# STANDARDIZATION OF METHODS OF HEATING AND SAMPLING MEAT

PATRICIA J. ROGERS

VIRGINIA POLYTECHNIC INSTITUTE

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When meat is prepared for research, it may be to study the changes occurring on heating or to evaluate other treatment effects. When studying cooking methods, novel procedures may be used and should be well defined. The primary methods used for meat cookery research have been broiling, braising, roasting, deep fat frying, and heating by microwaves.

Broiling involves setting the oven regulator for broiling and placing the meat on the rack of a broiler pan two to five inches from the heat. One side is broiled and then the other (National Livestock and Meat Board, 1964). Broiling differs from roasting in that transfer of heat is mainly by radiation rather than convection. Radiation from the broiler unit heats the meat. The air temperature of the oven does not reflect the true energy output of the broiler unit (Weir et al., 1962) but is influenced by sealing, insulation, and temperature of the room as well. Turning of the meat during broiling causes a loss of heat. If turning of the meat during broiling can be eliminated by placing the meat on a bright aluminum broiler pan or on a rack directly on the oven rack with a reflecting sheet below, this eliminates the necessity of opening and closing the oven door. Of course, opening the door affects only the air temperature not radiant energy. If a thermostatically controlled oven with a low oven temperature is used for broiling, the process resembles roasting, because the unit will be off most of the time and heating will be by convection not radiation. Charcoal broiling involves a low air temperature and a high radiant energy. The smoke and burning fat odors of charcoal affects the end products' flavor.

Braising is suitable for less tender cuts of meat. It involves browning the meat slowly on all sides in a heavy utensil, pouring off the drip after browning, then seasoning, adding a small amount of liquid, covering tightly, and cooking at a low temperature until tender. Braising may be done on top of the range or in a slow oven (149-163°C) (National Livestock and Meat Board, 1964). In braising, the transfer of heat is by convection within the saturated air in the covered pan, radiant heat and conduction from the pan. The addition of water seems to have little effect on braising except to assure that a saturated atmosphere is obtained. Since pan composition has a definite effect on braising, the type used should be stated. Browning appears to have little effect on the meat and could be disregarded especially for research. I feel that it is very difficult to get even browning in meat on all sides because of the shape of meat. Also, it is difficult to regulate the temperature of the element during browning. Cooking in tightly fitting aluminum foil is actually another braising method. It appears to have little advantage as a research method. The use of skewers speeds up the rate of cooking by conducting heat into the meat and can be used in braising or roasting.

Thickness affects the quality of broiled steaks and chops. Tenderness scores were higher and shear force values lower for 3 inch cuts than 1-1/2 in. cuts. Flavor was not affected by thickness (Hood et al., 1954). One and a half

inch broiled pork chops were less juicy and had a higher yield than 3/4 inch chops in a study by Weir et al., (1962). The thicker chops had better flavor than the thin chops. Similar results were noted by Holmes et al., (1966).

When thin steaks from the loin and bottom round were broiled or braised well-done, weight losses were similar regardless of cooking method, but juiciness scores were higher for braised steaks than for broiled steaks. While the Biceps femoris was made more tender by braising than by broiling, this was true for the Longissimus dorsi only if low grade carcasses were used (Cover and Shrode, 1955; Cover and Smith, 1956; Cover et al., 1957). According to Weir et al. (1962), broiling pork chops requires less cooking time and results in greater cooking losses than braising. Although, it had no effect on flavor, juiciness or tenderness, increasing the broiling temperature or braising time reduced the final yield of cooked meat. Hood et al (1954) found that cuts of beef 1-1/2 inches thick cooked by moist methods had significantly lower cooking losses than those cooked by dry heat. Three-inch cuts had higher losses from moist heat than from dry heat. However, thin chops cooked by broiling were found by Weir et al. (1962) to be more tender, more juicy and less flavorful than braised chops.

Skillet braising has been shown to give similar results to oven braising (Hood et al., (1954; Bowers and Goertz, 1966). The addition of water in skillet braising had little effect on the eating quality, cooking loss or cooking time but decreased the degree of browning of the chop (ibid). Roasting pan composition was found by Goertz and Hooper (1965) to influence cooking time and cooking losses but did not affect the flavor, tenderness or juiciness of braised turkey roasts. Listed in order of increasing cooking time, the compositions studied were enameled steel, aluminum, and magnesium alloy. The order of increasing total losses was aluminum, magnesium alloy, and enamel.

Pressure cooking, a modification of braising, has been shown to decrease cooking time and palatability scores (Clark and Van Duyne, 1949; Griswold 1955). However, Clark et al. (1955) found that palatability scores were unaffected.

Roasting is a dry heat method involving cooking the meat in a roasting pan on a rack with no cover or added water in an (149-176.5°C) oven to the desired degree of doneness (National Livestock and Meat Board, 1964). The major transfer of heat in roasting is by convection with radiant heat having a minor effect. A rack is used in roasting to provide for uniform heat distribution on all sides of the meat and to keep the meat out of the drip. This is probably the easiest method to standardize as there are fewer variables. The main one that has been studied is oven temperature.

Low oven temperatures for roasting have been used by various research workers. Cover (1943) noted that, if the rate of heat penetration was such that cooking to the well-done stage required 30 hours or more, the meat was tender. Cooking times were increased for low oven temperature cookery, but cooking losses were about the same. If beef was cooked only to the medium-rare stage (63°C internal temperature) however, tenderness was not improved by low oven temperature (Cover 1947). Two studies (Bramblett et al., 1959; Bramblett and Vail, 1964) showed that lower oven temperatures resulted in increased tenderness and juiciness scores, lower shear values and cooking losses, and higher press fluid yields and total moisture.

Use of skewers results in reduced cooking losses and cooking time and increased juiciness of roasts (Morgan and Nelson, 1926; Child, 1929; Cover 1941;

Bowers et al., 1965). Researchers differ on whether skewers make the meat more tender; Morgan and Nelson (1926) found that skewered roasts were less tender, whereas Cover (1941) observed that skewers increased the tenderness of roasts. The type of skewers used was investigated by Bowers et al. (1965), who found no significant difference between copper and aluminum skewers.

Funk et al. (1966) found that cooking beef loin roasts under forced circulation of air resulted in shorter cooking time, higher cooking losses, lower flavor and tenderness scores but similar juiciness scores than conventional roasting.

Comparisons of roasting and braising methods have been made. Cover and Shrode (1955) found that braised beef had higher flavor and tenderness scores, lower shear values, shorter cooking time and lower juiciness scores than if roasted. However, Paul et al. (1956) and Hoke et al. (1967) noted contrary results. Roasting resulted in higher palatability scores than braising for meat from the beef round in studies by Griswold (1955) and Hood et al. (1954).

Roasting in aluminum foil also may be considered as a braising method. Wrapping in aluminum foil resulted in increased weight loss, greater fuel consumption, and a steamed flavor compared to unwrapped beef roasts (Blaker et al., 1959; Hood, 1960). Martinsen and Carlin (1968) observed that total cooking losses and weight losses were unaffected by the use of foil on turkey roasts. If aluminum foil was used, a higher oven temperature was required to give the same appearance of doneness as ordinary roasting. Baity et al. (1969) found that the use of a tightly fitting foil wrap reduced the cooking time in comparison to the use of a loosely fitting foil wrap or ordinary roasting.

Transfer of heat in deep fat frying is by conduction from the oil to the meat. The outside tends to become cooked very rapidly and a hard crust results. This method also gives a characteristic flavor to the meat. Research papers vary on the recommended temperature and type of fat to be used for frying. Visser et al., (1960) found that more rapid heat penetration, slightly lower tenderness scores, and higher shear values and cooking losses resulted when beef roasts were fried in deep fat at 100°C than when they were roasted conventionally. Pork chops fried in deep fat were found to be less tender than those baked in the oven (Jacobson et al., (1962). However, Carpenter et al., (1968) observed that beef rib steaks cooked in deep fat were more tender than those broiled or cooked by microwaves. Roasting, broiling, deep fat frying, and electronic cookery were compared by Braniff et al., (1961) who found that tenderness and flavor were not affected by cooking method. For Longissimus dorsi, the highest juiciness scores resulted from broiling and roasting. Cooking losses were greatest in the electronic oven. In an independent comparison of these methods, Fielder et al., (1962) found that deep fat frying and electronic cookery decreased the collagen content significantly more than oven roasting and broiling. Moisture losses were significantly more than oven roasting and broiling. Moisture losses were greatest in deep fat and electronic methods. Juiciness was highest in broiled steaks and lowest in those cooked by microwaves. Cooking methods had no effect on the elastin or fat content of cooked steaks. Goodwin et al., (1962) studied the effect of method of cooking on the tenderness of precooked and raw turkey meat. The methods of cookery studied were microwave oven, deep fat frying, steam pressure, rotary reel, combination of deep fat frying and steam, and a combination of deep fat frying and microwave oven. They found that method of cooking had no effect on the shear values.

Microwave cooking is by means of high frequency electromagnetic energy converted into heat as it penetrates. Thus, the effect of microwave heating is throughout the product not just at the surface. According to Decareau (1967), standards need to be set up for microwave cookery that are different from the conventional, due to the greater reservoir of heat built up below the meat surface in microwave cooking than in conventional methods of cooking.

Several investigators have found that microwave cooking results in higher cooking losses, shorter cooking time, lower yield, lower flavor and juiciness scores than conventional methods. The effect on tenderness seems to be inconsistent (Moore et al., 1966; Pollak and Foin, 1960; Marshall, 1960; Fenton, 1957; Headley and Jacobsen, 1960; Apgar et al. 1959). Law et al. (1967) found, however, that beef loin steaks cooked by microwaves had lower cooking losses than conventionally broiled steaks. Paul (1963) summarized the effect of cooking methods on tenderness.

Waterproof boilable pouches are now available. This makes possible cooking meat by submerging in water a pouch containing meat. Commercially it is recommended that the pouch be dropped into boiling water and heated for a specified time. I found no studies that revealed the effect of different water temperatures on the meat in the pouch. However, a study by Essary et al., (1968) indicated that placing chicken broilers in cold water, then heating to boiling and boiling for 55 minutes, resulted in more tender meat and greater yield than placing broilers in either water at 65.5°C or boiling water and boiling for 55 minutes. The pouch method seems to be a hybrid between a moist and dry heat method. Heating is by conduction of the heat from the outside in. The meat is cooked in its own juices. Recently, in our lab, a comparison was made of the effects on ground beef Biceps femoris of pan broiling, oven broiling, deep fat frying, and heating in sealed pouches in a 65°C water bath. All meat was heated to an internal temperature of 65°C. The pouch method scored highest in all palatability factors, while deep fat frying scored lowest. Percent total moisture was highest in the meat cooked by the pouch method (Rogers, unpublished). This method presents problems in determining cooking losses, as the exuded fluid contains a mixture of drip, and the usual volatile components as there are no volatile losses in this method. This method appears to have possiblities for research, especially when small pieces of meat are to be cooked.

Roasting appears to be the most uniform method and one that is good for cooking large pieces of meat. There are problems in deciding on the oven temperature that should be used. Perhaps the low temperatures around 130°C need to be given more consideration. The very low oven temperatures seem impractical because of the length of time that it takes for cooking.

SAMPLING

In a research study, two types of sampling are necessary. One must first choose which portions of meat to cook; after cooking, one must sample to evaluate the effects of treatments.

Muscles within a given carcass vary in size, shape, tenderness, juiciness, and amounts of collagen, elastin, and fat. Early work by Ramsbottom and Strandine (1948,1949), Ramsbottom et al., (1945) and Hiner and Hankins (1950) indicated that the Psoas major was most tender followed by the Longissimus dorsi and the muscles of the round. However, in a study by Batcher and Dawson (1960), the Longissimus

dorsi was found to be intermediate in tenderness among ham muscles, with the Adductor being most tender in raw meat and the Semitendinosus most tender in the cooked meat. Cooking losses were found by Paul and Bratzler (1955a) to be higher in the Adductor than in the Semimembranosus.

Some muscles, such as the Psoas major and the Deep pectoral muscle, have been found to be relatively uniform from one area to another with regard to certain quality factors (Ramsbottom et al., 1945). Other muscles vary from one position to another. The Longissimus dorsi, being the largest muscle in the carcass, has probably been studied the most. The center portion of the loin has been found by some researchers (Weir, 1953; Harrison et al., 1967) to be the least tender, whereas juiciness scores and total moisture are highest. Harrison et al., (1967) observed that the anterior end of the loin scored highest in palatability scores and exuded less press fluid than the posterior end. Drip and total cooking losses increased from the rib through the loin (Mackey and Oliver, 1954). No difference in tenderness of cooked pork cuts from the anterior and posterior ends of the Longissimus dorsi muscle was found by Batcher and Dawson (1960). A very early study by Sartorius and Child (1938) showed that rib and loin pork were comparable only if physical qualities are to be measured and not if chemical analyses are to be made. Paul and Bratzler (1955a) noted variation from end to end in the Longissimus dorsi and also within the anterior and posterior positions.

Cross sectional variation in tenderness of the Longissimus dorsi muscle has been noted by Alsmeyer et al., (1965) and Urbin et al., (1962) using pork, Cover et al. (1962) with beef, and Carpenter and King (1965) using lamb. Each observed that the lateral locations were the most tender and the medial locations least tender. Cover (1937), Tuma et al., (1962) and Alsmeyer et al., (1962), working with beef, noted lower shear values at the dorsal positions of the Longissimus dorsi than the other two positions. Onate and Carlin (1963) found the medial sections more tender than the lateral sections when studying cooked pork roasts. Similar results were noted by Murphy and Carlin (1961) using raw pork. Pengilly and Harrison (1966) found no difference in shear values between medial and lateral positions of the Longissimus dorsi.

Other muscles have been found to vary in tenderness, also. The Biceps femoris muscle was found to increase in tenderness from the insertion to the origin. The anterior portion appears to be more tender than the posterior of the raw Biceps femoris muscle, but in the cooked muscle, there was no predominate effect (Batcher and Dawson, 1960).

In a study of the Semimembranosus, the center portion was found to be the most uniform in regards to tenderness (Paul and Bratzler, 1955a). Taylor et al. (1961) observed the posterior half of the Semimembranosus was relatively uniform with regards to press fluids and total moisture.

Variations due to position have been found in the Semitendinosus. Mjoseth (1951) stated that positional variations within this muscle affect the chemical composition and cooking losses. Although longitudinal variation in the Semitendinosus muscle was found by Taylor et al. (1961), the center portion tended to be uniform. The muscles just discussed represent those which have been most commonly used in research. Less work has been done using other muscles, and perhaps these need to be studied.

The effect of internal and external fat has been studied to a limited extent. Thille et al. (1932) found that exterior fat increased the rate of heat penetration, whereas interior fat retarded the rate of heat penetration because of the changes in heat conductivity of the fat as it changed from a solid to liquid. She also found that cooking losses were greater in fat covered roasts than in roasts without surface fat. Irmiter et al. (1967) studied in the effect of adding fat to ground beef cylinders of known fat content. They found that the rate of temperature rise decreased as the fat content of the meat increased. Cooking losses of meat with 10% or less fat (raw) were due to loss of moisture by evaporation. At fat levels of 20% or above, the loss of moisture by evaporation decreased, but the fat loss in the drip increased.

Funk et al., (1968a) reported on the effect of surface fat on ground beef cylinders containing 10, 20, and 30% added fat. They found that less time was required to cook the fat-wrapped cylinders than plain beef cylinders. Cooking time for fat-wrapped beef cylinders decreased as the fat content of the meat increased. The outer portion of fat-wrapped cylinders had a higher internal temperature than the center portion, due to differences in moisture evaporation. Percent moisture was higher in the fat-wrapped cylinders than the plain beef cylinders, and percents fat and protein were lower. Total cooking and volatile losses were less for the fat wrapped cylinders than the plain cylinders, whereas drip losses were higher.

Satorius et al. (1938) concluded that the fat content of meat increased during cooking because of the infiltration of melted fat from the surface of the muscle. However, the fat content of five muscles from each of eight animals was the same before and after cooking when calculated on a dry basis according to Lowe (1955). She suggested that the fat infiltration was not great during cooking because of the large size of the fat molecule. Kauffman et al. (1964) found that greater quantities of intramuscular fat were associated with higher flavor, tenderness and juiciness scores. The rate of internal temperature increase was independent of thickness of the fat cover on pork roasts, except for those with very little fat cover in a study by Weir (1960). Woolsey and Paul (1969) found that fat on a dry basis in cooked meat was higher than in raw meat with both fat cover on and off.

Bone influences the characteristics of cooked meat. Alexander (1931) and Alexander and Clark (1939) compared standing ribs with rolled roasts and found that cooking time was longer and cooking losses were less for the boneless rolls than for the bone-in roasts. Standing beef rib roasts were found by Child and Esteros (1937) to have a larger quantity of press fluids than rolled roasts, but flavor scores were similar. Heating rates through surface fat and through bone of beef rib roasts were compared by Thille et al. (1932). They found that the temperature rose at a much slower rate near the bone than near the fat, and concluded that bone was a poor conductor of heat. Paul et al. (1950) found no significant differences in cooking times or cooking losses between boned and unboned steaks. No significant difference was found by Carlin et al., (1968) in flavor, juiciness or tenderness between boned and unboned hams. Funk et al., (1968b) added bone to ground beef cylinders and found that the presence of bone helped to retain the shape of the beef cylinders and influenced pH. Bone had no consistent effect on moisture, fat, protein, ash, or cooking losses.

The presence and amount of connective tissue may influence the characteristics of the sample. Siemers et al., (1953) suggested that the addition

of connective tissue in finely minced suet and intact suet was inhibitory to heat penetration. Physical changes of connective tissue of beef heated in distilled water were found by Winegarden et al., (1952) to be softening, shortening in length, decrease in width, and increase in the thickness. The amount of collagen present in the tissue, the length of time and temperature of heating influenced the extent of change in dimensions. Funk et al., (1968c) in a study of the effects of different levels of connective tissue in cylinders of ground beef round observed no consistent effect on the connective tissue on percent moisture, fat, protein or pH. The presence of connective tissue appeared to decrease the rate of temperature rise at the beginning of the cooking period.

Coring meat for shear values is influenced by the presence of coarse intramuscular fat and connective tissue. These must be avoided if representative cores are to be obtained. Although there is a high degree of association among the values obtained using various core sizes, (Paul and Bratzler, 1955b), smaller cores result in higher variability of shear readings (Dill, 1964). Taking cores parallel to the meat fibers, Hostetler and Ritchey (1964) found a lower variability of shear readings than by taking cores without regard to the direction of the fibers.

## CONCLUDING REMARKS

In comparison of meat cookery methods, it appears to be difficult to choose standards. A number of studies have used appearance as the criterion of the degree of doneness. This varies from laboratory to laboratory. Others, have used internal temperature as the criterion of doneness. This would seem to be somewhat more reproducible than subjective evaluation. However, there are difficulties in positioning of thermocouples to avoid fat, connective tissue, and air pockets. Perhaps, there is need for a fluoroscope or X-ray or some other means of observing the inside of meat for positioning of each thermocouple. Cooking methods have been compared using different oven temperatures. This confounds the effects of oven temperature and cooking method along with perhaps variations in position of muscle, animal variation as well as other factors.

It appears that one still does not know what factors influence the rate of heat penetration. All have probably noted at one time or another that roasts of the same size using same oven temperature but cooked on different days have required widely varying cooking times. What is the reason for this? Could humidity and/or barometric pressure have an effect? Can we really say that research done at different altitudes is comparable? If barometric pressure and humidity do influence the cooking time this may in turn affect the tenderness of the meat. Perhaps there is need for a special oven with controlled temperature, humidity and barometric pressure.

It seems that little attention has been paid to the size of the piece of meat that is being cooked and its effect on the rate of heat penetration. For example, one cannot compare the tenderness of a 20 g chunk of *Biceps femoris* cooked by one method and the tenderness of an entire *Biceps femoris* cooked by another method. If you cooked these by the same methods, different results would be obtained because of the influence of cooking time on the end product.

Also, in research in order to standardize the cooking methods better controls of the source of heat must be obtained. Different laboratories have used different sizes and types of ovens and this may affect the final product. For example, in broiling meat, a means of controlling and measuring the radiant heat that is being absorbed by the meat is needed. In braising the temperature and humidity of the air within the pan and the temperature of the pan itself need to be controlled. Some of the mechanical variables in various cooking methods are summarized on the handout sheet.

All can see that there is need for much more work on standardization of meat cookery methods and related factors.

VARIABLES WHICH MUST BE SPECIFIED IN ORDER TO REPRODUCE COOKING CONDITIONS FOR VARIOUS COOKING METHODS.

| COOKING METHOD | VARIABLE |
|---|---|
| Roasting | Oven temperature<br>Atmosphere of oven including pressure, composition, flow |
| Braising | Temperature of braising pan during each portion of braising process<br>Type of oil used if meat is browned<br>Time of each portion of braising process if meat is browned.<br>Atmosphere within braising pan<br>(The temperature of the braising pan is influenced by the composition of the pan and all variables which influence roasting). |
| Deep Fat Frying | Temperature and composition of the oil. |
| Microwave Cookery | Frequency of microwaves<br>Density of microwave radiation at each location in the oven |
| Pouch Method | Composition and thickness of pouch<br>Temperature of water |

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P. ROGERS: Paper In.

HARRY BERNHOLDT: Thank you Dr. Rogers for that fine presentation. And now we're going to call on Dr. H. N. Draudt of Peter Eckrich Company to speak on the "Effect of Heating on Behavior of Meat Pigments." Dr. Draudt.

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