SELECTION OF COOKING METHOD BASED ON RESEARCH OBJECTIVES[1]

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INTRODUCTION

A cooking method for a research study on meat should be selected for its effects on the end product. In general, cooking tenderizes collagenous connective tissue by partially hydrolyzing collagen and toughens muscle fibers as myofibril proteins are denatured. Weir (1960) stated that both time and temperature are important to consider relative to those changes, with time being more influential for the softening process and temperature for toughening. Laakonen (1973) reviewed changes that occur in muscle tissue when heat is applied.

Cooking methods for meat have been classified as dry or moist heat, with those terms referring to the environment around the meat. Paul (1972) pointed out that differences between dry and moist heat methods, or differences between two dry or two moist heat methods may be attributed to the rate at which heat energy is supplied to the external surface of the meat, and to the temperature to which the external surface of the meat is exposed. Paul (1972) also summarized a number of techniques that have been used in research studies to heat (cook) meat. In her summary, an excellent reference to the literature concerned with cooking meat, she discussed the principles involved in generally used methods and the interrelated factors that affect the properties of the cooked meat.

Factors in addition to cooking method and cooking temperature that should be standardized in research involving meat cookery are: (1) weight and conformation of the cuts cooked, (2) degree of doneness of the meat (rare, medium, or well-done) and (3) the initial temperature of the meat. Those factors affect the characteristics of the end-product cooked by any method.

The discussion today will concern effects of different cooking conditions on selected parameters often used to evaluate cooked meat. Results of some studies in our laboratory and in other laboratories in which cooking methods were compared for effects on certain parameters will be presented. Cooking methods to be considered are: (1) oven roasting, (2) oven broiling, (3) modified oven broiling or roasting, (4) deep fat frying, (5) oven braising (covered utensil, foil, or oven film), (6) slow cooker, (7) pressure braising, and (8) microwave oven.

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These parameters will be given attention: (1) rate of heat penetration and cooking time, (2) degree of doneness (end point temperature and apparent doneness), (3) cooking losses, (4) tenderness (objective and sensory measurements), (5) juiciness (sensory measurement, total moisture, and waterholding capacity), and (6) flavor.

COOKING METHOD TERMINOLOGY

So that we all will have the same thing in mind for a particular cooking method, I'll briefly describe each method to be discussed.

Oven roasting--a dry heat method used for "blocky pieces" of meat (roasts that are placed on a rack in a shallow pan and cooked in an oven. Heat is transmitted to the meat principally by air convection. Rotary-hearth or forced-convection ovens have been used to increase uniformity of temperature within the oven.

Oven broiling--a dry heat method appropriate for broad, flat cuts such as steaks, chops, ham slices, or ground meat patties. Cooking is by radiant heat.

Modified oven broiling or modified roasting--a dry heat method used to cook cuts suitable for broiling. The meat is placed on a rack 4 to 8 in. high, set in a shallow pan (fig. 1) and cooked in an oven with the door closed. It is not necessary to turn the meat during cooking, because the heat is transmitted uniformly to all sides of the cut by air convection. Cover and Hostetler (1960) reported an oven broiling method to cook thin cuts in a preheated pan lined with bright aluminum foil. Paul (1972) described a method utilizing both an aluminum foil-lined drip pan and a rack with 4-in. legs.

Deep-fat frying--dry heat is transferred by conduction from hot fat to the surface of the meat immersed in fat to cover it. Heat is transferred more rapidly from the fat to the meat than it is within the meat; thus, the temperature of the fat must be adjusted to the thickness of the cut to retard the formation of a hard crust at the meat's surface. Bumping of the fat may be a problem, because of the high moisture content of skeletal muscle. Bumping may be retarded by using glass beads in the fat. The meat may be placed on a rack in the bottom of the cooking utensil.

Oven braising--long, slow cooking of meat on a rack in a covered utensil to create a moist atmosphere. Modifications of oven braising include cooking in heavy duty aluminum foil in oven film wrap, or in an oven film bag or pouch. The foil- or film-encased meat is placed on a rack in a shallow pan and cooked in an oven. A tight wrap with foil or oven film should be avoided. Several slits, approximately 3.5 cm long, are cut in the top of oven film wrap or bags to allow escape of steam and prevent the film from breaking.

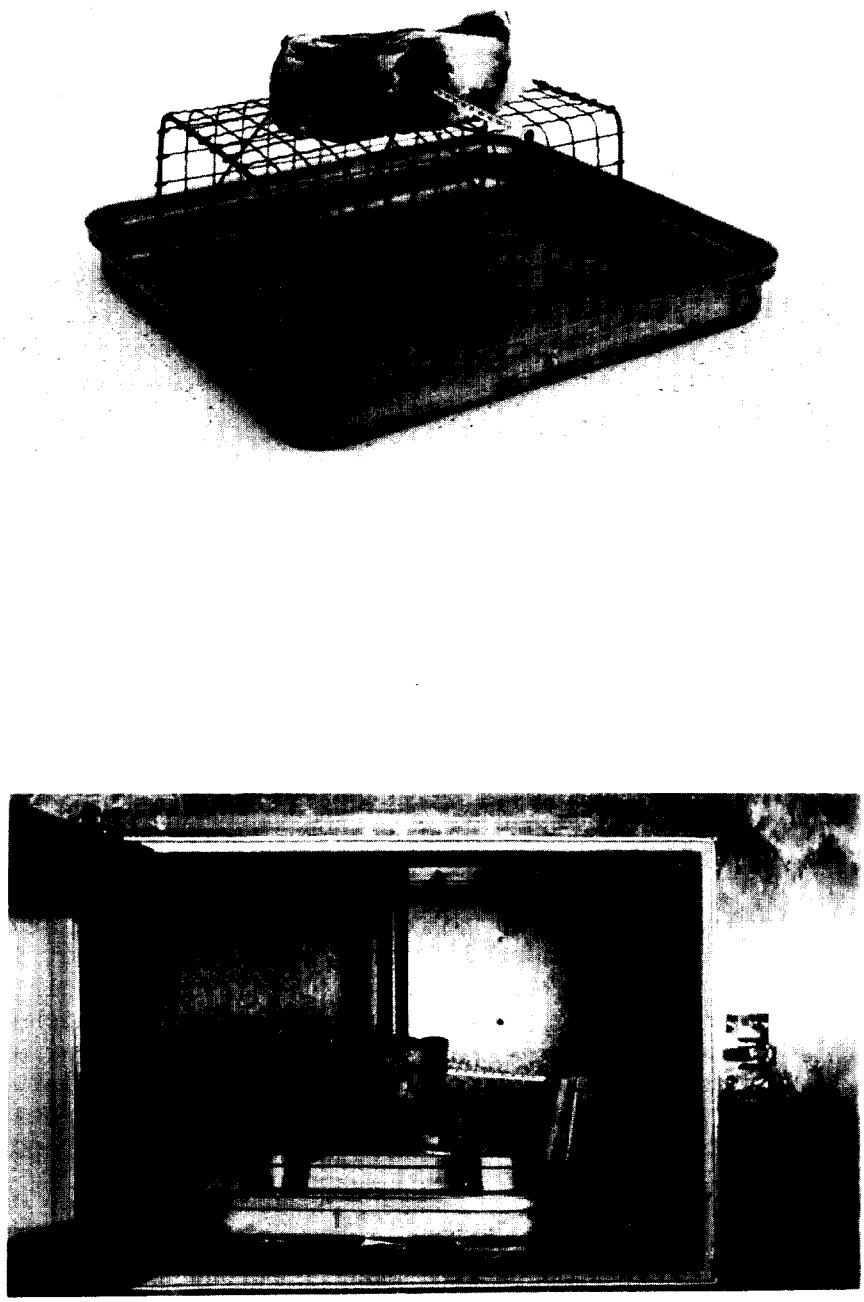


Fig. 1. Rib-steak on a 5-in. high wire rack with a thermometer in the geometric center of the longissimus dorsi muscle ready to be placed in the oven for modified broiling (roasting), and after placing on a rotary hearth in the oven.

Slow cooker--braising by cooking in an appliance such as a crock pot. Placing the meat on a rack in the appliance is recommended.

Pressure braising--braising under pressure (5, 10, 15 psig). In our laboratory, the meat is cooked with 30 ml of water, on a rack, in a pressure saucepan equipped with both a thermometer and a thermocouple (fig. 2).

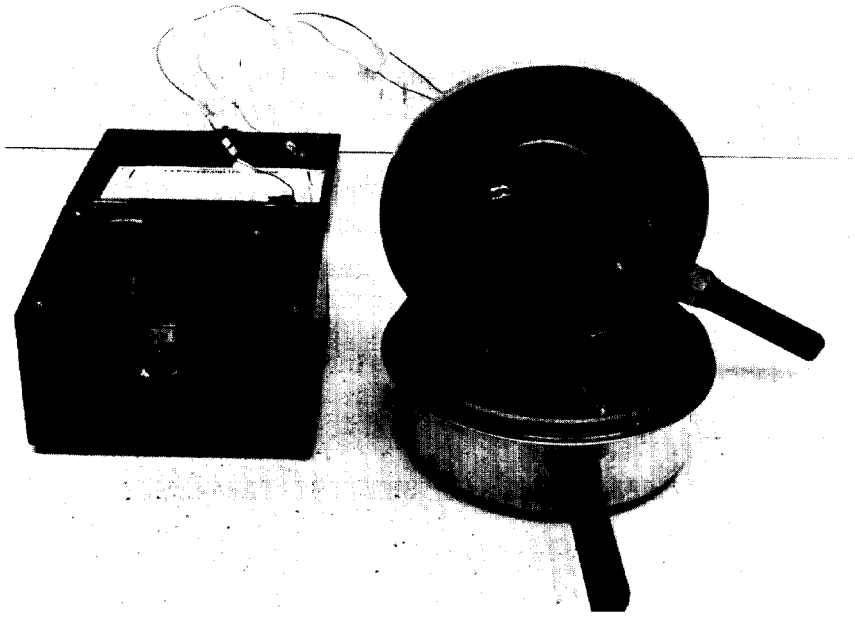
Microwave oven--cooking in a dry atmosphere, but using a heating principle entirely different from "conventional" dry heat methods. Energy is supplied to the meat as short electromagnetic waves that fall between light and radio waves in frequency. Microwaves cause the polar molecules in the meat to oscillate, converting the electrical energy into molecular motion, which results in heating or cooking the meat.

EFFECTS OF COOKING METHODS ON SELECTED PARAMETERS

Heat penetration, Cooking Time, and Doneness

Heat penetration. To study rate of cooking and measure degree of doneness at the end point of cooking, a temperature measuring device (thermometer or thermocouple) is inserted into the geometric center of each piece of meat to be cooked. The time required for the internal temperature to rise within a given temperature interval, e.g., min./5°C, is recorded. Data from our laboratory (Schock et al., 1970) indicated differences ($P < 0.01$) in the rate heat penetrated pieces (approx. 0.8 kg) of semimembranosus muscle cooked to 70°C by pressure braising (PB), deep-fat frying (DF), oven braising (OB), and oven roasting (OR), Fig. 3. Each cooking method differed ($P < 0.05$) from every other method in the rate that heat penetrated the muscle, except that OB and OR did not differ significantly from each other. Heat penetrated the muscle fastest in PB pieces; the order for the other cooking methods was DF>OB>OR. Cooking time, in minutes, for the four methods averaged: PB, 42.9; DF, 65.6; OB, 94.7; and OR, 101.2. In general, heat penetrated faster after the internal temperature of the meat reached 10°C than it did between the initial temperature (approx. 5°C) and 10°C. Heat penetrated PB and DF pieces at a fairly constant rate after an internal temperature of 10°C was reached. In OB pieces heat penetration was relatively constant throughout cooking. Heat penetrated OR pieces most rapidly between internal temperatures of approximately 12° and 50°C, but slowed down slightly between 40° and 50°C. After 88 min. of cooking, the internal temperature of both OB and OR pieces was approximately 65°C. Between 65° and 70°C the rise in internal temperature of OR pieces slowed down.

Heat penetration data from two other studies in our laboratory in which dry and moist heat cooking methods were compared were similar to those of Schock et al. (1970). Ferger et al. (1972) cooked rolled leg of lamb roasts (2.25 kg) and beef rib roasts (1.35-2.25 kg) from the frozen state at 163°C to an internal temperature of 75°C for lamb roasts, and at 149°, 163°, or 177°C to 60°C for beef roasts. For both lamb and



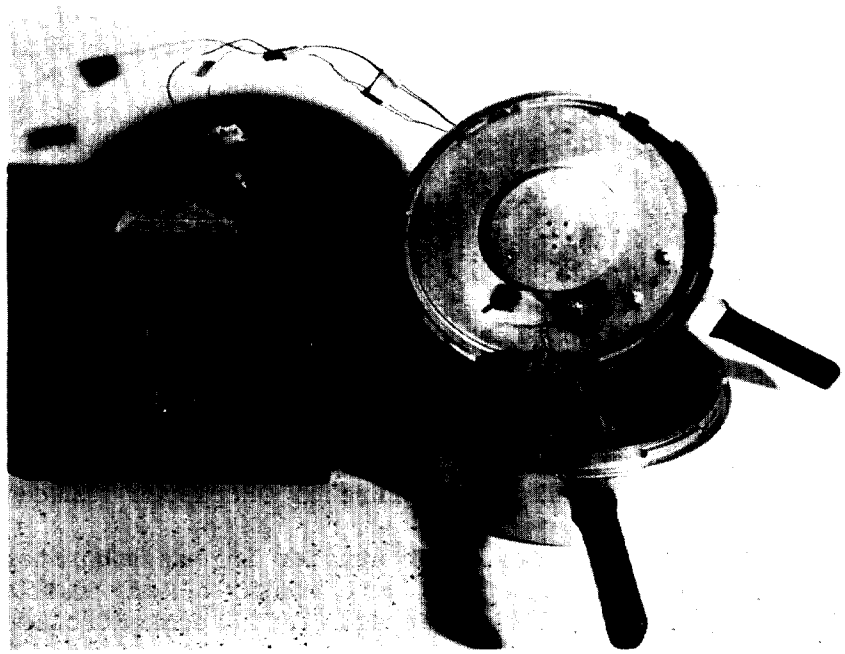


Fig. 2. Pressure sauce pan equipped with a thermometer and a thermocouple connected to a potentiometer to record the internal temperature of meat.

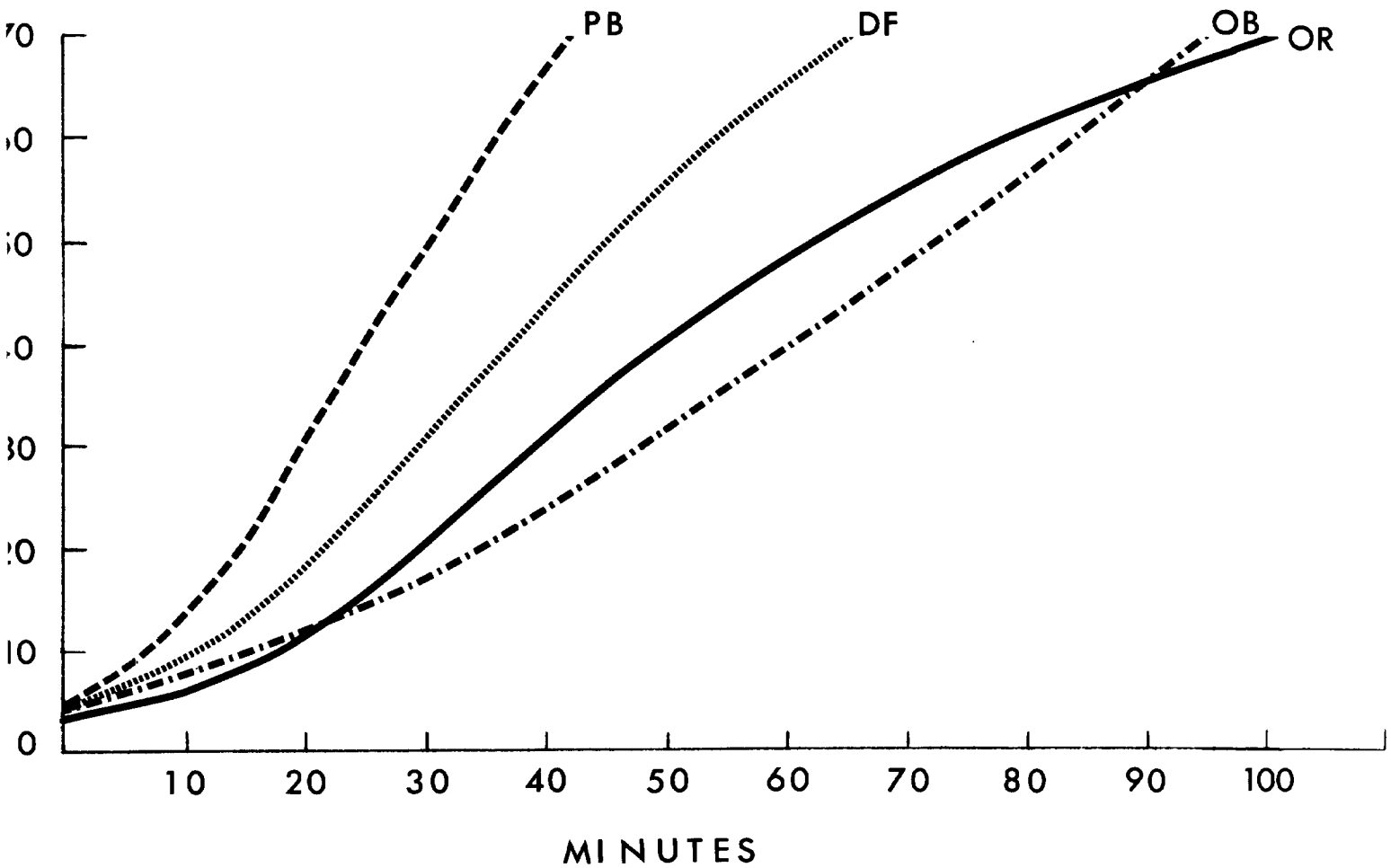


Fig. 3. Rate of heat penetration in semimembranosus muscle heated to 70°C in four cooking mediums: DF, deep-fat fried; OR, oven-roasted; OB, oven braised; PB, pressure braised, 10 psig (Schock et al., 1970).

beef roasts, they found no significant differences between oven roasting (open pan, dry heat) and oven braising (oven film pouches, moist heat) for mean heat penetration rate from 10°C to the end point temperature. However, a detailed study of heat penetration data for beef roasts revealed that when data for all three oven temperatures were combined, dry and moist heat differed ($P < 0.05$ or $P < 0.01$) at every 5°C interval from 20° to 60°C, except between 25° and 30°C. There were differences ($P < 0.05$) among all six types of heat-oven temperature combinations at each 5°C interval between 20° and 60°C, except between 25° and 30°, 35° and 40°, and between 55° and 60°C. Also, between 0° and 60°C, differences among oven temperatures for rate of heat penetration were greater with dry than with moist heat.

Shaffer et al. (1973) cooked top round roasts (1.1-1.2 kg) from the frozen state by oven roasting and oven braising (oven film bags) at 177° or 205°C to an internal temperature of 60°, 70°, or 80°C. With both moist and dry heat at both oven temperatures (figs. 4 and 5), heat penetrated the muscle at a fairly constant rate. At both oven temperatures, the internal temperature of roasts cooked by moist heat increased more rapidly than did the internal temperature of those cooked by dry heat. There were no significant differences between dry and moist heat for the time required for each 5°C increase from 15° through 35°C.

Less ($P < 0.05$, $P < 0.001$) time was required to increase the internal temperature from 35° to 40°C and from 45° through 80°C when cooking by moist heat than by dry heat. The magnitude of difference increased from 0.78 min/5°C at 45°C to 4.83 min/5°C at 80°C. With both dry and moist heat at the two oven temperatures, the average time for a 5°C increase in internal temperature was similar for all three end point temperatures.

Although there was no significant difference in weights of roasts assigned to the three end point temperatures, there was some variation in rate of heat penetration among those roasts. Conformation of all roasts was similar.

Cooking time. Cooking time indicates rate of heat penetration. Thus, in the three studies cited here cooking time, as expected, followed the same pattern as did rate of heat penetration. Differences in rate of heat penetration and cooking time may be explained, in part, by differences in the heat conductivity of the cooking medium. Both deep-fat frying and oven roasting are dry heat methods of cooking. However, at a given temperature, the heat conductivity of liquid fat is about six times that of air. Hence, roasts (0.45-0.90 kg) from nine beef muscles cooked by Visser et al. (1960) required two to three times longer to reach a given end point when oven roasted at 149°C than when cooked in deep fat at 100° or 110°C. Bennett et al. (1973) reported that the most striking difference between cooking pork chops by oven broiling and by deep-fat frying was that oven-broiled chops required three to four times longer to reach an internal temperature of 77°C than did deep-fat fried chops.

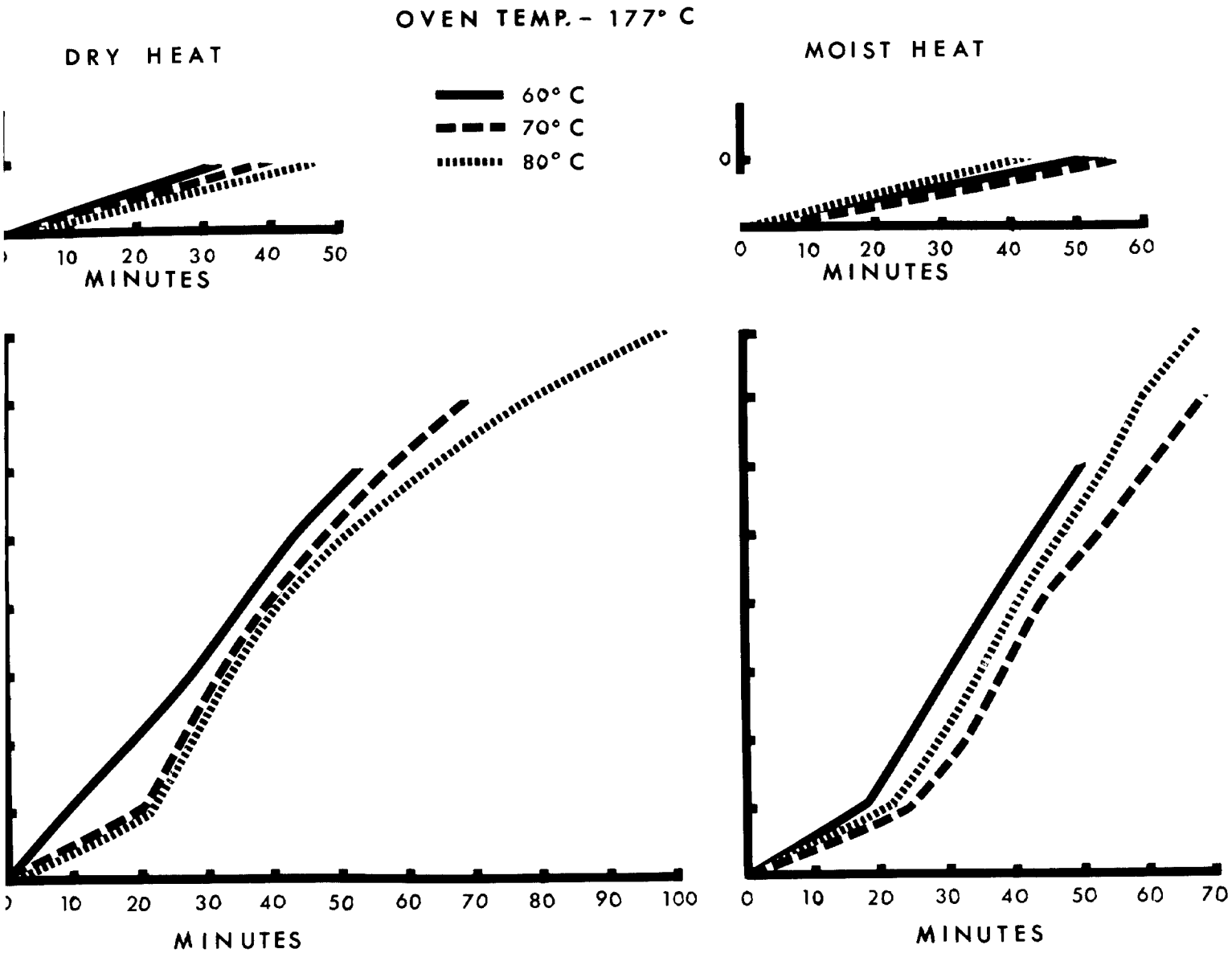


Fig. 4. Rate of heat penetration from initial temperature to 0°C and from 0° to 60°, 70° or 80°C for top round roasts cooked by dry or moist heat at 177°C (Shaffer et al., 1973).

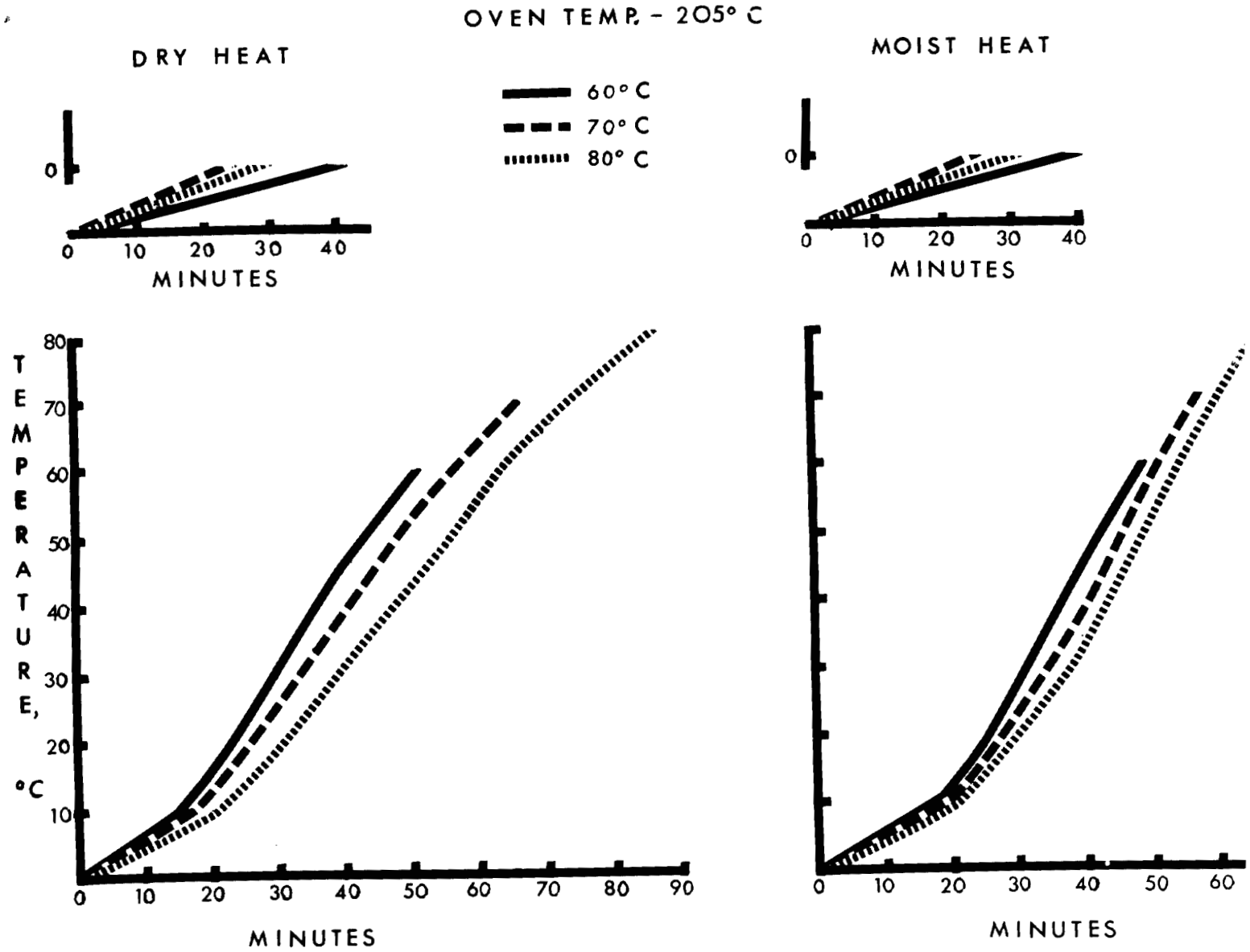


Fig. 5. Rate of heat penetration from initial temperature to 0°C and from 0° to 60°, 70° or 80°C for top round roasts cooked by dry or moist heat at 205°C (Shaffer *et al.*, 1973).

The specific heat of water is 1.0; of steam, 0.48; of air, 0.24; and of oil, 0.41-0.43. Steam is a more efficient conductor of heat than is dry air. Usually meat reaches a specific internal temperature faster in steam than in dry air, although the temperature of the steam never goes above that of boiling water unless the system is under pressure (Schock et al., 1970; Ferger et al., 1972; Shaffer et al., 1973).

Doneness. Visible color changes that occur during cooking of meat are related to the meat's internal temperature, and are associated with degree of doneness. Apparent doneness, as indicated by visible color change, varies with the cooking method.

When deep-fat frying at 100°C Visser et al. (1960) observed that internal temperatures of 45° and 65°C gave several beef muscles the appearance of rare and medium doneness, respectively; whereas, when the same muscles were oven roasted, internal temperatures of 55° and 70°C usually gave the appearance of rare and medium done meat. They concluded that the faster heat penetrates the meat, the more well-done it appears at a given internal temperature. Shaffer et al. (1973) described the appearance of beef top round roasts cooked from the frozen state by dry heat to an internal temperature of 60°C as bright red in the center fading to grey-brown around the edges. Those roasts exuded red juice on standing. Roasts cooked by moist heat to 60°C were pink in the center, fading quickly to light grey-brown through the remainder of the roast. At an end point of 70°C, roasts cooked by dry heat were pink in the center, fading rapidly to grey-brown halfway through the roast. Roasts cooked to 80°C by dry heat generally were slightly pink in the center, fading quickly to grey-brown throughout the remainder of the roast. Roasts cooked by moist heat to 70° or 80°C were uniformly grey-brown throughout.

The surface of roasts cooked by dry heat was a rich dark brown, and the surface texture was fine-grained; the surface of roasts cooked by moist heat was grey-brown and the surface texture was coarse.

Apparent doneness scores (laboratory panel) and Gardner a+ (redness) values reported by Schock et al. (1970), Ferger et al. (1972), and Shaffer et al. (1973) reflect the description of Shaffer et al. (1973) for appearance of beef cooked by dry or moist heat (table 1).

Vollmar et al. (1975) noted that top round oven roasts (OR) cooked from the frozen state at 94°C to an internal temperature of 60°C appeared bright red throughout, and exuded juice on standing; OR roasts cooked to 70°C appeared pink throughout and did not exude juice on standing. Top round roasts cooked from the frozen state in oven film bags (OFB) at 94°C to 60°C appeared pink throughout; those cooked to 70°C were pink-brown. Similar roasts cooked to 60°C in a slow cooker (SC) appeared red-pink throughout most of the roast; SC roasts cooked to 70°C were pink-brown. Both SC and OFB roasts cooked 10 hr (average internal temperature of 76° and 82°C, respectively) were brown throughout. In all SC roasts, a layer at the bottom of the roast (approx. 2.5 cm thick) faded to grey-brown.

Table 1. Mean apparent doneness scores and Gardner a+ (redness values for beef and lamb roasts reported in three studies

Authors	Cooking method	End point, °C	Apparent doneness score[a]	Gardner a+ value
Schock *et al.*	OR	70	2.2	7.31
(1970) Beef, 0.8	DF	70	2.8	6.75
kg	OB	70	2.9	6.92
Thawed	PB	70	2.7	6.81
LSD 0.05		-	0.42	0.20
Ferger *et al.*				
(1972) Beef, 1.4-	OR, °C			
2.3 kg	149	60	1.3	8.4
Frozen	163	60	1.6	6.8
state	177	60	1.6	8.9
	OFP, °C			
	149	60	1.9	6.1
	163	60	2.0	4.9
	177	60	2.1	6.2
LSD 0.05			0.6	2.3
Lamb, 2.3	OR	75	2.1**	7.06**
kg	OFP	75	2.8**	3.56**
Frozen				
State				
Shaffer *et al.*				
(1973) Beef, 1.1-	OR	60		
1.2 kg		70	2.0***	6.05***
Frozen		80		
state	OFB	60		
		70	2.6***	2.59***
		80		
	OR	60	2.1 ns	6.30***
	OFB	70	2.1 ns	4.19***
		80	2.4 ns	2.47 LSD=1.30 0.05

[a] 3, well done; 2, medium done; 1, rare.

OR, oven roasting; DF, deep-fat frying; OB, oven braising, PB, pressure braising; OFP, oven film pouch; OFB, oven film bag

** $P < 0.01$; *** $P < 0.001$

The cooking pot of the slow cooker was placed directly on the heating element and heat was transferred, via the metal rack on which the meat rested, to the bottom of the roast before it reached other parts of the roast.

The surface of OR roasts was crusty and a rich dark brown; the surface of OFB and SC roasts was grey-brown. Drip from OFB roasts was dark brown; that from SC roasts was orange-brown. The drip from those roasts included both dispersed coagulum and fat that stabilized on top of the drip after it was transferred to graduated cylinders. Drip from OR roasts formed a sticky mass, and with increased exposure to heat, the sticky mass formed a charred residue. That was attributed to the low oven temperature (94°C) and the long cooking time required for dry heat roasting.

Sanders and Harrison (1975) observed the appearance of top round steaks (5.0 cm thick) cooked by pressure braising (PB) at 10 p.s.i.g. or in a microwave oven (MW) to 70° or 80°C. MW steaks cooked to 70°C were bright red in the center and grey-brown from points 4.5 cm on either side of the center (internal temperature 90°-93°C) to the edge of steaks 13 to 15 cm long. PB steaks cooked to 70°C were pink in the center, fading to grey-brown around the edges of steaks 13 to 15 cm long. Both MW and PB steaks cooked to 80°C were grey-brown throughout the interior of the steak. All MW steaks had a coarse, dark crust and tended to curl on the ends.

Cooking Losses, Total Moisture, Waterholding Capacity and Sensory Characteristics

For a given cooking method, cooking losses and total moisture usually are related to cooking time, with losses increasing and total moisture decreasing as time increases. However, losses from meat that is oven roasted (OR, dry heat) usually are less than those from deep-fat fried (DF, dry heat) meat or losses from meat cooked by braising (moist heat), although cooking time is longer for OR meat than for meat cooked by the other methods. Schock *et al.* (1970) found that cooking losses from OR pieces of beef top round were lower ($P < 0.05$) than those from DF, oven braised (OB), or pressure braised (PB) pieces; cooking time was longer for OR pieces than for pieces cooked by any of the other three methods (fig. 3, table 2). Losses from PB pieces were greater ($P < 0.05$) than those from DF and OB pieces, with no significant difference between DF and OB pieces. Initial internal temperatures for those roasts, in °C, were: DF, 4.8; OR, 3.2; OB, 4.3; PB, 7.1.

When Shaffer *et al.* (1973) cooked from the frozen state pieces of top round that were slightly larger than those cooked by Schock *et al.* (1970), total losses from OR roasts were less ($P < 0.01$) than those from OB (OFB) roasts. In both studies, cooking time was longer for OR than for OB roasts, but the difference in time between the two methods was not significant (table 2). Ferger *et al.* (1972) found that cooking beef rib

Table 2. Means attributable to cooking method for cooking time and losses, total moisture, and waterholding capacity for beef and lamb roasts reported in three studies

Authors	Cooking method	Cooking time, min	Cooking losses, %	Total moisture, %	Waterholding capacity[a]
Schock *et al.*	OR	101.2	23.5	64.0	0.64
(1970) Beef, 0.8 kg		ns	*	*	ns *
thawed	OB	94.7	27.9	61.1	0.61
		*	ns	ns	
	DF	65.6**	28.7	60.9 ns	0.57 *
		*	*	ns	*
	PB	42.9*	33.2	59.6	0.55
Ferger *et al.*	Beef				
(1972) Beef, 1.4-2.3 kg	OR	195.6	25.5	64.4	0.65
Frozen state		ns	ns	**	ns
	OFP	188.8	25.5	62.9	0.66
Lamb, 2.3 kg	Lamb				
Frozen state	OR	255.0	28.4	67.2	0.74
		**	ns	**	**
	OFP	275.0	30.0	61.1	0.65
Shaffer *et al.*	OR	112.4	27.7	67.0	0.80
(1973) Beef, 1.1-1.2 kg		ns	***	***	**
Frozen state	OFB	107.8	34.9	63.6	0.76

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

OR, oven roasting; OB, oven braising, DF, deep-fat frying; PB, pressure braising; OFP, oven film pouch; OFB, oven film bag

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

roasts (1.4-2.3 kg) from the frozen state to 60°C, required an average of only 7 min longer to cook by the OR than by the OB (oven film pouch, OFP) method, and that cooking losses averaged the same for the two methods. Contrary to expected results, cooking rolled leg of lamb roasts (2.25 kg) from the frozen state averaged 20 min less ($P < 0.01$) by OR than by OB (OFB), but the average cooking losses were approximately the same for the two methods. In general, in all three studies cited here, total moisture and waterholding capacity of the muscle decreased as cooking losses increased (table 2).

Clark et al. (1955) reported that total cooking losses for OB and PB (10 or 15 p.s.i.g.) steaks thawed and cooked to 80°C were practically the same, but OB steaks required 3.5 to 4.5 times longer to reach the end point temperature than PB steaks did. Cooking losses from steaks cooked to 112°C were greater ($P < 0.01$) than losses from steaks cooked to 80°C. Thus, the internal temperature to which the steaks were cooked, rather than the cooking method, was important in determining cooking losses.

Several authors (Headley and Jacobson, 1960; Marshall, 1960; Kylen et al., 1964; Carpenter et al., 1968; Ruyack and Paul, 1972) compared microwave (MW) with conventional methods of cooking meat. They reported that meat (beef, pork or lamb) cooked by MW required significantly less time to reach a given internal temperature, but had significantly greater cooking losses than did meat cooked by oven roasting, oven broiling, oven braising, or deep-fat frying.

Data from most studies cited in this paper for effects of cooking method on quality attributes of meat indicated few significant effects on sensory characteristics that were attributable to cooking method. Exceptions were reported by Bennett et al. (1973) and Flynn and Bramblett (1975). They found that pork chops oven-broiled at 177°C were more ($P < 0.01$) tender, flavorful, and acceptable than pork chops deep-fat fried at 110°C.

GENERAL RECOMMENDATIONS

Selecting a cooking method(s) for experiments with meat is an important part of planning and conducting the research. The same principles used to select methods for any part of the work apply to the selection of a cooking method.

First, review the literature in which effects of two or more cooking methods on characteristics of cooked meat are reported. Consider the importance of those effects on measurements you plan to use to evaluate effects of treatments to be studied. For example, did the cooking methods reported differ significantly in effects on sensory characteristics of the meat and related objective measurements of those characteristics? Usually the method causing the least severe effects favors detection of differences attributable to treatments.

Before final selection of a cooking method, you may need to do a preliminary experiment using two or more methods to establish which method is best for your proposed work. Such an experiment may be a part of the standardization and refinement of technique, which is of paramount importance. Good technique is both accurate and precise, and is accomplished by practice. "Preliminary" work may require more time and effort than collecting data for the planned experiment.

Roasting

Roasting was standardized by the Committee on Preparation Factors, National Cooperative Meat Investigations (1942). It is easy to control, and has been used in many experiments.

Broiling

Precise broiling conditions are difficult to maintain. Paul (1972) explained that the intensity of radiation varies within and among broiler units, and that the air temperature of the oven does not reflect the true energy output of the broiler unit. The internal temperature-measuring device is easily displaced when the meat is turned halfway through the cooking process.

Bennett *et al*. (1973) cooked pork chops of three muscle types (normal, pale-soft-exudative, dark-firm-dry) by oven broiling at 177°C or deep-fat frying at 110°C. They found significant interactions of cooking method x type of muscle for cooking time, cooking losses, total moisture, press fluid yield, panel tenderness scores, and Warner-Bratzler shear values. They believe their data suggest that for detecting differences among samples oven broiling is a more appropriate cooking method than is deep-fat frying. Flynn and Bramblett (1975), using the same techniques as Bennett *et al*. (1973), found that oven broiled pork chops were more ($P < 0.01$) tender, flavorful, and acceptable than deep-fat fried chops. Cooking method had no significant effect on juiciness or percentage lipid in the meat.

Modified Oven Broiling or Roasting

Modified oven broiling or roasting is recommended for cooking cuts suitable for broiling, because by this method, it is easier to control cooking conditions than it is with broiling. Two or three chops or meat patties may be cooked as a unit on one rack and cooking losses computed for the group.

Deep-fat Frying

Visser *et al*. (1960) discussed problems encountered in cooking with deep fat when studying degree of doneness of beef muscles of different weights and shapes. At 147°C (297°F) meat shrank considerably and a

thick, hard crust formed on its surface. At 120°C (248°F), that effect was not so pronounced as it was at 147°C, but it seemed desirable to try a lower temperature. After experimenting they used temperatures of 100° or 110°C (212° or 230°F) to deep-fat fry roasts weighing 0.45-0.90 kg. Results of that experiment indicated that both lower cooking and internal end point temperatures were necessary to obtain meat comparable to the usual conception of rare and medium-done beef.

There was little difference in tenderness scores for roasts cooked in the oven at 149°C and those cooked in deep fat at 110°C. Generally, average tenderness scores for roasts cooked in fat at 100°C were slightly lower than for oven-cooked roasts and those cooked in fat at 110°C. Shear values were a little lower for oven-cooked roasts than for those cooked in fat. Oven roasted meat and that cooked in fat at 100°C was juicier than meat cooked in fat at 110°C.

Braising and its Modifications

Braising is recommended when long, slow cooking in a moist atmosphere is desirable to soften collagenous connective tissue. All variations of braising affect the meat about the same. Conditions of most variations are easy to control.

Microwave Oven

Data from most studies reviewed indicate that microwave cooking is not satisfactory for research (Headley and Jacobson, 1960; Marshall, 1960; Pollak and Foil, 1960; Kylen et al., 1964; Ream et al., 1974). As compared with the so-called conventional methods of meat cookery, effects of microwave cooking on characteristics of the cooked product are harsh, and tend to mask effects of treatments being studied.

Decareau (1967) pointed out that conventional cooking standards and techniques do not always apply to microwave cookery, but perhaps when the product heating performance is analyzed thoroughly, a system involving microwave energy may yield a better quality product than the conventional methods that microwaves replace. Van Zante (1973) stated that tender cuts of meat, when cooked properly in the microwave oven, retain their natural juices and have good flavor. She also pointed out that less tender cuts will not become tender, because the long, slow cooking process exposing connective tissues to moisture is not a condition produced by microwave cookery.

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H. R. Cross: I will now ask the three speakers to come forward to answer any questions put to them.

P. K. Lewis: Dr. Harrison, did you do any sizing of the cooked sample? It appeared that there were differences in size and shape when you compared oven roasting with the film bag method.

D. L. Harrison: No, we did not size the steaks but we did try to standardize the initial weight. When we started out there were no significant differences in size of steaks between treatments.

P. K. Lewis: In the raw?

D. L. Harrison: Yes.

P. K. Lewis: I meant in the end product? Were there differences in size?

D. L. Harrison: I didn't analyze the data from that standpoint. We probably could go back and look at the data and see what the final weight was and how it varied.

P. K. Lewis: Well, I was thinking not of final weight but size or volume of sample. It appeared from the pictures you presented, that there were differences in volume. Now this may have been a happenstance with the way you presented them.

D. L. Harrison: The only data we have in this regard is the initial and final weight where we could look at the change from start to finish to see if there was a difference in the way those pieces changed. But in the beginning of the study we controlled the size and conformation as much as possible. Even though you control these variables, the cooked meat will change in all dimensions--length, width, thickness, etc. When working with biological materials like skeletal muscle, that's one of the problems that is encountered. We can't work with model systems and compare them to skeletal muscle.

M. Dikeman: I'd like to direct a question to Brad. Brad, maybe you didn't have time, but you did not make any recommendations or suggestions regarding the temperature of a product being served to the taste panel. Whether it should be the hot temperature or room temperature or whatever. Would you care to elaborate on that?

B. W. Berry: Well, I think from the standpoint of at least evaluating flavor, it is very critical that it be served as hot as possible especially if the sample is being prepared and sized for presentation to a consumer panel for flavor or juiciness evaluation. I think when we are interested in flavor and juiciness, it is important to keep the temperature of the cooked sample very close to the final end point temperature.

D. S. Harrison: I'd like to make a comment. Many people agree that the samples should be served warm but when they talk about being served hot, I don't know how they do it. I never believed it when somebody said the samples were served hot because the size pieces we work with cool rather rapidly. It's practically impossible to physically handle the samples when they're hot. Also, by the time you get them prepared for the taste panel the samples are at best only warm. Also, by the time you get them prepared for the taste panel, the samples are at best only warm. Also, it is necessary to have the panel present before the samples are prepared and this is not always possible. One has to allow time for the panel to arrive. I think that we do need to control those conditions, but I'm not so sure that we can always serve samples hot.

H. R. Cross: Would anyone like to comment on that?

R. Staggs: I had decided this morning that I was only going to comment twice so I won't appear to be on the program. We have noticed in work that we do, and we do a tremendous amount of meat cookery work at the Meat Board, that when we judge meat at a temperature which might be appropriate for serving hot, and also when it's chilled or when it's cold, one obtains a different impression of tenderness. I think that this is something that's rather significant in evaluating factors associated with palatability. I'd like to make a few additional comments if I may. The Meat Board, whether we say it or not, is considered the source of information on meat cookery. In the years I've worked at the board, I've said at least 1000 times that we are endebted to colleges and universities and the Department of Agriculture for the research they do. They are the background for our meat cookery recommendations. With the many changes that are taking place today in food preparation, not only in product development, but also the equipment used in meat preparation, we need to constantly review and update our recommendations. In reviewing research in the last year, I sometimes have questions raised by people who are doing the work in microwave ovens whether they would need the 915 or 2450 Mega Hertz ovens. I know of one manufacturer who prefers the 915, but this does not rule out an effect of oven type on evaluation.

H. R. Cross: Thank you, Reba, for those comments. Questions?

P. B. Addis: Question for Dr. Harrison. You showed that oven film bags tended to give a more well done appearance at the same internal temperature, I wonder if this is not due to the fact that at 60° C you'll have a greater increase in post oven temperature rise using the oven film bags than you would using a dry oven because you have a greater temperature differential on that system versus the dry oven method. Furthermore, when you use very low oven temperatures for the oven film bag type system, such as using a water bath temperature of only 3° above the internal temperature, which can be done on large pieces of meat, you'll find that using an oven film bag will actually give you a more rare appearance; therefore, I think it really depends on the temperature range that you're using.

D. L. Harrison: I think that's true. I was just showing what we had done on a limited basis in our laboratory. There's much more that needs to be done in this area such as why if you cook to a certain end point temperature you get differences in degree of doneness. We are also interested in knowing why if you cook for a certain length of time you'll obtain a different end point temperature. We've done some limited work studying electrophoretic patterns of the sarcoplasmic proteins, but didn't get the answer. I'd like to study some other factors but our laboratory is limited in what it's able to do.

R. F. Kelley: I'd like to offer a question to Dr. Heldman. On the formulas you presented, is there a place for the effect of pressure to be measured?

D. R. Heldman: No, there isn't. I'm trying to think how it might be accounted for. Certainly pressure is a factor. I guess it would depend on which of the parts of the presentation you might have been referring to specifically. There are things where such factors as the thermal properties are affected by pressure and obviously those are inputs to any of the expressions that we discussed this morning that need to be determined experimentally. Therefore, you start with the experimental conditions and pressure would be one of those experimental conditions that would enter in.

R. F. Kelly: The reason that I raise this question is that we've cooked a good number of roasts by dry roasting methods over an extended period of time and it seemed to us that a change in atmospheric pressure sometimes would have an influence on the rate of reaching a certain internal temperature. It almost convinced me that that's something we need to study.

D. R. Heldman: I guess I can't doubt what you're saying but I don't have a quick explanation either.

J. D. Fox: What is the most acceptable method for measuring the internal temperature of beef being cooked in a microwave oven?

D. R. Heldman: I'll answer that quick. I'm not sure. I think I'll have to admit that I'm not that well acquainted with what has been done in that particular area to comment on it. I wouldn't think, off hand that it would make any difference as long as you're accounting for any of the typical errors that might be encountered with any one of the three that I mentioned. Maybe there are others that would like to comment.

D. L. Harrison: Well, my knowledge is limited too, except that I have gone to the literature to see how they measured the temperatures in the microwave oven. It's a problem because you can't use a metal thermocouple or anything with metal in it. You can't use a thermometer containing mercury. Several years ago we purchased some thermometers from Taylor that were specially designed for microwave ovens. Reviewing

the literature I found at least one report that gave Taylor credit for using a thermometer specifically designed for microwave ovens. Some researchers have cooked in the microwave based on time and checked the temperature when they removed the meat from the oven. That's not an accurate way of getting the temperature. This spring we wanted to start some new work and we have only four of those thermometers. We needed to have more than four before we started a study so I thought I'd try to get some more, but was not successful since there was no mark or number on the thermometers. When we tried to trace it down by writing to Taylor Company we were referred to a company in Kansas City. They sent a catalog and there was absolutely nothing in it that answered our questions. I finally did find a company located in New York. I told some of the people that were at the MIRC in March about it and gave them the address. It's called the Everready Thermometer Company and they did make them for us. They did not tell us what the material is that records the temperature in the bulb but it has a small bulb that will fit into small samples. We have found it satisfactory for our work with the microwave oven.

D. H. Kropf: Dr. Heldman, you mentioned conduction error. Are you aware of any insulating materials or systems that have been used in making thermometers or putting around traditional thermometers where we would not have conduction?

D. R. Heldman: There is really no way that you can insulate against it. The best solution is to make the stem or wire as small as possible so that the cross-sectional area leading from the point of high temperature to the point where the sensor is actually located is as small as possible. This will reduce the error to a minimum. Obviously the conductivity of the type of material used will influence this also, but the only real solution is to make that as small as possible. That's why something like a thermocouple wire is better than the larger stem of a typical metal or glass thermometer.

D. L. Anderson: I understand your committee is interested in standardizing cooking methods for research purposes. I can appreciate the need for this but how are you going to standardize cooks and housewives? How will you adjust to technological change? How will you adjust to shifting customs of cookery or just individual preferences if you do establish some standard base for this?

H. R. Cross: First, we're not sure whether we can standardize meat cookery methods. Second, I'm not certain that we know how the consumer is eating or cooking meat today. This is something that we really need to know. I think, personally, that a lot of our research cookery methods should be patterned in this direction without losing control during cooking. Some of our speakers might like to comment.

B. W. Berry: I'd just like to say that it is probably an extremely difficult task and we conduct a large number of closely confined studies trying to control cooking variables but I think you brought out a good point that anytime we do this, we should perform similar types of studies utilizing consumer type cookery systems to see whether we are really getting the same differences and, if not, why?

R. L. Hendrickson: Dr. Heldman, while we have the thermocouple, it seems to me the most important thing is where we place it and it has to be placed at the mass average point. My question is how can we calculate the mass average point?

D. R. Heldman: I can answer that best by maybe reflecting on some of the things I either said or was trying to convey. Geometry is really the key. When we have geometry similar to those ideals that I talked to and some that are similar to those that can be described by the geometric index that I mentioned quite briefly. That particular position can be located and there are methods to go about doing that. That really doesn't help, though, in the final analysis because there are just very few of the products that you are working with that fit the ideal pattern so our task is not an easy one. I don't have a quick solution. I just have to say that, okay, here are things that we do know and probably in the final analysis it maybe takes a set of temperature measurements within a product--two or three that are close to what you can visualize as the slowest or the mass average temperature and measure more than one location rather than just depending on one.

D. E. Schafer: One comment that may not require a response, but it's kind of related to what these people are talking about as well as Tom Bidner earlier this morning. This relates to the sampling that we do when we sample steaks for taste panel evaluation or analysis. It's been my thought at least, that when we take a core out of a steak--particularly now when we're getting into forage finished beef--that we may be biasing the results because perhaps flavor differences may not be picked up in the strictly lean tissue nearly as much as they may be in the intermuscular or subcultaneous fat. I think we need to be aware of this because, if this is true, our research results certainly will not reflect consumer results with the same product.

H. R. Cross: That's a good point. I think we have time for one more question this morning.

D. L. Harrison: I think Mr. MacIntosh will remember that a good many years ago when we were working together on pork we always sampled the fat for palatability evaluation as well as the lean tissue. We didn't get too great a difference between the two except that maybe we could pick up off flavors sooner (i.e. oxidation) in the fat tissue. One of the problems with this approach is that we have difficulty getting taste panels that will taste the fat and particularly with the attitude toward the mouth feel it leaves. One also has trouble getting rid of some of the after taste between samples.

H. R. Cross: I hate to break off the discussion, but it is time for lunch. We certainly appreciate your attendance this morning. We appreciate the speakers so let's give them a hand.

* * *

J. H. Ziegler: The Sensory Evaluation Conference Committee, through the liasison with Director Larry Borchert has attempted to put together an interesting and informative program for you this afternoon. The committee to which we owe a debt of gratitude is listed on page 13 of your official program. From the committee that is listed on page 13, we obtained many more good suggestions for the program than we were for one reason or another able to use. The names and addresses of the three of our program participants who are not members of AMSA are listed on pages 16 and 17. As an aside, several of us also learned the definition of another word through the recommendations of one, F. Warren Tauber. Warren recommended that we look into the "holistic" approach and it just happened that my secretary misspelled it and the whole committee ran around for a couple of days trying to find out what we really wanted to happen.

By the way of an introduction, I would like to take this opportunity to make a couple of general comments. It has been quite awhile since I had the opportunity to address this conference so I am going to take a minute or two to indicate that I think the RMC is a really great thing, particularly from a personal viewpoint. Through it and from it both Penn State and I have profited tremendously. Several years ago we at Penn State had the opportunity to host this conference and some of you will laugh and say, "Yeah, that's an opportunity!" But believe me it is, and everyone gets a real sense of satisfaction from doing a job that needs doing. Once it is over you realize what an opportunity you had to get that sense of accomplishment. Also, since most of us are teachers, we recognize the fact that you really never own anything until you have shared it.

Another real value of the RMC obviously is what we learn, how we have been stimulated, what we have seen and been able to take back home and use. And I really believe that every RMC that I have attended has added something significant to the Penn State program. I'll reminisce just a minute. I remember the first conference I attended quite a while ago. I discovered "Meat Extension Boys" and their programs and I returned home and started to campaign to obtain one for the Keystone State. In those days, Pennsylvania had the largest number of meat packers and processors. We had over 2,700. We also had almost 12 million consumers, but we didn't have an extension specialist in the meats area. Well, it took a few years to get the job done but the idea was finally sold to our administrators, and you have to be careful about talking about administrators anymore at this conference, but we did finally establish the position that brought Bill Jones to the vale of the Nittany Lions.

Another idea that I took home was the necessity to do something in the way of panel testing to supplement some of the things that we were doing in the meats area. This area had not been completely ignored and I wouldn't like to leave the impression that I think it was. Over the years, P. Thomas Ziegler, an Agricultural Engineer by the name of Dr. John E. Nicholas, a Home Economist by the name of Dr. Mary L. Dodds, and some other people had started some early freezing work. They were

primarily interested in home preservation by freezing and had employed panel testing to determine things like storage life, package preparation, and other aspects of freezer preservation. I took my idea home from an RMC and I attempted to initiate it and I soon discovered that there was still some activity being carried on in this area in our College of Home Economics. However, there was absolutely no opportunity for product testing. The main concern among my coworkers at University Park was the development of methodology. Now we all understand that methodology is important in order to obtain the data that can be interpreted and compared. But we must also understand the practical and possible use of the methodology that we establish. Again, after some time we resolved this problem and today we have and use at Penn State a really complete set-up with a trained panel on call. I have to be careful how I say that, too. Some of you observed our panel facilities two years ago.

As with the cooking that we learned about this morning it appears that we will continually have problems to solve and that every now and then we will require in one form or another an update of this subject. Now, through our presentations today we hope to touch at least two aspects of sensory evaluation. One dealing with methodology and the other with use, and there may be a few other related aspects of sensory evaluation thrown in along the way for which we will charge nothing. So without any additional remarks we will ask our first speaker to discuss "Human Subjects in Food Research."

She is Dr. Elizabeth Davis. Dr. Davis is currently Coordinator of Research for Home Economics, the Cooperative State Research Service of the USDA. She received degrees from Colorado State University and also from Auburn University. And from the latter she received the Ph.D. in nutritional biochemistry with a minor in physiology. She has had an active and varied career and is the author of numerous scientific publications and a member of a lot of honorary and scientific organizations. One of which stood out in my mind because I know so many of you have close associations with Gamma Sigma Delta. Our speaker is a member of that organization. At lunch time yesterday you all were requested to participate in some testing and asked to sign the necessary release forms. And by the way, one member of this conference refused to do so, and I don't know what we are going to do with him. But with that as an introduction and noting the title of "Human Subjects in Food Research," I will turn the podium over to Dr. Davis.