE YOUR TIME to score each sample. Rinse your mouth between samples.

Scoring for apparent doneness

View the samples under the MacBeth skylight. Record a score within the range of 5 to 1 that describes your impression of the apparent doneness of the sample, using the descriptive terms on the scorecard.

Scoring for flavor and juiciness

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

Scoring for tenderness

Initial score- Record a score for tenderness that describes your initial impression of the sample (within the first few bites). Refer to the scorecard for descriptive terms for specific scores within the range of 5 to 1.

Count the number of times you chew the cube of meat before swallowing. Chew until the meat is masticated completely, then swallow. Record the number of chews required to masticate the cube.

Final score- Record an overall score for tenderness based on the number of chews.

Use the number of chews to help standardize your tenderness scores from day to day. Establish a range of the number of chews for each score from 5 to 1. For example, if you chew from 25 to 35 times, record a score of 4, if that score represents your impression of tenderness; then if you chew 35 to 45 times, record a score of 3. Continue to reduce the score by one for a given number of increased chews. Each judge sets his own range of chews for a given score.

Comments

Comments about the sample and/or explaining your reason for giving a particular score are helpful. Please comment on any aspect of the sample that affects its overall sensory qualities.

Table 4 -Means, F-values, and probability that means are equal for subsampling roasts within rounds, Expt. I

Measurements	Roast 1	Roast 2	F-value	P
Sensory scores				
Initial tenderness[a]	3.9	3.3	2.21	0.17
Final tenderness[a]	3.6	3.2	2.05	0.19
Juiciness[a]	3.8	3.8	0.02	0.89
Rare beef flavor[b]	3.4	3.6	0.89	0.37
Apparent doneness[c]	3.0	1.8	4.10	0.07
Instron texture measurements				
Hardness	6.03	6.34	0.67	0.44
Cohesiveness	0.46	0.44	0.10	0.76
Elasticity	5.45	5.90	1.26	0.29
Chewiness	14.93	16.38	0.64	0.44
Shear	6.77	7.21	0.29	0.60
Firmness	33.23	46.27	2.51	0.15
WHC[d]	0.6662	0.6586	0.10	0.76
pH	5.51	5.55	0.36	0.56
Total moisture, %				
A.O.A.C.	65.9	66.6	—	0.70
Brabender	67.0	67.1	0.12	0.80
Ether extract, %	3.2	4.8	—	0.07
Cooking losses, %				
Total	21.0	21.8	0.97	0.35
Drip	3.5	4.0	0.41	0.54
Volatile	17.0	17.4	0.65	0.44
Cooking time, min				
Total	95.5	98.0	0.92	0.41
0°-60°	71.8	73.0	0.08	0.78
Initial weight, g	1349.0	1344.3	0.01	0.91
Volume, cm^3	1162.5	1096.0	0.24	0.66
Length, cm	14.0	13.9	0.09	0.79
Width, cm	12.1	12.5	0.36	0.59
Depth, cm	6.8	6.4	0.23	0.66
Rate of heat penetration, min				
0°-5°	37.5	40.5	0.98	0.35
5°-10°	6.3	5.0	0.94	0.36
10°-15°	4.5	5.5	0.55	0.48
15°-20°	4.8	4.3	0.33	0.58
20°-25°	4.5	4.8	0.38	0.56
25°-30°	4.8	5.3	0.60	0.46
30°-35°	4.8	4.5	0.12	0.74
35°-40°	4.5	4.5	0.00	1.00
40°-45°	5.3	6.0	1.43	0.26
45°-50°	5.5	5.8	0.58	0.75
50°-55°	6.3	5.5	1.18	0.31
55°-60°	7.0	6.5	0.41	0.54

[a]5-tender or juicy; 1-slightly tough or dry. [b]5-intense rare beef flavor; 1-no rare beef flavor. [c]5-well done; 1-rare
[d]1.0 minus (expressible liquid index)

Table 5 -Means, F-values and probability that means are equal between replications (rounds), Expt. I

Measurement	Rounds I	II	III	IV	F	Probability
Sensory scores						
Initial tenderness[a]	3.7	3.8	4.2	3.6	0.79	0.53
Final tenderness[a]	3.6	3.7	3.7	3.5	0.12	0.94
Juiciness[a]	4.1	3.8	4.1	3.8	0.44	0.73
Flavor[b]	3.9	3.2	3.6	3.7	3.12	0.08
Doneness[c]	2.6	2.4	2.3	2.5	0.09	0.96
Instron texture measurements						
Hardness, kg	5.06	5.04	6.03	6.12	4.86	0.03
Cohesiveness	0.44	0.40	0.44	0.45	0.44	0.73
Elasticity, mm	5.6	5.7	5.2	5.2	0.44	0.73
Chewiness, kg-mm	12.3	11.5	14.0	14.6	0.96	0.45
Shear, kg	6.20	6.94	6.19	5.90	0.60	0.63
Firmness, kg/min	27.39	30.45	22.82	37.89	1.18	0.37
Water-holding capacity[d]	0.6621	0.6547	0.6567	0.6560	0.04	0.99
pH	5.48	5.63	5.54	5.43	3.20	0.08
TM, A.O.A.C. %	67.5	65.3	64.1	64.7	2.27	0.17
TM, Brabender %	66.2	66.4	66.9	67.0	0.84	0.51
Ether extract %	4.8	5.1	5.6	4.7	0.53	0.68
Cooking losses, %						
Total	21.6	21.2	20.4	19.6	2.59	0.12
Volatile	9.5	9.0	8.5	9.1	1.75	0.23
Drip	11.8	11.8	11.3	10.3	1.24	0.35
Cooking time, min						
Total	101.5	88.0	92.5	105.0	9.15	0.05
0^{o}-60^{o}	77.0	75.8	75.5	79.5	0.36	0.79
Initial wt., g	839.0	749.3	835.8	840.8	2.60	0.12
Volume, cm^3	1127.0	1027.5	1091.5	1271.0	0.58	0.67
Length, cm	13.5	13.8	14.5	14.0	1.00	0.50
Width, cm	12.5	11.5	13.5	11.8	2.07	0.28
Depth, cm	6.7	6.5	5.7	7.7	1.15	0.45

Table 5-(concluded)

Measurement	Rounds I	II	III	IV	F	Probability
Rate of heat penetration, min						
0^o-5^o	31.5	25.3	30.5	30.0	1.67	0.24
5^o-10^o	5.8	5.0	4.5	5.5	0.37	0.78
10^o-15^o	5.3	4.3	4.3	5.5	0.48	0.71
15^o-20^o	4.0	4.8	4.3	4.5	0.27	0.84
20^o-25^o	5.3	4.3	3.5	5.0	7.50	0.008
25^o-30^o	5.0	4.8	4.8	5.5	0.60	0.63
30^o-35^o	4.8	4.3	5.8	5.5	1.78	0.22
35^o-40^o	5.0	6.0	5.3	4.8	2.62	0.11
40^o-45^o	5.3	5.8	5.3	6.0	0.72	0.57
45^o-50^o	6.5	6.0	5.8	5.8	0.45	0.72
50^o-55^o	6.5	6.8	7.0	7.0	0.24	0.87
55^o-60^o	7.3	7.5	6.8	8.3	1.27	0.34

[a]5-tender or juicy; 1-slightly tough or dry

[b]5-intense rare beef flavor; 1-no rare beef flavor

[c]5-well done; 1-rare

[d]1.0 minus (expressible liquid index); the greater the value the more liquid expressed.

Table 6 -Means, F-values, and probability that means are equal for rate of heat penetration

Rate of heat penetration, min	Means			Probability that means are equal		
	OFB	OR	Strips	OR=OFB	Strips=OFB	Strips=OR
Expt. I						
0^o-5^o		39.0	19.6			———
5^o-10^o		5.6	4.8			0.34
10^o-15^o		5.0	4.6			0.68
15^o-20^o		4.5	4.3			0.67
20^o-25^o		4.6	4.4			0.44
25^o-30^o		5.0	5.0			1.00
30^o-35^o		4.6	5.5			0.10
35^o-40^o		4.5	6.0			0.001
40^o-45^o		5.6	5.5			0.78
45^o-50^o		5.6	6.4			0.15
50^o-55^o		5.9	7.8			0.004
55^o-60^o		6.8	8.1			0.02
Expt. II						
5^o-10^o	5.3	6.5	4.9	0.14	0.70	0.07
10^o-15^o	3.9	4.8	4.6	0.11	0.17	0.81
15^o-20^o	3.5	4.3	4.3	0.14	0.11	0.90
20^o-25^o	3.1	3.9	4.5	0.07	0.002	0.12
25^o-30^o	3.3	4.0	4.4	0.006	0.0002	0.08
30^o-35^o	3.3	4.5	4.8	0.0004	0.0001	0.37
35^o-40^o	3.6	4.6	5.4	0.02	0.0003	0.06
40^o-45^o	3.4	4.9	5.9	0.0002	0.0001	0.004
45^o-50^o	3.4	5.4	6.8	0.0001	0.0001	0.001
50^o-55^o	4.1	5.5	7.3	0.01	0.0001	0.002
55^o-60^o	4.4	6.3	9.4	0.001	0.0001	0.0001

Table 7 -Means, F-values, and probability that means are equal between replications (rounds), Expt. II

Measurements	Rounds I	II	III	IV	V
Sensory scores					
Initial tenderness[a]	4.0	3.7	4.1	3.8	3.8
Final tenderness[a]	4.0	4.1	4.1	3.7	3.7
Juiciness[a]	3.6	3.8	3.7	3.6	3.9
Flavor[b]	3.2	3.0	3.4	3.0	3.7
Doneness[c]	2.9	3.4	2.7	2.1	2.5
Instron texture measurements					
Hardness, kg	6.06	7.16	7.10	7.77	7.18
Cohesiveness	0.39	0.38	0.41	0.44	0.48
Elasticity, mm	5.9	7.0	7.7	7.3	8.4
Chewiness, kgmm	14.2	19.3	23.2	25.1	29.7
Shear, kg	5.9	6.3	6.7	10.6	8.9
Firmness, kg/min	23.7	23.7	20.6	33.6	26.9
WHC[d]	0.6567	0.6027	0.6351	0.5919	0.6471
pH	5.38	5.40	5.49	5.39	5.58
TM, A.O.A.C., %	63.4	64.7	65.2	65.4	64.3
Ether extract, %	4.9	4.6	3.4	4.9	6.0
Cooking losses, %					
Total	23.5	23.6	23.4	22.6	25.5
Volatile	—	8.4	8.4	7.8	9.2
Drip	15.0	14.5	14.4	14.4	15.9
HunterLab color measurements					
L-value	48.0	49.4	47.0	45.2	46.7
a-value	6.78	6.88	6.40	7.50	8.15
b-value	10.00	10.36	9.61	9.61	10.09
Cooking time, min					
Total[e]	96.0	98.5	104.5	96.0	105.5
0°-60°	69.0	68.0	68.0	65.0	67.7
Initial weight	1038.0	1052.7	1089.0	1034.7	1075.0
Volume[e]	930.0	1237.5	1146.0	1055.5	1248.0
Length[e]	13.5	13.0	12.8	13.5	13.0
Width[e]	12.0	12.5	11.8	11.0	12.0
Depth[e]	5.8	7.7	7.8	7.2	8.0
Heat penetration rates, min					
0°-5°	39.8	26.7	20.3	29.8	17.5
5°-10°	5.7	5.2	5.7	6.0	5.0
10°-15°	3.7	5.0	4.5	4.0	4.0
15°-20°	3.5	4.2	3.3	4.7	4.3
20°-25°	4.0	4.2	3.5	4.2	3.5
25°-30°	3.8	4.2	4.0	3.5	4.2
30°-35°	4.5	4.2	4.0	3.7	4.3
35°-40°	4.2	4.5	4.3	4.3	4.7
40°-45°	4.8	4.7	4.7	4.8	5.0
45°-50°	5.2	5.5	5.7	4.7	5.7
50°-55°	5.5	5.5	5.2	5.5	5.5
55°-60°	6.2	7.0	6.3	6.2	6.7

Table 7 -(concluded)

Measurements	Rounds VI	VII	VIII	F	P
Sensory scores					
Initial tenderness[a]	3.8	4.2	3.7	0.27	0.96
Final tenderness[a]	3.7	4.2	3.7	0.71	0.66
Juiciness[a]	3.7	3.7	3.6	0.11	1.00
Flavor[b]	3.4	3.5	3.2	1.00	0.47
Doneness[c]	2.9	2.7	2.9	0.73	0.65
Instron texture measurements					
Hardness, kg	7.47	6.98	4.75	2.26	0.09
Cohesiveness	0.47	0.46	0.48	1.46	0.26
Elasticity, mm	7.6	7.7	8.4	3.73	0.02
Chewiness, kg-mm	26.7	25.7	19.7	2.11	0.11
Shear, kg	7.3	7.1	7.3	3.29	0.03
Firmness, kg/min	23.5	26.2	21.5	1.58	0.22
WHC[d]	0.6388	0.6169	0.6673	1.48	0.25
pH	5.62	5.48	5.42	6.35	0.002
TM, A.O.A.C., %	64.4	64.9	64.9	3.64	0.02
Ether extract, %	5.3	4.5	4.0	1.80	0.17
Cooking losses, %					
Total	26.2	24.2	26.7	2.97	0.04
Volatile	9.3	8.6	8.2	0.76	0.63
Drip	16.0	15.3	17.2	1.23	0.35
HunterLab color measurements					
L-value	46.1	47.9[e]	49.9	9.55	0.0003
a-value	7.58	5.73[e]	5.34	1.32	0.31
b-value	9.80	9.88[e]	9.89	0.71	0.66
Cooking time, min					
Total[e]	105.5	101.0	96.5	0.93	0.54
0°-60°	72.7	69.0	67.7	0.70	0.67
Initial weight[e], g	1089.7	1069.3	1017.0	2.89	0.04
Volume[e], cm^3	1280.5	1037.5	1021.5	1.99	0.19
Length[e], cm	12.3	13.0	13.5	0.64	0.71
Width[e], cm	12.0	12.0	11.0	0.53	0.79
Depth[e], cm	8.8	6.7	6.9	1.56	0.28
Heat penetration rates, min					
0°-5°	32.8	28.5	18.2	1.01	0.47
5°-10°	6.2	5.7	5.2	0.20	0.98
10°-15°	4.7	4.0	5.5	1.08	0.42
15°-20°	4.0	4.2	5.0	0.94	0.51
20°-25°	3.5	3.7	4.2	0.54	0.79
25°-30°	3.7	3.5	4.3	1.41	0.28
30°-35°	4.5	4.3	3.8	1.00	0.47
35°-40°	5.5	4.7	4.2	1.03	0.45
40°-45°	4.3	5.0	4.7	0.45	0.85
45°-50°	5.3	5.0	4.5	1.14	0.39
50°-55°	6.2	5.3	6.3	0.56	0.78
55°-60°	7.0	6.8	7.2	0.56	0.78

[a]5-tender or juicy; 1-tough or dry [b]5-intense rare beef flavor; 1-no rare beef flavor [c]5-well done; 1-rare [d]1.0 minus expressible liquid index; [e]average for OR and OFB roasts only

Table 8 -Correlation coefficients for selected pairs of measurements

	Expt. I		Expt. II		
	OR	Strips	OFB	OR	Strips
Initial tenderness vs					
Hardness	0.23	-0.46	-0.21	-0.38	-0.28
Cohesiveness	0.43	0.09	0.35	-0.51	-0.49
Elasticity	-0.55	-0.47	0.59	-0.42	-0.003
Chewiness	0.16	-0.40	0.31	-0.42	-0.47
Shear	-0.40	0.05*	-0.29	-0.61	-0.24
Firmness	-0.37	-0.77**	-0.26**	-0.68**	-0.16*
Final tenderness	0.64	0.87**	0.83	0.92	0.72
Juiciness	0.27	0.94	0.49	0.17	0.35
Doneness	0.51	-0.21	-0.17	0.27	-0.16
pH	-0.64	0.30	0.22	-0.13	-0.23
0^{o}-60^{o} time	0.06	-0.30	0.56	0.69	-0.36
50^{o}-55^{o}	0.36	0.60*	-0.15	0.43	-0.11
55^{o}-60^{o}	-0.04	-0.72	-0.29	-0.42	-0.36
Final tenderness vs					
Hardness	-0.40	-0.24	-0.24	-0.57	-0.23*
Cohesiveness	0.50**	0.32	0.11	-0.46	-0.71
Elasticity	-0.90	-0.27	0.45	-0.55	-0.24
Chewiness	-0.42	-0.02	0.10	-0.61	-0.66
Shear	-0.54	0.13	-0.60	-0.60	-0.43
Firmness	0.08	-0.51*	-0.40	-0.57	-0.14
Juiciness	-0.09	0.77	0.21	0.31	0.35
Doneness	0.55*	-0.15	0.23	0.48	-0.13
pH	-0.79	0.24	0.005	-0.45*	-0.17
0^{o}-60^{o} time	0.31	-0.56	0.56	0.81	-0.41
50^{o}-55^{o}	0.37	0.24**	-0.17	0.51	-0.48
55^{o}-60^{o}	0.45	-0.88	-0.43	-0.26	-0.16
Doneness vs					
a-value	———	———	-0.03	0.25**	-0.82*
0^{o}-60^{o} time	-0.42	0.21	0.02	0.84	0.38
Rare flavor	-0.15	-0.15	-0.28	0.56	-0.69

Table 8 -(continued)

	Expt. I		Expt. II		
	OR	Strips	OFB	OR	Strips
Juiciness vs					
TM, Brabender	0.22	0.35	—	—	—
TM, A.O.A.C.	0.64	0.11	0.34	0.03	-0.18
Water-holding capacity	0.16	-0.40	-0.17	0.04	0.32
Ether extract	-0.61	0.05	-0.44	-0.14	0.43
Total cooking loss	0.003	-0.11	-0.46	-0.28	-0.46
Volatile loss	0.10	-0.05	0.31	-0.14	-0.12
Drip loss	-0.05	-0.28	-0.43	-0.44	-0.50
a-value	—	—	0.21	-0.10	0.44
Doneness	0.005	-0.25	-0.56	0.25	-0.83**
Rare beef flavor	0.67	0.48	0.88**	0.34	0.50
pH	-0.16	0.08	0.60	-0.68	0.15
0°-60° time	-0.33	-0.16	0.53	0.42	-0.50
50°-55° time vs					
Hardness	0.19	-0.76*	0.62	-0.45	-0.57
Cohesiveness	0.31	-0.06	-0.22	0.20	0.07
Elasticity	-0.25	-0.46	-0.26	0.20	0.70
Chewiness	0.18	-0.70	0.15	-0.02	-0.06
Shear	0.50	0.16	0.44	-0.13	0.10
Firmness	0.36	-0.76*	0.43	-0.36	0.02
55°-60° time vs					
Hardness	-0.46	0.21	0.64	0.06	-0.59
Cohesiveness	-0.29	-0.30	-0.20	0.46	-0.38
Elasticity	-0.35	0.03	-0.55	0.27	0.69
Chewiness	-0.64	-0.10	0.09	0.23	-0.34
Shear	0.32	-0.29	0.08	0.42	0.11
Firmness	0.60	0.48	-0.13	0.33	0.35

Table 8- (concluded)

	Expt. I		Expt. II		
	OR	Strips	OFB	OR	Strips
Shear vs					
Hardness	0.32	-0.73*	0.33	0.57	0.41
Cohesiveness	-0.40	0.12	-0.03	0.68	0.32
Elasticity	0.59	0.62	-0.75*	0.50	0.10
Chewiness	0.28	0.17	-0.48	0.73*	0.54
Firmness vs					
Hardness	0.05	0.55	0.15	0.47	0.54
Cohesiveness	-0.003	-0.28	0.03	0.07	0.21
Elasticity	-0.16	0.34	0.56	-0.23	0.00
Chewiness	-0.05	0.30	0.53	0.17	0.51

df=6; *-r $\geq$ 0.707; significant at 5% level; **-r $\geq$ 0.834; significant at 1% level.

Table 9 -Sample variances and F-value testing equality of variances between treatments for a given measurement, Expt. I

Measurement	OR	Strips	F-value[a]
Initial tenderness	0.1584	0.4571	2.89
Final tenderness	0.1755	0.1850	1.05
Juiciness	0.2343	0.1613	1.45
Flavor	0.2527	0.0943	2.68
Doneness	1.2229	0.1241	9.85**
Hardness	0.7977	0.2221	3.59
Cohesiveness	0.0025	0.0045	1.77
Elasticity	0.2821	0.6707	2.38
Chewiness	9.7200	6.4498	1.51
Shear	1.2050	0.9079	1.33
Firmness	245.4882	52.0654	4.71
WHC	0.0008	0.0010	1.32
pH	0.0091	0.0150	1.65
TM, A.O.A.C.	4.6818[b]	3.7257	1.26
TM, Brabender	0.6164	0.5879	1.05
Ether extract	1.0800[b]	0.5051	2.14
Total cooking losses	0.7641	3.6141	4.73
0°-60° cooking time	51.1250	3.4286	14.91**
Heat penetration rates			
5°-10°	3.6964	1.6429	2.25
10°-15°	3.7143	1.9821	1.87
15°-20°	1.1429	1.0714	1.07
20°-25°	0.8393	0.8393	1.00
25°-30°	0.5714	0.8571	1.50
30°-35°	0.8393	1.4286	1.70
35°-40°	0.2857	0.8571	3.00
40°-45°	1.1250	0.2857	3.94
45°-50°	0.5536	1.1250	2.03
50°-55°	0.9821	0.7857	1.25
55°-60°	1.0714	1.2679	1.18

[a]n=8; $F_{.025,7,7}=4.99$; *-significant at 5% level; $F_{.005,7,7}=8.89$; **-significant at 1% level;

[b]n=6; $F_{.025,5,7}=5.29$; *-significant at 5% level; $F_{.005,5,7}=9.52$; **-significant at 1% level

Table 10 -Sample variances and F-value testing equality of variances between treatments for a given measurement, Expt. II

Measurements	OR	Strips	OFB	F-values[a] OR vs Strips	F-values[a] OR vs OFB	F-values[a] Strips vs OFB
Initial tenderness	0.1857	0.0857	0.4079	2.17	2.20	4.76
Final tenderness	0.1507	0.0841	0.2641	1.79	1.75	3.14
Juiciness	0.1370	0.0686	0.3213	2.00	2.35	4.68
Flavor	0.1127	0.1398	0.3555	1.24	3.15	2.54
Doneness	0.8027	0.3527	0.6070	2.28	1.32	1.72
Hardness	3.3542	0.8426	1.0700	3.98	3.13	1.27
Cohesiveness	0.0047	0.0033	0.0027	1.42	1.74	1.22
Elasticity	1.8086	0.6298	0.5507	2.87	3.28	1.14
Chewiness	92.0441	14.6850	36.7455	6.27*	2.50	2.50
Shear	1.7867	1.6719	7.5124	1.07	4.20	4.49
Firmness	26.8514	12.5086	73.9213	2.15	2.75	5.91*
WHC	0.0023	0.0020	0.0006	1.15	3.97	3.45
pH	0.0059	0.0164	0.0097	2.78	1.64	1.69
TM, A.O.A.C.	1.0421	0.5849	0.2958	1.78	3.52	1.98
Ether extract	1.0175	0.9525	1.9845	1.07	1.95	2.08
L-value	3.1481	4.2978[b]	2.2615	1.37	1.39	1.90
a-value	1.4762	4.3262[b]	0.0596	2.93	24.77**	72.58**
b-value	0.1590	0.5376[b]	0.1136	3.38	1.40	4.73
Total cooking losses	2.6384	7.5793	0.7955	2.87	3.32	9.53**
0^{o}-60^{o} cooking time	34.5000	10.5714	7.5536	3.26	4.57	1.40
5^{o}-10^{o}	4.0000	1.2455	0.5000	3.21	8.00*	2.49
10^{o}-15^{o}	1.0714	1.4821	0.6964	1.38	1.54	2.13
15^{o}-20^{o}	0.2143	1.2813	1.1429	5.98*	5.33*	1.12
20^{o}-25^{o}	0.4107	0.3571	0.6964	1.15	1.70	1.95
25^{o}-30^{o}	0.0000	0.2455	0.5000	—	—	2.04
30^{o}-35^{o}	0.5714	0.0714	0.2143	8.00*	2.67	3.00

Table 10-(concluded)

				F-values[a]		
Measurements	OR	Strips	OFB	OR vs Strips	OR vs OFB	Strips vs OFB
35^{o}-40^{o}	0.2679	0.8393	0.5536	3.13	2.07	1.52
40^{o}-45^{o}	0.4107	0.1964	0.2679	2.09	1.53	1.36
45^{o}-50^{o}	0.8393	0.4955	0.2679	1.69	3.13	1.85
50^{o}-55^{o}	1.1429	0.7143	0.4107	1.60	2.78	1.74
55^{o}-60^{o}	1.0714	0.5536	0.5536	1.94	1.94	1.00

[a] n=8; $F_{.025,7,7} = 4.99$; *- significant at 5% level; $F_{.005,7,7} = 8.89$; **- significant at 1% level

[b] n=7; $F_{.025,6,7} = 5.12$; *- significant at 5% level; $F_{.005,6,7} = 9.16$; **- significant at 1% level

Table 11-Mean squares, Expt. I

Measurements	Source of variation		
	Rounds	Treatment	Error
df	3	1	11
Initial tenderness	0.2373	0.8556	0.3270
Final tenderness	0.0273	0.9506	0.2220
Juiciness	0.1106	0.1806	0.2215
Rare beef flavor	0.3540	0.0306	0.1243
Apparent doneness	0.0640	0.0506	0.8397
Hardness	1.4058	6.2500	0.2656
Cohesiveness	0.0020	0.0036	0.0039
Elasticity	0.2417	1.0000	0.5405
Chewiness	8.2873	102.5156	8.0297
Shear cohesiveness	0.7928	7.4393	1.1284
Firmness	160.3955	1637.2139	145.6080
WHC	0.00004	0.0004	0.0011
pH	0.0283	0.0023	0.0076
TM, Brabender	0.5750	2.5600	0.6095
Total cooking losses	3.2175	8.4100	1.9086
0°-60° cooking time	13.3958	333.0625	31.0625
Heat penetration rates			
5°-10°	1.2292	3.0625	3.0625
10°-15°	1.7292	0.5625	3.1534
15°-20°	0.4167	0.2500	1.2955
20°-25°	2.5000	0.2500	0.3864
25°-30°	0.5000	0.0000	0.7727
30°-35°	1.8958	3.0625	0.9261
35°-40°	1.1667	9.0000	0.4091
40°-45°	0.5625	0.0625	0.7443
45°-50°	0.5000	2.2500	0.9318
50°-55°	0.2292	14.0625	1.0625
55°-60°	1.5625	7.5625	1.0625
df	3	1	9
Ether extract	0.1637	17.8564	0.9383
TM, A.O.A.C.	7.7601	4.7960	2.9118

Table 12-Mean squares, Expt. II

Measurements	Rounds	Treatment	Error
	Source of variation		
df	7	2	14
Initial tenderness	0.7976	1.2950	0.2998
Final tenderness	0.1312	1.0929	0.1839
Juiciness	0.0286	1.6663	0.2491
Rare beef flavor	0.2028	2.2850	0.2026
Apparent doneness	0.4709	2.4200	0.6457
Hardness	2.7963	10.8302	1.2352
Cohesiveness	0.0045	0.0056	0.0031
Elasticity	3.7295	0.5379	1.9441
Chewiness	77.8198	271.4779	60.7917
Shear cohesiveness	6.8247	20.6408	2.0732
Firmness	13.4476	262.5867	27.7048
WHC	0.0021	0.0051	0.0014
pH	0.2433	0.0005	0.0038
TM, A.O.A.C.	1.2405	25.2419	0.3412
Ether extract	1.8724	1.6666	1.0410
Total cooking losses	6.5836	169.0829	2.2148
0°-60° cooking time	13.6607	1696.6250	19.4821
Heat penetration rates			
5°-10°	0.5223	5.4688	2.6116
10°-15°	1.1429	1.7917	1.0536
15°-20°	0.8438	1.6354	0.8973
20°-25°	0.3095	3.7917	0.5774
25°-30°	0.3080	2.8854	0.2188
30°-35°	0.2857	5.1667	0.2857
35°-40°	0.5655	6.1667	0.5476
40°-45°	0.1607	12.6667	0.3571
45°-50°	0.5818	23.8438	0.5104
50°-55°	0.4940	19.6250	0.8869
55°-60°	0.4762	51.0417	0.8512
df	7	2	13
L-value	7.6136	0.9857	0.7969
a-value	2.1827	51.6868	1.6484
b-value	0.2037	3.2380	0.2852
df	7	7	1
Volume	32398.2054	28476.5625	16243.7054
Length	0.3839	0.5625	0.5982
Width	0.5513	1.8906	1.0335
Depth	1.6914	0.3600	1.0814

Table 13-Initial tenderness[a] scores

Replication	Treatments		
	Strips	OR	OFB
	Expt. I		
I1	3.4	4.0	
I2	4.3	3.2	
II1	4.4	3.4	
II2	4.4	3.1	
III1	4.9	3.9	
III2	4.4	3.4	
IV1	2.8	4.2	
IV2	3.8	3.5	
Avg.	4.1	3.6	
	Expt. II		
I	4.0	4.8	3.3
II	4.6	3.9	2.7
III	4.7	3.4	4.3
IV	4.1	4.1	3.1
V	4.2	4.1	3.1
VI	4.0	4.3	3.0
VII	4.4	3.7	4.5
VIII	4.1	3.7	3.4
Avg.	4.3	4.0	3.4

[a]Range: Expt. I 5-tender; 1-slightly tough
Expt. II 5-tender; 1-tough

Table 14-Final tenderness[a] scores

Replication	Treatments		
	Strips	OR	OFB
		Expt. I	
I1	3.4	3.8	
I2	3.9	3.4	
II1	4.4	3.3	
II2	4.0	3.2	
III1	4.4	3.6	
III2	4.1	2.5	
IV1	3.4	3.8	
IV2	3.4	3.5	
Avg.	3.9	3.4	
		Expt. II	
I	4.1	4.7	3.3
II	4.6	4.0	3.6
III	4.6	3.3	4.3
IV	4.0	3.9	3.1
V	4.2	3.9	3.0
VI	3.9	4.2	3.0
VII	4.4	3.9	4.2
VIII	3.9	3.9	3.4
Avg.	4.2	4.0	3.5

[a]Range: Expt. I 5-tender; 1-slightly tough
Expt. II 5-tender; 1-tough

Table 15-Juiciness[a] scores

Replication	Strips	OR	OFB
		Treatments	
		Expt. I	
I1	3.7	4.4	
I2	4.2	3.9	
II1	4.2	3.8	
II2	4.0	3.1	
III1	4.4	3.1	
III2	4.4	4.3	
IV1	3.2	4.0	
IV2	4.0	3.8	
Avg.	4.0	3.8	
		Expt. II	
I	4.2	4.2	2.3
II	4.0	4.7	2.6
III	4.0	3.8	3.4
IV	3.7	4.1	3.1
V	4.0	3.7	3.9
VI	3.9	4.0	3.3
VII	3.6	3.6	3.9
VIII	3.4	4.4	3.0
Avg.	3.9	4.1	3.2

[a]Range: Expt. I 5-juicy; 1-slightly dry
Expt. II 5-juicy; 1-dry

Table 16-Rare beef flavor[a] scores

Replication	Treatments		
	Strips	OR	OFB
	Expt. I		
I1	3.7	3.7	
I2	3.7	4.3	
II1	3.3	3.1	
II2	3.4	2.8	
III1	3.5	3.0	
III2	4.1	3.6	
IV1	3.2	3.8	
IV2	3.9	3.8	
Avg.	3.6	3.5	
	Expt. II		
I	3.9	3.7	2.1
II	3.3	3.6	2.0
III	3.9	3.0	3.3
IV	3.6	3.1	2.4
V	4.0	3.5	3.7
VI	4.2	3.3	2.8
VII	3.9	3.7	3.0
VIII	3.1	4.0	2.4
Avg.	3.7	3.5	2.7

[a]Range: 5-intense rare beef flavor; 1-no rare beef flavor

Table 17-Apparent doneness[a] scores

Replication	Treatments		
	Strips	OR	OFB
		Expt. I	
I1	2.8	3.6	
I2	2.8	1.2	
II1	2.6	3.0	
II2	2.9	1.2	
III1	1.9	3.5	
III2	2.5	1.3	
IV1	2.5	1.9	
IV2	2.1	3.5	
Avg.	2.5	2.4	
		Expt. II	
I	1.8	3.0	4.0
II	2.3	3.6	4.4
III	2.0	1.8	4.2
IV	2.0	1.1	3.1
V	1.5	2.9	3.0
VI	2.0	3.8	2.9
VII	2.7	3.0	2.5
VIII	3.4	2.9	2.4
Avg.	2.2	2.8	3.3

[a]Range: 5-well done; 1-rare

Table 18-Hardness values, kg

Replication	Treatments		
	Strips	OR	OFB
		Expt. I	
I1	4.37	5.36	
I2	4.82	5.68	
II1	4.86	5.43	
II2	4.69	5.19	
III1	5.11	6.75	
III2	4.61	7.66	
IV1	5.93	6.59	
IV2	5.11	6.84	
Avg.	4.94	6.06	
		Expt. II	
I	6.08	5.17	6.92
II	5.30	8.27	7.90
III	4.93	8.90	7.47
IV	6.57	8.57	8.17
V	5.87	8.20	7.47
VI	6.47	5.97	9.97
VII	5.20	7.77	7.97
VIII	3.80	3.93	6.53
Avg.	5.53	7.10	7.80

Table 19-Cohesiveness values

Replication	Treatments		
	Strips	OR	OFB
		Expt. I	
I1	0.39	0.42	
I2	0.43	0.51	
II1	0.51	0.41	
II2	0.29	0.39	
III1	0.41	0.46	
III2	0.49	0.41	
IV1	0.42	0.53	
IV2	0.40	0.45	
Avg.	0.42	0.45	
		Expt. II	
I	0.47	0.31	0.39
II	0.31	0.42	0.42
III	0.40	0.41	0.43
IV	0.45	0.45	0.43
V	0.42	0.52	0.49
VI	0.48	0.46	0.47
VII	0.36	0.48	0.53
VIII	0.39	0.52	0.53
Avg.	0.41	0.45	0.46

Table 20-Elasticity values, mm

Replication	Strips	OR	OFB
	Expt. I		
I1	6.7	5.4	
I2	5.0	5.4	
II1	5.9	6.0	
II2	4.7	6.0	
III1	4.9	5.0	
III2	4.2	6.7	
IV1	5.5	5.4	
IV2	4.5	5.5	
Avg.	5.2	5.7	
	Expt. II		
I	5.7	5.0	6.9
II	7.4	5.9	7.7
III	6.5	7.7	9.0
IV	6.9	6.9	8.2
V	6.9	9.5	8.7
VI	7.2	7.7	7.9
VII	7.0	7.2	8.9
VIII	8.5	7.7	8.9
Avg.	7.0	7.2	8.3

Table 21-Chewiness values, kg-mm

Replication	Treatments		
	Strips	OR	OFB
	Expt. I		
I1	11.3	12.1	
I2	10.4	15.5	
II1	14.2	13.4	
II2	6.3	12.2	
III1	10.2	15.5	
III2	9.4	20.9	
IV1	13.7	18.7	
IV2	9.2	16.9	
Avg.	10.6	15.7	
	Expt. II		
I	16.2	8.0	18.5
II	12.1	20.3	25.4
III	12.8	27.9	28.9
IV	20.3	26.4	28.7
V	16.9	40.5	31.7
VI	22.2	21.0	36.8
VII	13.1	26.7	37.2
VIII	12.6	15.7	30.7
Avg.	15.8	23.3	29.7

Table 22-Shear cohesiveness values, kg

Replication	Treatments		
	Strips	OR	OFB
		Expt. I	
I1	7.08	5.62	
I2	5.98	6.10	
II1	6.59	8.65	
II2	5.85	6.67	
III1	4.69	6.50	
III2	5.66	7.91	
IV1	4.69	6.30	
IV2	4.45	8.15	
Avg.	5.62	6.99	
		Expt. II	
I	4.83	5.33	7.58
II	4.87	8.23	5.93
III	4.97	7.47	7.77
IV	8.47	8.57	14.63
V	7.10	8.97	10.53
VI	5.47	5.97	10.37
VII	5.27	8.80	7.20
VIII	5.70	7.80	8.30
Avg.	5.84	7.64	9.04

Table 23-Firmness values, kg/min

Replication	Treatments		
	Strips	OR	OFB
		Expt. I	
I1	20.93	31.01	
I2	11.87	45.74	
II1	20.04	41.50	
II2	24.31	35.93	
III1	12.44	35.66	
III2	14.51	28.67	
IV1	33.80	24.76	
IV2	18.26	74.74	
Avg.	19.52	39.75	
		Expt. II	
I	16.3	21.8	33.1
II	16.4	28.1	26.5
III	11.8	22.1	28.0
IV	21.6	27.4	51.9
V	23.0	22.1	35.7
VI	17.5	17.6	35.4
VII	18.7	34.0	25.8
VIII	15.5	21.3	27.7
Avg.	17.6	24.3	33.0

Table 24-Water-holding capacity values

	Treatments		
Replication	Strips	OR	OFB
		Expt. I	
I1	0.6485	0.6952	
I2	0.6305	0.6741	
II1	0.6071	0.6920	
II2	0.6627	0.6576	
III1	0.6196	0.6650	
III2	0.6756	0.6665	
IV1	0.6771	0.6126	
IV2	0.6984	0.6360	
Avg.	0.6524	0.6624	
		Expt. II	
I	0.6130	0.6870	0.6700
II	0.5941	0.5561	0.6578
III	0.6672	0.6047	0.6333
IV	0.5799	0.6254	0.6303
V	0.6352	0.6275	0.6786
VI	0.6483	0.5859	0.6823
VII	0.6079	0.6050	0.6379
VIII	0.6114	0.6984	0.6922
Avg.	0.6121	0.6238	0.6603

Table 25-pH values

Replication	Treatments		
	Strips	OR	OFB
		Expt. I	
I1	5.55	5.44	
I2	5.37	5.55	
II1	5.55	5.65	
II2	5.74	5.57	
III1	5.56	5.54	
III2	5.39	5.65	
IV1	5.40	5.41	
IV2	5.49	5.43	
Avg.	5.51	5.53	
		Expt. II	
I	5.36	5.40	5.39
II	5.41	5.39	5.39
III	5.41	5.55	5.51
IV	5.35	5.50	5.33
V	5.62	5.58	5.55
VI	5.69	5.54	5.63
VII	5.49	5.44	5.51
VIII	5.37	5.40	5.50
Avg.	5.46	5.48	5.48

Table 26-Percentage total moisture, A.O.A.C. method

	Treatments		
Replication	Strips	OR	OFB
	Expt. I		
I1	66.1	66.9	
I2	68.0	69.3	
II1	66.4	67.6	
II2	61.9	____	
III1	65.2	63.0	
III2	64.1	____	
IV1	64.6	66.2	
IV2	63.1	65.0	
Avg.	64.9	66.1	
	Expt. II		
I	64.6	63.7	61.8
II	65.8	65.3	62.9
III	66.9	66.0	62.9
IV	66.5	67.0	62.7
V	66.7	64.5	61.8
VI	65.5	64.7	63.0
VII	66.2	65.7	62.8
VIII	65.5	66.0	63.2
Avg.	65.9	65.4	62.6

Table 27 -Percentage ether extract

Replication	Strips	OR	OFB
		Treatments	
		Expt. I	
I1	6.4	2.8	
I2	5.5	4.5	
II1	7.1	2.9	
II2	5.2	___	
III1	5.2	4.6	
III2	6.9	___	
IV1	5.9	2.5	
IV2	5.9	4.7	
Avg.	6.0	3.7	
		Expt. II	
I	5.6	4.6	4.7
II	6.8	3.8	3.3
III	3.9	2.9	3.4
IV	5.4	3.5	5.7
V	4.6	6.0	7.4
VI	5.7	5.1	5.0
VII	4.4	3.6	5.7
VIII	4.2	4.2	3.6
Avg.	5.1	4.2	4.8

Table 28-Percentage total cooking losses

Replication	Strips	OR	OFB
		Treatments	
		Expt. I	
I1	21.4	21.5	
I2	20.4	23.0	
II1	22.6	21.6	
II2	19.3	21.3	
III1	19.4	21.2	
III2	19.9	21.2	
IV1	20.6	19.8	
IV2	16.1	21.7	
Avg.	20.0	21.4	
		Expt. II	
I	19.3	20.4	30.8
II	19.1	22.3	29.3
III	19.3	21.8	29.1
IV	18.9	20.2	28.8
V	23.3	24.5	28.7
VI	23.6	24.3	30.8
VII	19.8	23.1	29.6
VIII	26.1	23.3	30.6
Avg.	21.2	22.5	29.7

Table 29-Percentage drip cooking losses

	Treatments		
Replication	Strips	OR	OFB
		Expt. I	
I1	20.0	3.9	
I2	19.3	4.0	
II1	20.8	3.3	
II2	19.3	3.8	
III1	17.3	4.3	
III2	18.8	4.7	
IV1	19.9	2.3	
IV2	15.4	3.6	
Avg.	18.7	3.7	
		Expt. II	
I	18.7	2.4	23.8
II	17.6	2.6	23.4
III	18.4	2.8	21.9
IV	18.7	3.0	21.6
V	22.8	2.8	22.1
VI	21.6	2.9	23.6
VII	19.1	3.6	23.3
VIII	25.1	3.2	23.4
Avg.	20.3	2.9	22.9

Table 30-Percentage volatile cooking losses

Replication	Strips	OR	OFB
		Expt. I	
I1	1.4	17.1	
I2	0.7	18.6	
II1	1.0	17.7	
II2	0.3	17.0	
III1	1.0	16.2	
III2	0.7	16.0	
IV1	0.7	17.0	
IV2	1.0	17.8	
Avg.	0.8	17.2	
		Expt. II	
I	0.5	17.6	—
II	0.5	19.4	5.3
III	0.9	18.0	6.4
IV	0.2	16.7	6.5
V	0.7	21.1	5.7
VI	0.5	21.2	6.1
VII	0.7	19.2	5.8
VIII	0.8	19.5	4.4
Avg.	0.6	19.1	5.6

Table 31-0°-60° cooking time, min.

Replication	Treatments		
	Strips	OR	OFB
	Expt. I		
I1	85	62	
I2	80	81	
II1	80	68	
II2	82	73	
III1	80	74	
III2	82	66	
IV1	80	83	
IV2	83	72	
Avg.	81.5	72.4	
	Expt. II		
I	80	76	51
II	77	74	53
III	85	61	58
IV	83	61	51
V	82	68	53
VI	87	74	57
VII	85	66	56
VIII	85	66	52
Avg.	83.0	68.3	53.9

Table 32-Initial weight values, g

Replication	Strips	OR	OFB
		Expt. I	
I1	285	1384	
I2	280	1407	
II1	288	1222	
II2	290	1197	
III1	289	1378	
III2	282	1394	
IV1	286	1412	
IV2	286	1379	
Avg.	285.8	1346.6	
		Expt. II	
I	379	1372	1363
II	387	1384	1387
III	436	1417	1414
IV	418	1308	1378
V	403	1409	1413
VI	402	1456	1411
VII	414	1361	1433
VIII	379	1322	1350
Avg.	402.3	1378.6	1393.6

Table 33-HunterLab L, a, and b values, Expt. II

Replication	Strips	OR	OFB
		L-value	
I	47.18	47.89	48.96
II	48.89	50.45	48.79
III	46.72	47.75	46.45
IV	44.90	44.63	46.09
V	47.39	46.87	45.76
VI	45.38	47.41	45.56
VII		48.60	47.12
VIII	50.97	49.64	49.11
Avg.	47.35	47.91	47.23
		a-value	
I	8.82	7.43	4.10
II	9.35	6.87	4.42
III	9.45	5.46	4.29
IV	10.79	7.77	3.95
V	13.34	6.57	4.55
VI	9.16	8.90	4.67
VII		7.35	4.10
VIII	6.49	5.19	4.33
Avg.	9.63	6.94	4.30
		b-value	
I	10.33	10.15	9.52
II	10.86	10.50	9.71
III	9.97	9.77	9.10
IV	10.21	9.65	8.96
V	12.04	9.52	8.70
VI	9.94	10.28	9.19
VII		10.55	9.20
VIII	10.35	9.76	9.56
Avg.	10.53	10.02	9.24

Table 34- Volume and total cooking time for OR and OFB roasts

Replication	Volume cm^3 OR	Volume cm^3 OFB	Total cooking time min OR	Total cooking time min OFB
		Expt. I		
I1	1008		97	
I2	1251		106	
II1	986		88	
II2	1069		88	
III1	1238		94	
III2	945		91	
IV1	1418		103	
IV2	1124		107	
Avg.	1129.9		96.8	
		Expt. II		
I	936	924	101	91
II	1149	1326	109	88
III	1050	1242	106	103
IV	1050	1061	96	96
V	1326	1170	118	93
VI	1311	1250	114	97
VII	827	1248	106	96
VIII	970	1073	106	87
Avg.	1077.4	1161.8	107.0	93.9

Table 35-Heat penetration rates, min., Expt. I

	Strips					
Replication	0^{o}-5^{o}	5^{o}-10^{o}	10^{o}-15^{o}	15^{o}-20^{o}	20^{o}-25^{o}	25^{o}-30^{o}
I1	16	7	7	3	6	6
I2	22	3	5	3	5	4
II1	20	5	4	5	4	4
II2	18	6	3	6	4	6
III1	23	4	3	4	4	4
III2	20	4	6	4	3	5
IV1	18	4	4	5	5	5
IV2	20	5	5	4	4	6
Avg.	19.6	4.8	4.6	4.3	4.4	5.0
Replication	30^{o}-35^{o}	35^{o}-40^{o}	40^{o}-45^{o}	45^{o}-50^{o}	50^{o}-55^{o}	55^{o}-60^{o}
I1	5	6	5	7	8	9
I2	6	5	5	7	8	7
II1	5	7	6	6	7	7
II2	4	7	6	6	8	8
III1	5	7	6	5	8	7
III2	8	6	5	7	9	8
IV1	6	5	5	8	6	9
IV2	5	5	6	5	8	10
Avg.	5.5	6.0	5.5	6.4	7.8	8.1

Table 35-(concluded)

	OR					
Replication	0^o-5^o	5^o-10^o	10^o-15^o	15^o-20^o	20^o-25^o	25^o-30^o
I1	46	5	2	4	5	4
I2	42	8	7	6	5	6
II1	31	5	4	4	4	5
II2	32	4	6	4	5	4
III1	37	6	4	5	3	5
III2	42	4	4	4	4	5
IV1	36	9	8	6	6	5
IV2	46	4	5	3	5	6
Avg.	39.0	5.6	5.0	4.5	4.6	5.0
Replication	30^o-35^o	35^o-40^o	40^o-45^o	45^o-50^o	50^o-55^o	55^o-60^o
I1	4	4	6	5	5	7
I2	4	5	5	7	5	6
II1	4	5	5	6	7	8
II2	4	5	6	6	5	7
III1	6	4	5	6	6	7
III2	4	4	5	5	5	5
IV1	5	5	5	5	7	6
IV2	6	4	8	5	7	8
Avg.	4.6	4.5	5.6	5.6	5.9	6.8

Table 36-Heat penetration rates, min., Expt. II

	Strips					
Replication	0^{o}-5^{o}	5^{o}-10^{o}	10^{o}-15^{o}	15^{o}-20^{o}	20^{o}-25^{o}	25^{o}-30^{o}
I	20.5	6.0	4.0	4.5	4.0	4.5
II	19.0	3.5	4.0	3.5	4.5	4.5
III	21.0	4.0	4.5	4.0	4.5	5.0
IV	21.5	4.0	4.0	4.0	4.5	4.5
V	20.5	6.0	5.0	4.0	3.5	4.5
VI	24.5	4.5	4.0	4.0	4.5	4.0
VII	22.5	5.0	4.0	3.5	5.0	3.5
VIII	15.5	6.5	7.5	7.0	5.5	5.0
Avg.	20.6	4.9	4.6	4.3	4.5	4.4
Replication	30^{o}-35^{o}	35^{o}-40^{o}	40^{o}-45^{o}	45^{o}-50^{o}	50^{o}-55^{o}	55^{o}-60^{o}
I	4.5	5.5	5.5	6.5	6.5	8.5
II	4.5	5.5	6.0	6.5	6.5	9.0
III	5.0	6.0	6.0	8.0	7.5	9.0
IV	5.0	5.0	6.5	7.0	7.5	9.5
V	5.0	5.0	6.0	7.0	6.5	9.0
VI	4.5	6.5	6.0	7.0	7.5	9.0
VII	5.0	6.0	6.0	7.0	7.0	10.5
VIII	4.5	3.5	5.0	5.5	9.0	10.5
Avg.	4.8	5.4	5.9	6.8	7.3	9.4

Table 36 -(continued)

	OR					
Replication	0^o-5^o	5^o-10^o	10^o-15^o	15^o-20^o	20^o-25^o	25^o-30^o
I	48.0	7.0	4.0	4.0	4.0	4.0
II	14.0	7.0	6.0	5.0	5.0	4.0
III	10.0	7.0	5.0	4.0	4.0	4.0
IV	12.0	8.0	5.0	4.0	4.0	4.0
V	22.0	3.0	3.0	4.0	4.0	4.0
VI	32.0	9.0	6.0	4.0	3.0	4.0
VII	10.0	7.0	5.0	5.0	4.0	4.0
VIII	29.0	4.0	4.0	4.0	3.0	4.0
Avg.	22.1	6.5	4.8	4.3	3.9	4.0
Replication	30^o-35^o	35^o-40^o	40^o-45^o	45^o-50^o	50^o-55^o	55^o-60^o
I	5.0	4.0	5.0	5.0	6.0	5.0
II	5.0	5.0	5.0	7.0	6.0	8.0
III	4.0	4.0	5.0	5.0	4.0	6.0
IV	3.0	4.0	4.0	4.0	4.0	5.0
V	5.0	5.0	5.0	6.0	7.0	7.0
VI	5.0	5.0	4.0	6.0	6.0	6.0
VII	5.0	5.0	5.0	5.0	5.0	6.0
VIII	4.0	5.0	6.0	5.0	6.0	7.0
Avg.	4.5	4.6	4.9	5.4	5.5	6.3

Table 36-(concluded)

	OFB					
Replication	0^o-5^o	5^o-10^o	10^o-15^o	15^o-20^o	20^o-25^o	25^o-30^o
I	51.0	4.0	3.0	2.0	4.0	3.0
II	47.0	5.0	5.0	4.0	3.0	4.0
III	30.0	6.0	4.0	2.0	2.0	3.0
IV	56.0	6.0	3.0	3.0	4.0	2.0
V	10.0	6.0	4.0	5.0	3.0	4.0
VI	42.0	5.0	4.0	4.0	3.0	3.0
VII	53.0	5.0	3.0	4.0	2.0	3.0
VIII	10.0	5.0	5.0	4.0	4.0	4.0
Avg.	37.4	5.3	3.9	3.5	3.1	3.3
Replication	30^o-35^o	35^o-40^o	40^o-45^o	45^o-50^o	50^o-55^o	55^o-60^o
I	4.0	3.0	4.0	4.0	4.0	5.0
II	3.0	3.0	3.0	3.0	4.0	4.0
III	3.0	3.0	3.0	4.0	4.0	4.0
IV	3.0	4.0	3.0	3.0	5.0	4.0
V	3.0	4.0	4.0	4.0	3.0	4.0
VI	4.0	5.0	3.0	3.0	5.0	6.0
VII	3.0	3.0	4.0	3.0	4.0	4.0
VIII	3.0	4.0	3.0	3.0	4.0	4.0
Avg.	3.3	3.6	3.4	3.4	4.1	4.4

Table 37-Length, width, and depth values for OR or OFB roasts

Replication	Length, cm		Width, cm		Depth, cm	
	OR	OFB	OR	OFB	OR	OFB
			Expt. I			
I1	14.0		12.0		6.0	
I2	13.0		13.0		7.4	
II1	14.0		11.0		6.4	
II2	13.5		12.0		6.6	
III1	14.0		13.0		6.8	
III2	15.0		14.0		4.5	
IV1	14.0		12.5		8.1	
IV2	14.0		11.0		7.3	
Avg.	13.9		12.3		6.6	
			Expt. II			
I	13.0	14.0	12.0	12.0	6.0	5.5
II	13.0	13.0	13.0	12.0	6.8	8.5
III	14.0	13.5	10.0	11.5	7.5	8.0
IV	14.0	13.0	10.0	12.0	7.5	6.8
V	13.0	13.0	12.0	12.0	8.5	7.5
VI	12.0	12.5	11.5	12.5	9.5	8.0
VII	13.0	13.0	12.0	12.0	5.3	8.0
VIII	14.0	13.0	11.0	11.0	6.3	7.5
Avg.	13.3	13.1	11.4	11.9	7.2	7.5

Table 38-Total moisture, Brabender, %, Expt. I

Replication	Strips	OR
I1	65.6	66.4
I2	66.0	66.8
II1	65.1	66.4
II2	67.1	67.1
III1	67.4	66.3
III2	66.3	67.4
IV1	65.8	68.7
IV2	66.5	67.1
Avg.	66.2	67.0

Table 39-Means and probability that means are equal for misc. measurements, Expt. II

	Means		
Measurement	OFB	OR	P
Initial weight, g	1393.6	1378.6	0.29
Volume, cm^3	1161.8	1077.4	0.23
Length, cm	12.9	13.3	0.36
Width, cm	12.1	11.4	0.22
Depth, cm	7.5	7.2	0.58
Total cooking time	93.9	107.0	0.004

DIFFERENCES BETWEEN CONVENTIONALLY COOKED TOP ROUND ROASTS AND SEMIMEMBRANOSUS MUSCLE STRIPS COOKED IN A MODEL SYSTEM

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

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1981

ABSTRACT

To study effects of heating on muscle, some researchers have used model systems in which small pieces of muscle are heated in plastic bags or test tubes in a water bath in place of roasts cooked by conventional methods. The assumption was made that if the muscle was heated at the rate that occurs with conventional methods the quality characteristics of the meat would be the same. Researchers should know whether the method of heating significantly affects the meat, especially if results from studies that used a model system are to be compared to studies that used conventional methods.

In two experiments, randomized complete block designs were used to evaluate differences between 1.4-kg top round roasts (SM and AD muscles) cooked by oven roasting (OR) or oven film bags (OFB) and SM strips (2 x 2.3 x 7 cm) heated in test tubes in a water bath. Roasts were cooked in a 177°C rotary hearth electric oven to an end point temperature of 60°C. Strips were cooked to an end point temperature of 60°C at an average heat penetration rate that occurred with oven roasting 1.4-kg top round roasts.

Roasts cooked by moist heat (OFB) cooked faster ($P<0.0001$), and were less tender ($P<0.05$), less juicy ($P<0.003$), had less rare beef flavor ($P<0.004$), less red ($P<0.001$) and yellow ($P<0.01$) color, and more total cooking losses ($P<0.0001$) than roasts cooked by dry heat (OR).

Strips had significantly lower values for Instron texture measurements of hardness, chewiness, shear cohesiveness, and firmness than roasts cooked by dry or moist heat. Strips had a longer cooking time ($P<0.0001$) and a slower rate of heating above 50°C

($P < 0.02$) than roasts. Although strips were cooked in a moist atmosphere at a rate that occurred with oven roasting, strips were more like roasts cooked by dry heat than they were like roasts cooked by moist heat.

Correlation coefficients showed no consistent trends between experiments or between treatments except moderate or high correlation between initial and final tenderness. Variance for a given measurement was similar between meat cooked in a model system or by conventional methods.