Destruction of *Trichinella Spiralis* by Microwave Cooking

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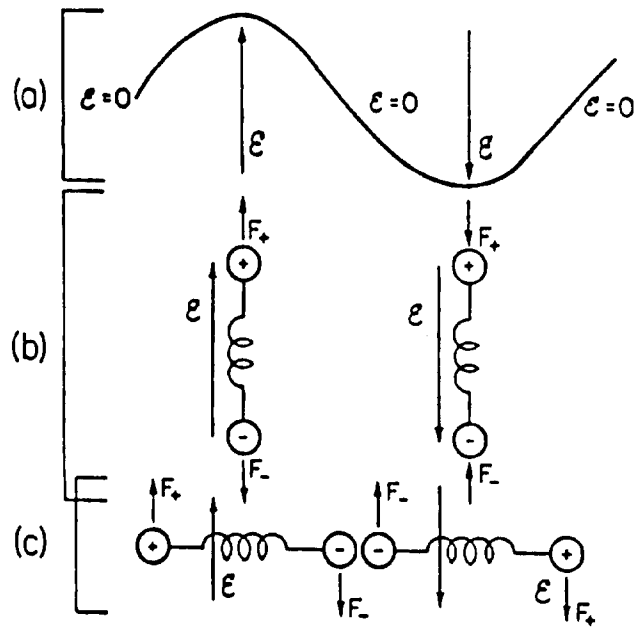
Interest in use of microwave energy to cook pork is based in part on the prospect that cooking time can be decreased substantially, the energy expended is utilized completely in heating the product, the inner portions of the meat might be heated more uniformly (Nykvist and Decareau, 1976) and the destruction of *Trichinella spiralis* larvae might be readily accomplished without overcooking the meat surface. To improve the ease and rapidity with which pork could be cooked by the hotel, restaurant and institutional (HRI) trade, rapid methods for pork cookery were evaluated from the standpoint of yield and palatability of pork chops (Kotula, et al 1981). In these tests, because of its many potential benefits, microwave energy was used as a preheating treatment to speed the uniform heating of pork chops; with subsequent browning of the pork chops with a charbroiler or a deep fat fryer. Very palatable pork chops with good eye appeal were produced by these cooking methods. As one of the last evaluations of the cooking methodologies, pork chops from pigs experimentally infected with *T. spiralis* larvae were evaluated to ensure the cooking procedures would destroy the larvae. Unexpectedly, the rapid cooking methods yielded pork chops which contained motile larvae and in some instances, wherein the chops had been thawed in a commercial microwave oven, then charbroiled, the larvae were infectious when tested by rat bioassay (Kotula, et al 1982c). To better understand the reason for the positive bioassay, the manner in which pork chops are heated by microwave energy was considered in greater detail.

Heat Penetration

Unlike cooking in the conventional oven, wherein radiant heat raises the surface temperature of the meat being cooked, the electromagnetic energy of microwave energizes the polar and nonpolar molecules of the meat about 2.54 cm from the surface (Decareau, 1967, Van Zante, 1968). Then, as in conventional cooking, the inner portion of the roast is heated through conduction from the location containing the greatest energy source. In polar molecules such as water, (Fig. 1) the energy wave form of the microwave energy alternately attracts and repels the ends of the molecule around the ionic bonds

Figure 1



from Curnutte, 1980

(Curnutte, 1980, Michael, 1979). The rapid movement causes friction with a concomitant rise in temperature. In nonpolar molecules, polarity is induced by the electrical field created from the microwaves and because of the induced polarity, even molecules such as fats can vibrate and increase the temperature of surrounding, more stable molecules (Curnutte, 1979). If levels of energy applied to a roast are exceedingly high for the mass being heated, the area at which the energy is focused may become superheated; energy has been applied at a faster rate than it can be dissipated by conduction to the inner and outer portions of the roast (Nykvist and Decareau, 1976). For this reason, some cooking instructions recommend roasts be held 5 to 16 min after cooking for temperature equalization throughout the roast. The effectiveness of the holding period is improved by covering the roast with aluminum foil. Decareau (1967) demonstrated the heat distribution in 7-rib roasts of beef when cooked at microwave energies of 2450 mHz (Fig 2). He demonstrated a temperature difference of over 55°C between the center of the roasts and the area 2.54 cm below the surface. After 45 min at room temperature, the temperature gradient was reduced to only a few degrees and the meat is ready to be served. Chops, having less mass than roasts, likewise exhibit smaller temperature gradients

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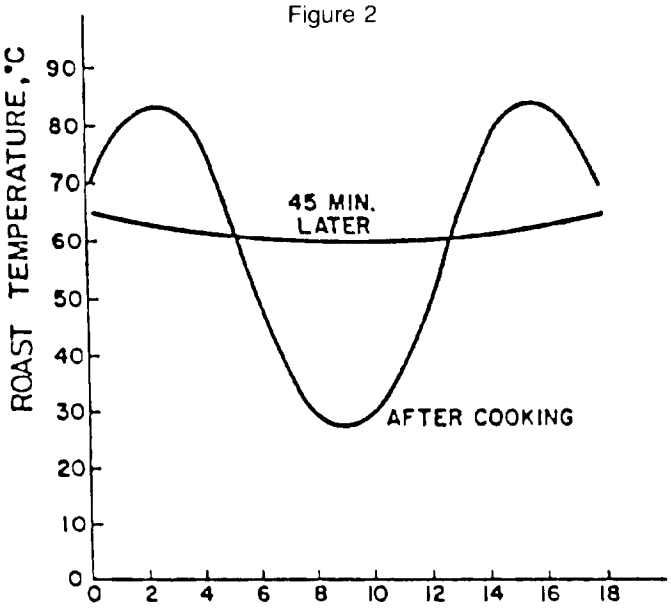
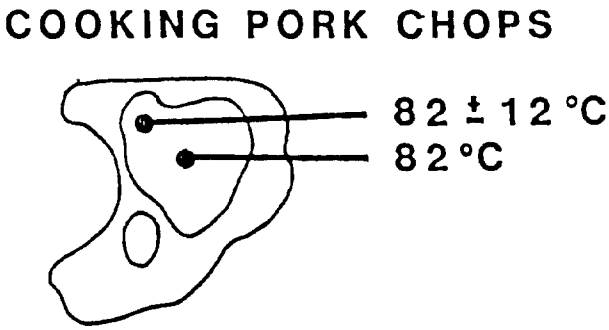
Figure 2



from Decareau, 1967

between the hottest and coldest portions of the chops and require less time for equilibration. Kotula et al (1982a) reported the temperatures at the geometric center of pork chops and at a point about .8 cm from the bone to vary by as much as 12°C when chops were cooked to 82°C in a microwave oven at 619W and 2450 mHz (Fig. 3).

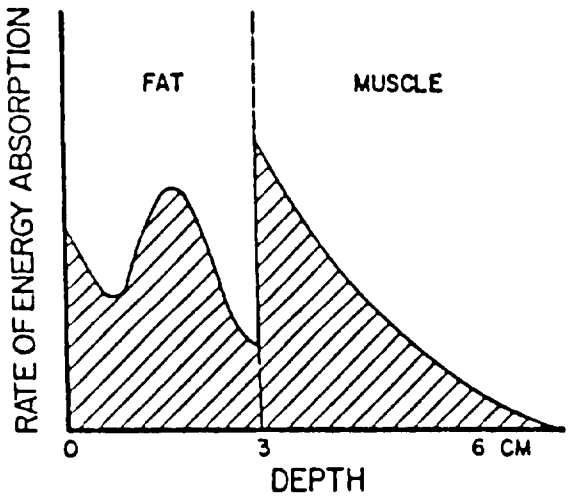
Figure 3



from Kotula et. al., 1982

The temperature as recorded at these two positions in the chops was influenced not only by the geometry of the chops, but the presence of fat and bone cover over the lean. The interface of the fat and lean acts as a partial reflector of microwave energy (Curnutte, 1980). Though the fat is not heated as rapidly as the lean, it is heated irregularly because it accumulates some of the energy passing through it to the lean and also obtains additional energy reflected from the interface to a particular depth of the fat. (Fig. 4) Likewise, the bone reflects microwave energy so that it is quite possible for temperatures adjacent to the bone to exceed the temperature near the center of the meat (Van Zante, 1968). Since bone can reflect microwave energy, it can also cause a "shadow" in the adjacent meat (Van Zante, 1968). Though we can hypothesize about the non-uniformity of heating of meat in a microwave oven, it is difficult to predict with any degree of certainty the heat distribution which will occur when the size and shape of the meat to be cooked differs from the piece evaluated. The standard wave pattern, which would be developed within a microwave oven in response to the design of the equipment, is normally disrupted intentionally with a mode stirrer (Fig. 5) to equalize the distribution of energy (Anonymous, 1976, Annis, 1980). Even with such design innovations, uneven heat distribution (Fig. 6) is still not unusual (Van Zante, 1968 Anonymous, 1980, Dahl and Matthews, 1980, Kotula et al 1982c).

Figure 4



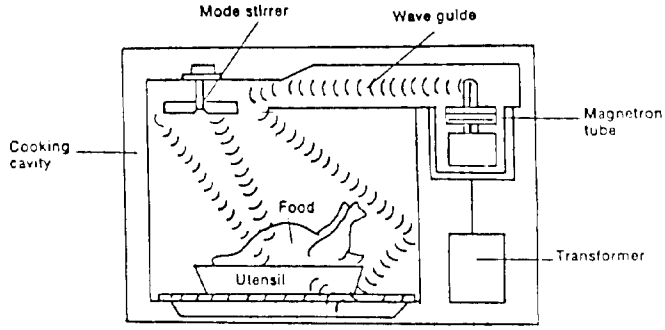
from Curnutte, 1980

The understanding of meat cookery in microwave ovens might be improved greatly by thorough characterization of heat distribution in pieces of meat varying in size, shape and composition when exposed to varying levels of microwave energies. Such research data were not found in the literature.

Heat to Destroy *T. spiralis*

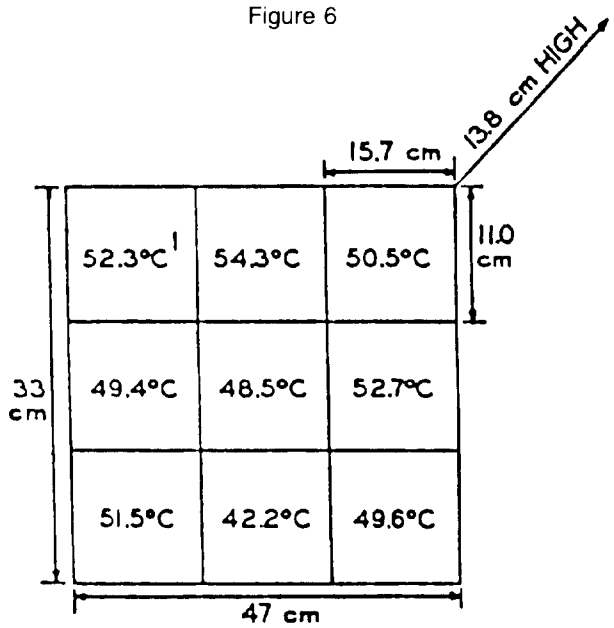
The original research of Ransom and Schwartz (1919) established that most *T. spiralis* larvae can be effectively destroyed in meat if the meat is heated to 55°C. Those authors presupposed a come up time of about 15 min with additional time necessary for cooling of the meat. Additional research by Otto and Abrams (1939) confirmed the results of the earlier authors. Based in part on the research of Ransom and Schwartz (1919), the U.S. Department of Agriculture (1960)

Figure 5



from Michael, 1979

Figure 6

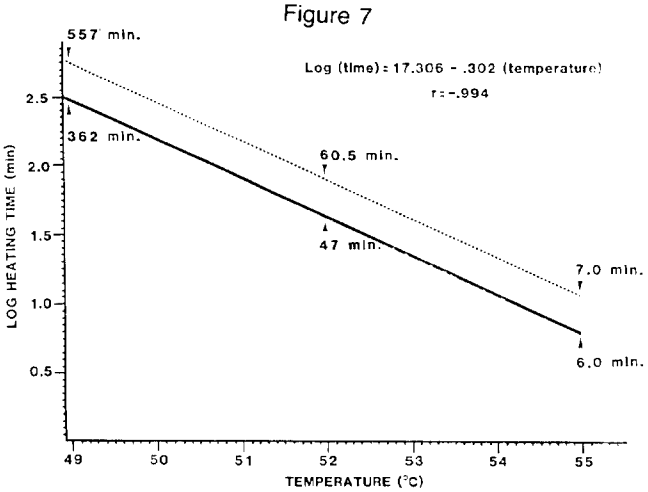


from Dahl et. al., 1980

established 58.3°C as the end point for cooking of pork in federally inspected establishments. That temperature provided a 3°C safety margin and the cooking procedure, which requires clearance by the Department, was required to be one that ensured that *T. spiralis* larvae would be destroyed, if present. Recent research by Kotula, et al (1982b) indicated that most of the larvae can be destroyed at 55°C if exposed to that temperature for 6 min. (Fig. 7). The heating times representing the upper confidence limit at the 99% and 99.999% level of probability were 7 and 24 min, respectively. The equation for the curve for the complete destruction of the larvae by heat, as indicated by rat bioassay, is Log (Time) = 17.3 − .302 (temp).

The correlation between the temperature and heating time in that study was r = −.994. The larvae can be destroyed at lower temperatures using longer heating times. For example, at 49°C, six hours of heating would be required. At 60°C, only 2 min would be required to destroy most of the larvae.

Figure 7



Microwave Cookery

G. Starrak of The National Live Stock and Meat Board recommended that neither high nor medium power of a microwave oven be utilized because the cooking will be extremely rapid and adequate time will not be allowed for the heat to penetrate the center and it will not be cooked adequately (Anonymous 1980). She also indicated that the extremely fast cooking of microwave ovens is one of the biggest advantages of the units, but rapid cooking produces dried out, overcooked roasts with a raw center. From the standpoint of ensuring the destruction of *T. spiralis* larvae, if present, the center and all other parts of the pork must be cooked to 77°C (United States Department of Agriculture, 1981). Low power on microwave ovens is recommended by Starrak to achieve this temperature, though cooking time is increased. The meat cuts which are most uniformly cooked in a microwave oven are boneless cuts that do not have both thin and thick parts or narrow projections; compact, uniform shaped meat cuts are best (Anonymous, 1982). The National Live Stock and Meat Board (1981) recommended cooking pork at 200W for 40 to 44 min/kg or for 26 to 33 min/kg at 325W.

Zimmermann and Beach (1982) studied the devitalization of *T. spiralis* larvae in experimentally infected pork roasts and chops using six household-type microwave ovens. Most of their cooking procedures were based on time and power recommendations of the manufacturers or the National Pork Producers Council. They did not cook the pork to an end point temperature because of their perception that few homemakers use thermometers to determine the degree of doneness of the cooked meat. All the ovens used were 2450 mHz frequency and had mode stirrers to distribute the microwaves more uniformly within the oven. The roasts were cooked from 18 to 33 min/kg. Of the 18 cooking methods for roasts utilized in the study, 8 were those recommended by the manufacturer. Two procedures were designated as having been recommended by the National Pork Producers Council (NPPC) and 8 were methods which incorporated the authors' modifications to attempt to improve the cooking methodology. Pork chops were cooked by a method recommended by the NPPC and a method modified by the authors. Eight of 48 pork roasts and 4 chops cooked in one of 3 of the 3 pork chop tests contained infective *T. spiralis* larvae after the meat was cooked. Four of the 8 positive roasts had been cooked using recommended cooking procedures for time, power, turning and standing time. One of the 7 roasts cooked utilizing the microwave oven probe, following the manufacturer's recommendations, was positive for infectivity when tested by rat bioassay. Two of 8 roasts cooked using recommended procedures, but not using a standing time, and one of 12 roasts cooked using procedures modified by the authors had infective larvae. The pork chop cooking method recommended by the NPPC yielded positive larvae when tested by bioassay. Of the 8 roasts and 4 chops which were positive by rat bioassay, 6 of the roasts and all of the chops had final temperatures in the center of the meat of less than the 77°C recommended by the United States Department of Agriculture (1981); and 5 of those roasts had temperatures lower than the 58.3°C recommended by the USDA (1960) for carefully monitored heating procedures in federally inspected establishments, so the positive rat bioassays might have been expected. Two positive roasts had final

internal temperatures exceeding 82°C. It is hypothesized that though the roasts had standing times of 5 and 15 min, the heat conduction was not complete and a portion of the roast may not have reached a temperature adequately high to destroy the larvae. Though these pork products sometimes contained bones and were of non-uniform shape, elimination of these 2 parameters would not necessarily result in complete inactivation of *T. spiralis* larvae because Zimmermann and Beach (1982) cited unpublished research by Carlin, Zimmermann and Sundberg which demonstrated the survival of infective *T. spiralis* larvae in uniformly shaped, boneless beef-pork loaves cooked in microwave ovens. Zimmermann and Beach (1982) reported positive larvae in pork products cooked in 5 of the 6 ovens utilized, thus they concluded the problem of non-uniformity of microwave heating is industry-wide.

Kotula et al 1982c utilized a commercial microwave oven to thaw pork chops which had been frozen 18 h at −23°C prior to cooking on a charbroiler. Chops, 3.81 cm thick, cooked to a final internal temperature of 77°C at the geometric center were infective as determined by rat bioassay. The temperatures at other locations in the chop were not determined. Chops 2.54 cm thick, cooked to 77°C, were negative by rat bioassay. When the study was repeated (Kotula et al 1982a), none of the 48 chops, 2.54 cm thick, cooked to 77°C by this method were infective. Also, 32 chops, 2.54 cm thick, cooked on a charbroiler to 77°C without prior freezing and thawing with a microwave oven, were negative by rat bioassay. When 32 chops were cooked to 77°C at the geometric center using only the microwave oven, the rat bioassay was positive. Microwave cooking to an end point temperature of 82°C at the geometric center of the chop also yielded positive rat bioassay. The cooking time for both end point temperatures of 77 and 82°C at the geometric center was only about 3 min. The temperature rise was so rapid that at a desired end point of 77°C, the actual mean temperature at the geometric center of 32 chops was 81.7°C with a standard deviation of 8.9°C. The mean temperature near the bone was 78.7°C with a standard deviation of 18.7°C. The temperature during cooking was monitored using two Luxtron Fluoroptic Temperature Sensing Instruments[1] each having one probe; temperature was recorded with a modified Hewlett-Packard 9815A calculator. Chops preheated in a microwave oven to 66°C and then cooked to 82°C in a deep fat fryer (162°C) had infective larvae. Thirty-two chops cooked to 77°C after being preheated to 60°C in a microwave oven did not have any infective larvae. Statistically, the likelihood exists that with additional samples, positive samples would be obtained at 77°C, since some positive samples were obtained in pork chops cooked to 82°C.

Discussion

The advantages of microwave cookery include the rapidity with which meat can be heated. However, if the power input is high, the desired temperature may be reached in one portion of the meat, whereas another portion of the meat may be undercooked. Nonuniformity can be overcome in part by letting the meat stand, wrapped in aluminum foil, to allow the temperature to equilibrate through conduction. The equilibration might be accomplished during cooking by utilizing lower power, thereby minimizing super heating of portions of the meat, and allowing greater temperature equilibration to occur during cooking. Bone and fat confound the uniform distribution of microwave energy into the meat, therefore the use of boneless, trimmed meat might be considered desirable. The present cooking methodologies recommended by manufacturers appear to need review before the homemaker can be assured the method will effectively destroy *T. spiralis* larvae, if present. The recommendations by the USDA (1981) are not contradicted by any of the known research to date, and therefore continue to provide the best criteria for cooking pork in a microwave oven. The recommendation states that those who prepare pork in microwave ovens in the home or food institutions should a) check the manufacturer's directions for cooking times, b) rotate dishes during cooking, c) let the pork sit several minutes after cooking to assure uniform temperature distribution, d) wrap the pork in aluminum foil after cooking to improve the effectiveness of the dwell time, and e) check various places with a meat thermometer to ensure that all parts have reached 77°C.

[1]Mention of brand names does not imply endorsement by the United States Government.

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