STANDARDIZATION OF DRY HEAT COOKERY METHODS*

BRAD W. BERRY
Colorado State University

The concept of standardization of meat cookery techniques has confronted meats researchers for some time. The research literature indicates that many cookery procedures and variations thereof have been attempted. Presentations on the standardization of meat cookery and the changes that occur in meat during cookery have been made at recent previous Reciprocal Meats Conferences (Rogers, 1969; and Draudt, 1972). It has been established that factors such as physiological maturity, sex, pre-slaughter management and nutrition, fat content, post-mortem aging and contraction, storage temperature and connective tissue can exert an influence on ultimate meat palatability. With so many influencial factors on palatability prior to cooking, it would appear that standard methods for meat cookery would be well established. However, wide variation exists among researchers in the methodology employed. Perhaps with so many pre-cookery influencial factors on palatability, standardization of cookery methods should basically consist of procedures that when employed with a certain degree of deviation or variation, exert no appreciable effect on palatability.

Much of our meat cookery information and many of the meats cuts are suitable for dry heat methods of cookery. Thus, attempts to standardize or develop recommended procedures for dry heat cookery methods would seem appropriate.

Internal or End-Point Temperature

Unquestionably, the final internal temperature to which meat is cooked determines many of the palatability attributes. Draudt (1972) summarized the effects of heating small samples for 60 minutes at the following temperatures:

40 C will provide an indication of initial tenderness before much heat change has affected the mechanical properties.

50 C will indicate the area of maximum shear value before collagen shrinkage occurs. The meat has undergone denaturation of most of the contractable proteins but the collagen shrinkage reaction, the hardening reaction, and collagen solubilization has not entered the picture.

60 C will show the effect of the collagen shrinkage reaction without appreciable hardening reaction and collagen solubilization as well as the effect of enzyme treatment if this is a variable.

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74 C will indicate the magnitude of the hardening reaction with only limited effect due to collagen solubilization.

90 C will show some effect of solubilization of collagen though time is a factor of substantial importance in "seeing" this effect.

Recent work by Davey and Gilbert (1974) has provided additional insight into the effect of temperature on tenderness (figure 1). Utilizing the beef sternomandibularis muscle, two distinct toughening phases were identified, one between 40 and 50 C and the other between 65 and 75 C. Toughening in the first phase was attributed to the actomyosin effects while the second phase was linked to connective tissue components. Generally, the second phase toughening was closely associated with muscle fiber shrinkage and weight loss (figure 2). Noted in this study, as well as others, was a decreased rate of temperature rise between 65 and 75 C, which was attributed to the massive movement of water from a hydrated to a free form. Collagen shrinkage was presumed to be the driving force in squeezing fluid from muscle. The range of 65 to 75 C frequently encompasses the end point temperature for which meat cookery studies are designed. Thus, unless highly sensitive temperature measuring systems are employed, tenderness differences could in part be due to final interval temperature.

Somewhat different results were obtained by Penfield and Meyer (1975) who observed substantial decreases in shear force values of beef semitendinosus from 50 to 60 C (figure 3). Heating from 60 to 70 C produced no change in shear force, but a substantial solubilization of hydroxyproline. The great decrease in shear values between 50 and 60 C was paralleled by an increase in proteolytic enzyme activity.

Similar results in terms of substantial reductions in shear force between 50 and 60 C with no appreciable change between 60 and 70 C was reported by Bouton and Harris (1972) with the deep pectoral muscle (figure 4). The decreased shear values between 50 and 60 C was attributed to the collagen shrinkage reaction. The increased shear values up to 50 C was believed to be affected partially by (a) a bunching up of connective tissue, not solubilized by heating, caused by the thermal shortening of the sarcomeres and (b) the large increase in the moisture loss from the meat as cooking temperature was increased.

Nonsignificant differences ($P > .05$) in shear force for beef semitendinosus and biceps femoris were found by Paul et al. (1973) among final internal temperatures of 58, 67, 75 and 82 C. However, significant ($P < .01$) increases in collagen solubility occurred with advancement in temperature. End-point temperatures of 60, 70 and 80 C exerted no influence on volume of drippings, percentage lipids in drippings, water holding capacity, shear force values and sensory measurements of beef round roasts in the study of Shaffer et al. (1973).

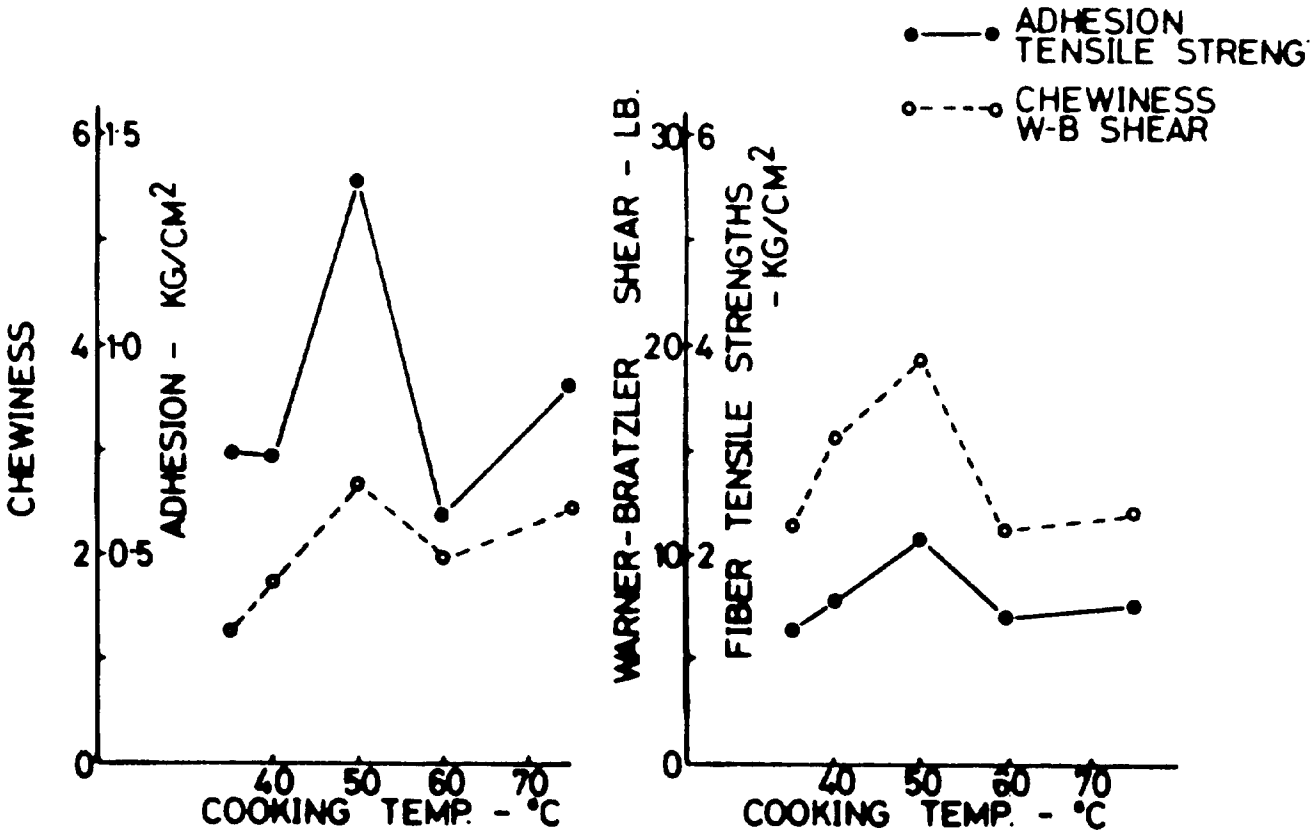

Figure 4. Effect upon Instron compression (chewiness), adhesion, fiber tensile and Warner Bratzler shear values of cooking deep pectoral muscle from 1-yr old steers at 40, 50, 60 and 75 C for 1 hr.
Bouton and Harris (1972).

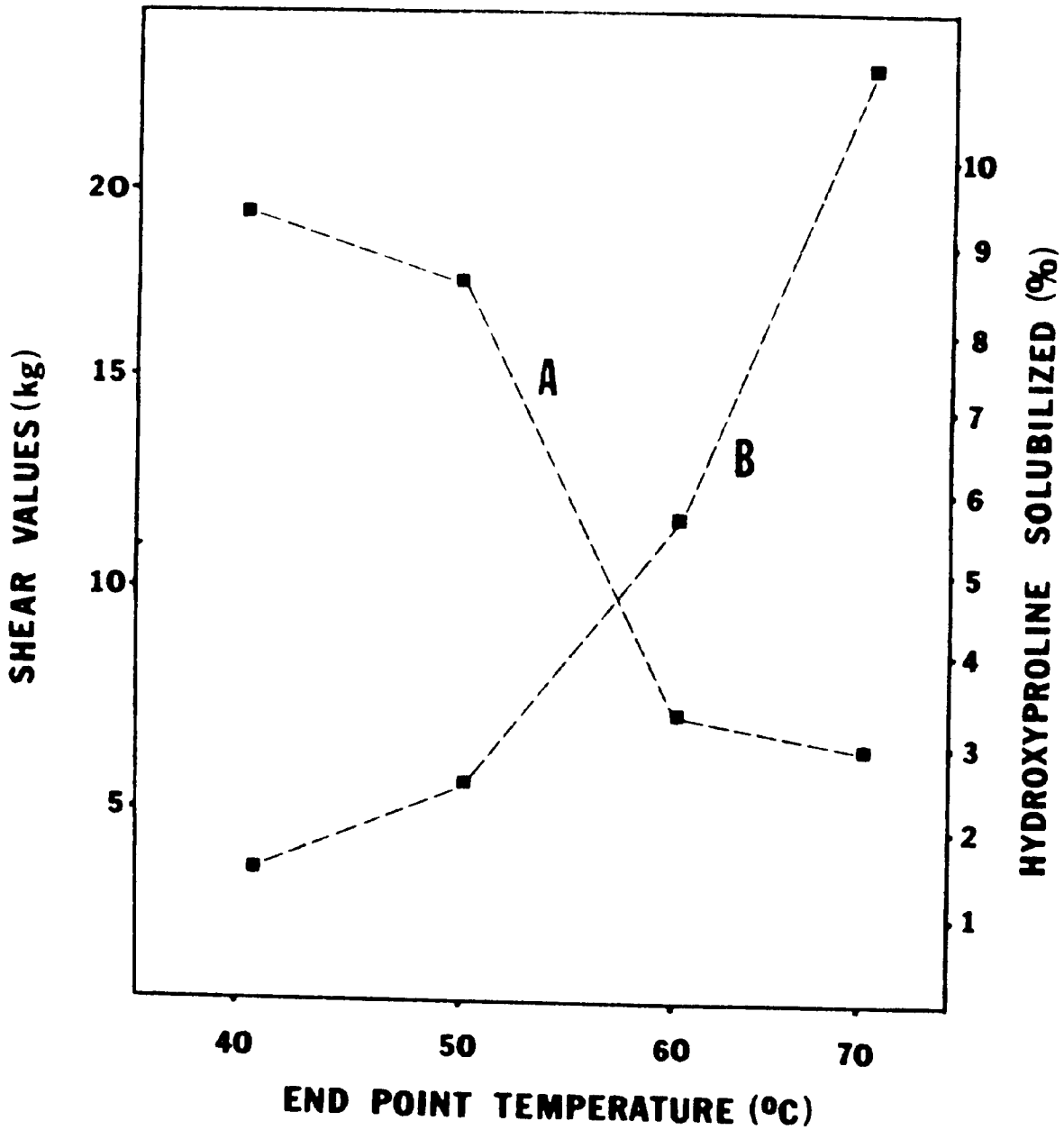

Figure 3. The effect of end point temperature on shear values (A) and percentage of hydroxyproline solubilized (B). Penfield et al. (1975).

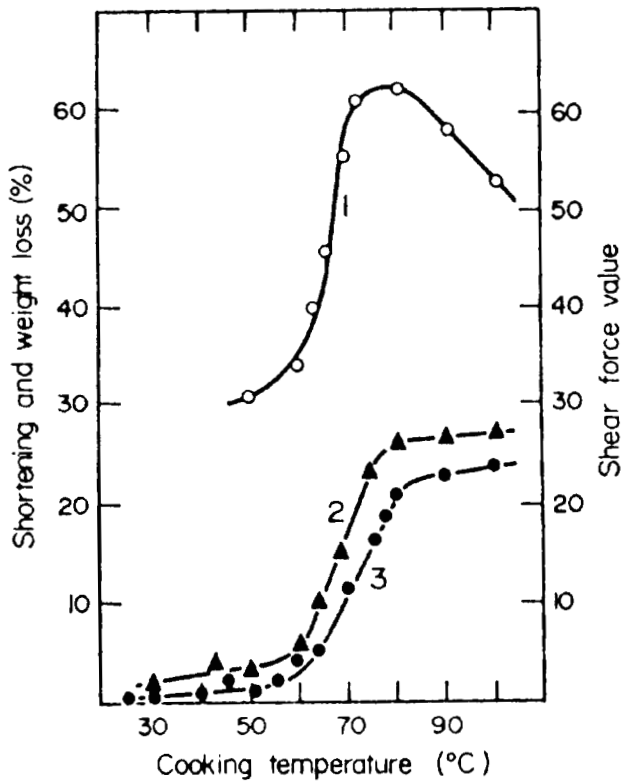

Figure 1. The two-phase effect of cooking temperature on shear force values. Standard deviations are given by vertical lines. Each point is the mean of 8 to 16 determinations from the muscles of four bulls. Davey and Gilbert (1974).

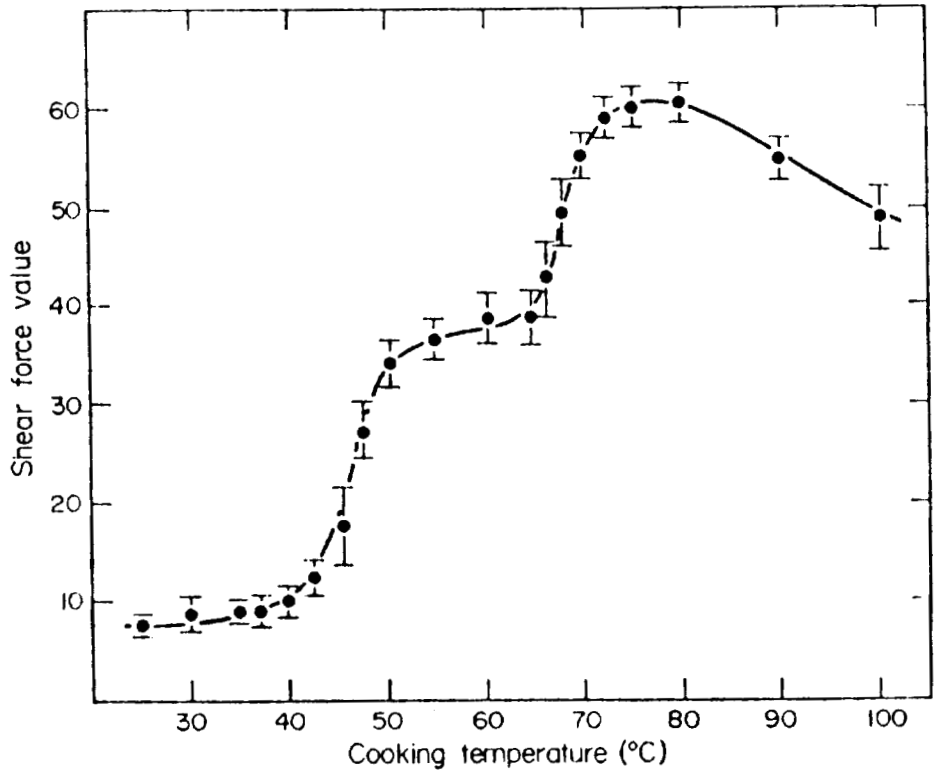

Figure 2. The relationship of the second toughening phase to shrinkage and weight loss. Curve 1, shear-force values (mean of 6 determinations); curve 2, shrinkage along the fibres; curve 3, weight loss. Davey and Gilbert (1974)

Cooking Methods

A variety of dry-heat methods of cookery have been employed to obtain a product of optimum juiciness, flavor and tenderness. Numerous studies have compared microwave or electronic cookery vs roasting and oven-broiling (table 1). Lower shear force values have been reported in some studies for samples prepared by roasting in contrast to samples cooked by microwave. In other experiments no differences in palatability have been reported attributable to cookery method. Goodwin *et al.* (1962) compared microwave, deep fat frying, steam pressure, rotary reel, combination of deep fat frying and steam and a combination of deep fat frying and microwave with the results showing no effect on shear values in turkey muscle.

Table 1. Shear force values (kg) as affected by method of cookery

Cooking method					
Microwave	Roasting	Oven-broiling	Deep fat frying		
3.8	3.2			beef *longissimus*	Berry (1974)
4.4[a]		3.9[b]	3.5[c]	beef *longissimus*	Carpenter *et al.* (1968)
4.2[a]	4.5[a]	4.4[a]		beef *semitendinosus*	McCrae (1973)
6.8[a]	6.1[b]			beef *longissimus*	Ream (1971)
7.8[a]	6.9[a]			beef *longissimus*	Taylor (1969)

[abc] Means on the same line bearing the same superscripts are not significantly different either at $P < .05$ or $P < .01$.

Cooking losses have been shown to be substantial using microwave cookery (table 2). Several investigators have found that microwave cooking results in lower flavor and juiciness scores than conventional methods. However, Fielder *et al.* (1962) reported that deep fat frying and electronic cookery decreased the collagen content more extensively than oven-roasting and broiling. While deep fat frying may aid in controlling certain external variables in cookery as a system it appears somewhat removed from cookery techniques employed by consumers. Cipra

Table 2. Total cooking losses as affected by method of cookery

Cooking method					
Microwave	Roasting	Oven-broiling	Deep fat frying		
27.5	23.0			beef *longissimus*	Berry (1974)
35.0[a]		30.4[b]	29.1[b]	beef *longissimus*	Carpenter *et al*. (1968)
28.3[a]	28.2[a]	23.7[b]		beef *semi-tendinosus*	McCrae (1973)
31.7[a]	17.5[b]			beef *longissimus*	Ream (1971)
39.4	27.6			beef *longissimus*	Taylor (1969)
38.8[a]	17.5[b]			beef *longissimus*	Kylen *et al*. (1964)

[ab] Means on the same line bearing the same superscripts are not significantly different at $P < .05$ or $P < .01$.

et al. (1970) evaluated microwave and conventional roasting from the standpoint of precooking and reheating turkey roasts and concluded that less stale flavors were associated with microwave cookery. Combining both conventional vs microwave cookery and cooking with or without plastic bags, Cole (1973) found more favorable responses in color acceptability, juiciness, flavor and tenderness under microwave cookery when pork roasts were cooked in plastic bags vs cooking out of plastic bags.

Deethardt and Tuma (1971) compared the following four cooking treatments on pork loin roasts: (1) open pan; (2) covered with aluminum foil the entire time; (3) open to 52 C then covered with foil, and (4) covered to 52 C then opened. Texture, tenderness and flavor were unaffected by cooking method. The open pan method resulted in higher juiciness scores than the covered-open system and both methods yield higher juiciness scores than the covered and open-covered methods.

Time-Temperature Effects

The stage of doneness at a given internal temperature will vary with the time required to reach that temperature. Bouton and Harris (1972) evaluated the effects of cooking time on some mechanical properties of meat (table 3).

Table 3. Effect of cooking for up to 16 hr at 70° C upon some mechanical parameters of beef biceps femoris muscle[a]

Mechanical parameter	Cooking time in hr 1	2	4	8	16
Chewiness (Arb. units)	2.50[a]	2.55[a]	2.03[b]	1.95[b]	1.28[c]
Instron Adhesion (kg/cm^2)	1.14[a]	0.84[a]	0.95[a]	0.89[a]	0.48[b]
W-B shear (lb)	17.6[a]	17.9[a]	18.8[a]	16.3[a]	13.5[b]

[abc] Any means in same line with same superscript are not significantly different (Duncan's Multiple Range Test) at $P < 0.05$. Bouton and Harris (1972).

Shear force and adhesion measurements were not decreased until eight hours of cooking time had elapsed. Compression values were also significantly reduced after eight hours of cooking. Their studies indicated that for a standard cooking time of one hour minor variations in the time taken for samples to reach the specified cooking temperatures, due to differences in sample size, would be unlikely to affect the mechanical measurements significantly.

A study performed by Winstead (1970) compared both the time and temperature of heating biceps femoris cores. Shear force values according to temperature (averaged across time) and time (averaged across temperature) are given in table 4. A trend toward increased tenderness with increased time was observed at all three temperatures. A similar comparison of the time-temperature effects for collagen is provided in table 5. Increased amounts of collagen were solubilized with each increase in temperature.

Locker and Daines (1974) used a fast cooking method (40 min. at 80 C and a slow cooking method (55 min. from room temperature to 80 C followed by an extra 30 min. at 80 C and found higher cooking losses in the slow cooking method. Prolonged cooking at 90 C for three hours in

Table 4. Mean shear values associated with temperature and with time of heating

Temperature (°C)	Shear value	Time (min)	Shear value
55	22.7	30	22.6[a]
60	19.4[a]	60	20.8[ab]
65	19.8[a]	120	18.6[b]

[ab] Values in the same column with the same superscripts do not differ ($P > .05$). Winstead (1970).

Table 5. Mean collagen decreases associated with temperature and with time of heating

Temperature (°C)	Decrease	Time (min)	Decrease
55	2.6[a]	30	4.4[a]
60	6.2[b]	60	4.8[a]
65	9.2[c]	120	8.8[b]

[abc] Values in the same column with the same superscripts do not differ ($P > .001$). Winstead (1970).

contrast to one hour has been shown to result in only minimal decreases in shear force (Bouton et al., 1974). Adhesion values were reduced with the additional two hours of cooking regardless of myofibrillar contraction state.

Many studies have illustrated that cooking losses increase as a result of higher internal temperature. Davis et al. (1973) observed constant, steady rates of cooking losses during the first 60 to 90 min until an internal temperature of 20 to 25 C had been reached. After that, accelerated rates of weight loss were noted due to moisture evaporation and drip formation from the hot surface of the meat.

Post-Oven Temperature Increase

The situation of post-oven temperature rise occurs more with larger meat cuts that have been cooked by methods that bring the surface of the meat to a considerably higher temperature than that of the interior. Composition may affect the duration of the temperature rise more than the extent. Samples possessive of considerable fat, especially on the surface may take considerable time to reach the maximum inner temperature. Shaffer et al. (1973) observed more frequent post-oven rise when moist cookery rather than dry heat procedures were used with round roasts. Greater post-oven temperature rises were found at lower end-point temperatures both in this study and that of Rogers et al. (1967).

Thermal Conductivity and Heat Penetration

According to Paul and Palmer (1972) the rate at which an interior section of meat will heat is influenced by: (1) the rate at which energy is supplied; (2) the rate at which it is transmitted to the meat; (3) the shape and size of the sample being heated; (4) the sample composition, (5) spatial distribution of areas of lean, fat, connective tissue and bone, (6) characteristics of the meat surface and (7) changes induced in meat by heat, including protein denaturation, loss of water and melting of fat. Concerning the thermal conductivity of meat, Haughey (1968) states that cooking time depends on (1) heat transfer to the surface of the meat (2) internal heat transfer which, by raising the temperature, denatures the proteins and produces the cooked state; and (3) mass transfer resulting from the release of water originally immobilized by the proteins, the diffusion of this water (and possibly also fat) through the meat due to concentration gradients and the evaporation of water and drip loss from the meat surface.

Mean values for rates of heat penetration (McCrae et al., 1974) as related to cookery method are provided in table 6. The rate of heat penetration was most rapid between 30 and 50 C which may be due to a decrease in the temperature differential between the outside and center portions. The slowest heating rates in the 60-70 C and 50-60 C intervals was theorized as being due to an increased energy utilization for protein denaturization and water evaporization. Roasting had the slowest rate of heat penetration and microwave cookery the fastest.

Flavor

Most of the discussion has centered on how tenderness, juiciness and cooking loss is affected by various factors in meat cookery. Meat surfaces are exposed to high temperatures during dry-heat cookery. Concentration of flavor contributors occurs on the surface. Cooking time and temperature may also affect flavor becoming undesirable if extensive protein and fat decomposition occurs.

Table 6. Mean values for rates of heat penetration

Temperature interval in degrees C	Heat penetration rate as minutes per degree			
	Microwave	Braising	Roasting	Oven-broiling
10-20	0.25	0.60	0.90	0.30
20-30	0.25	0.45	0.75	0.30
30-40	0.15	0.30	0.75	0.30
40-50	0.10	0.45	0.90	0.30
50-60	0.20	0.45	1.20	0.45
60-70	0.35	0.60	1.80	0.45

McCrae *et al*. (1974)

Summary

It would appear that with a continuation of conflicting research information, complete standardization of meat cookery techniques is impossible. Certainly, pre- and post-slaughter factors influencing the experimental meat sample will partially determine the cookery standards employed. A more closely confined set of standards for use in dry heat cookery research would certainly aid in interpretation of research literature.

The following are areas that need to be considered in establishing recommended guidelines for dry heat cookery methods for meat. Some have been elaborated on in this paper, while on others, little information is known and they appear to be fertile ground for future research.

1. Cookery method--roasting vs oven-broiling vs microwave vs deep-fat frying.

2. Cookery temperature and sensitivity of control of that temperature.

3. End-point or internal temperature.

4. Post-oven temperature increase.

5. Systems of temperature measurement in sample and oven.

6. Number of steaks per oven and position of steaks in oven.

7. Effect of opening oven door during cooking.

8. Type of containers to cook in.

9. Size and weight of sample prior to cooking.

10. Cooking constant time vs constant final temperature.

11. Cooking frozen vs thawed.

12. Sample size and serving temperature for sensory panels.

Much of the information now known concerning changes in meat as a result of cooking has been derived from cooking cores of meat in tubes in hot water baths. There is a definite need to determine if results collected if this fashion can be extrapolated to the cookery techniques employed by consumers.

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H. R. Cross: Our next speaker, Dr. Dorothy Harrison, is presently on the staff of the Foods and Nutrition Department at Kansas State University. Dr. Harrison received her B.S. degree from Dakota Wesleyan University and her M.S. and Ph.D. degrees from Iowa State University. Dr. Harrison will speak to us this morning on the subject of "Selection of Cookery Methods Based on Research Objectives."