UTILIZATION OF MICROWAVE COOKERY IN MEAT PROCESSING

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Microwave cooking is cooking by means of electromagnetic energy in the high frequency range. The energy is actually converted into heat by action in the product at the atomic and molecular level. Time does not permit elaboration of this mechanism, however for those interested, a number of references which cover the subject in some detail are listed in the table of references. For the purpose of this presentation it is sufficient to say that microwave energy penetrates deeply into food materials and gives up energy in the form of heat as it penetrates; that the penetration is a function of frequency and temperature; and that of the microwave frequencies allocated by the Federal Communications Commission only two--915 mHz and 2450 mHz -- are of practical significance for food processing at the current state of the art.

Since the generating equipment is electronic it has no thermal inertia; that is, there is no heating lag. One does not have to wait for the equipment warm up or cool down. It is a very controllable form of energy, and very efficient because it is not wasted in heating the product environment. In other words all of the calories generated in this way are put where they can do the most good --in the product. Thus even though this is a more costly form of energy, none is wasted in a properly designed system, whereas in conventional systems which use steam, hot air, hot oil, or electricity much energy "goes up the stack" and is lost.

Microwave heating is also called volume heating to distinguish it from conduction heating because its effect is throughout the product rather than just at the surface. This is not to say that conduction heating does not play a part. Temperature gradients are established in products heated by microwave energy and the magnitude of the gradients depend on the size of the product being heated--the thicker the product the steeper the gradient. An example of this is shown in Figure 1.

Figure 1 is a graph of the temperature pattern in a 7-rib, oven-prepared roast of beef. One curve represents the results obtained at 915 mHz and the other at 2450 mHz. Both roasts received the same total heat input. The temperature in the center can be called the "microwave reference temperature" and is the temperature to which a large roast should be cooked with microwave energy to obtain the best yield and a rare degree of doneness. It is obvious also that at this temperature the roast is not rare but rather raw. However when the roast is allowed to stand at room temperature for about 45 minutes the heat located about one inch below the surface will be conducted inward and outward, and a final cross section temperature of 135-145°F. will be reached. Attempts to cook directly to this temperature with microwave energy would result

in severe overcooking of the outer layers and final yields of usable meat might be as low as 50 per cent. Indeed several studies reported in the literature have penalized microwave cooking by attempting to apply conventional cooking reference standards. (Pollack, G. A. et al, 1966; Marshall, Nancy, 1959). Properly applied microwave cooking has given yields of better than 80 per cent for roasts of this size.

It might also be pointed out that in the cooking of such large roasts, advantage can be taken of the fact that microwave energy is reflected from metal. Thus after an initial cooking period of perhaps 20 minutes, the ends of the roast can be wrapped in aluminum foil to prevent further cooking of the ends while permitting the total energy to be directed to the heating of the thicker center portion. The foil is removed after 20 minutes of cooking. In terms of cooking rates such large roasts are cooked at a rate of about 2.0 minutes per pound or about 44 minutes for a 22 pound roast. The center temperature will then coast to rare doneness at 1.0 to 1.5 degrees per minute. The surface appearance will be comparable to that obtained in a hot oven.

It is possible in many instances to obtain adequate browning with microwave cooking. Small domestic size roasts cooked at the lower power levels of domestic microwave ovens (0.5 to 1.0 kilowatts) will be adequately browned though the time to cook may be 20 minutes or less. The reference temperature is increased to 100 to 110°F. for roasts in the neighborhood of five pounds. A piece of steak or a hamburger patty however would have a gray exterior though the interior appearance would be as desired. It is necessary to pre-sear or post-sear such small items as the very short cook time--two to three minutes--for an 8-10 ounce steak is too short for much browning to take place.

The rate at which meat is cooked is also important. At very high power levels meat pieces such as cut-up poultry parts can be cooked in a few seconds to give an extremely tough product. When the rate is reduced to give a cooking time of 10 to 12 minutes, shear press values as an index of toughness were equivalent to values obtained by all steam cooking. As a result of cooking studies with steam and microwave energy, singly as well as simultaneously, a system was designed, built, and installed in the plant of a major poultry processor (Anon, 1966). Steam cooking studies alone indicated that the outer $\frac{1}{4}$ inch of meat could be cooked to doneness in about six minutes, but that the heating curve for the meat at the bone tapered off rapidly requiring about 40 minutes to reach a done condition, and further time to insure cooking of the marrow. It made economic sense to use steam to accomplish cooking of the outer layers of meat. Microwave energy made sense to insure adequate cooking to the bone. As a result the microwave content of the process was minimized to the point where the equipment costs were not prohibitive; the yields were substantially increased over water or steam cooking; the quality was actually enhanced because of the greater retention of natural juices; and a short enough cook cycle was obtained which permitted the entire operation to be conveyorized, thus resulting in a reduction in the labor requirement. In practice two parallel conveyors are used; one in which breasts and thighs are cooked, and the other for wings and drum sticks. This is necessary because it takes less energy to cook the smaller parts. If all parts were cooked together until the breasts and thighs were done then the smaller parts would be overcooked.

In summary, a number of general rules for the microwave cooking of meats can be formulated:

1). Each type of meat has its own optimum cooking rate.
2). A reference temperature needs to be established for each meat item, and this temperature will vary with the size of the item.
3). Roasting should not be carried to completion with microwave energy, rather advantage should be taken of the reservoir of heat built up below the meat surface to complete the cooking.
4). Wrapping the ends of large roasts with aluminum foil during a portion of the cooking cycle will facilitate cooking of the generally thicker center portion.
5). For production cooking it is desirable to employ a combination of microwave and other forms of energy.

It cannot be overemphasized that conventional cooking standards and techniques are not always applicable to microwave cookery, but that when the product heating performance has been properly analyzed, a system involving microwave energy may give better yields and finer quality than the conventional methods which it replaces.

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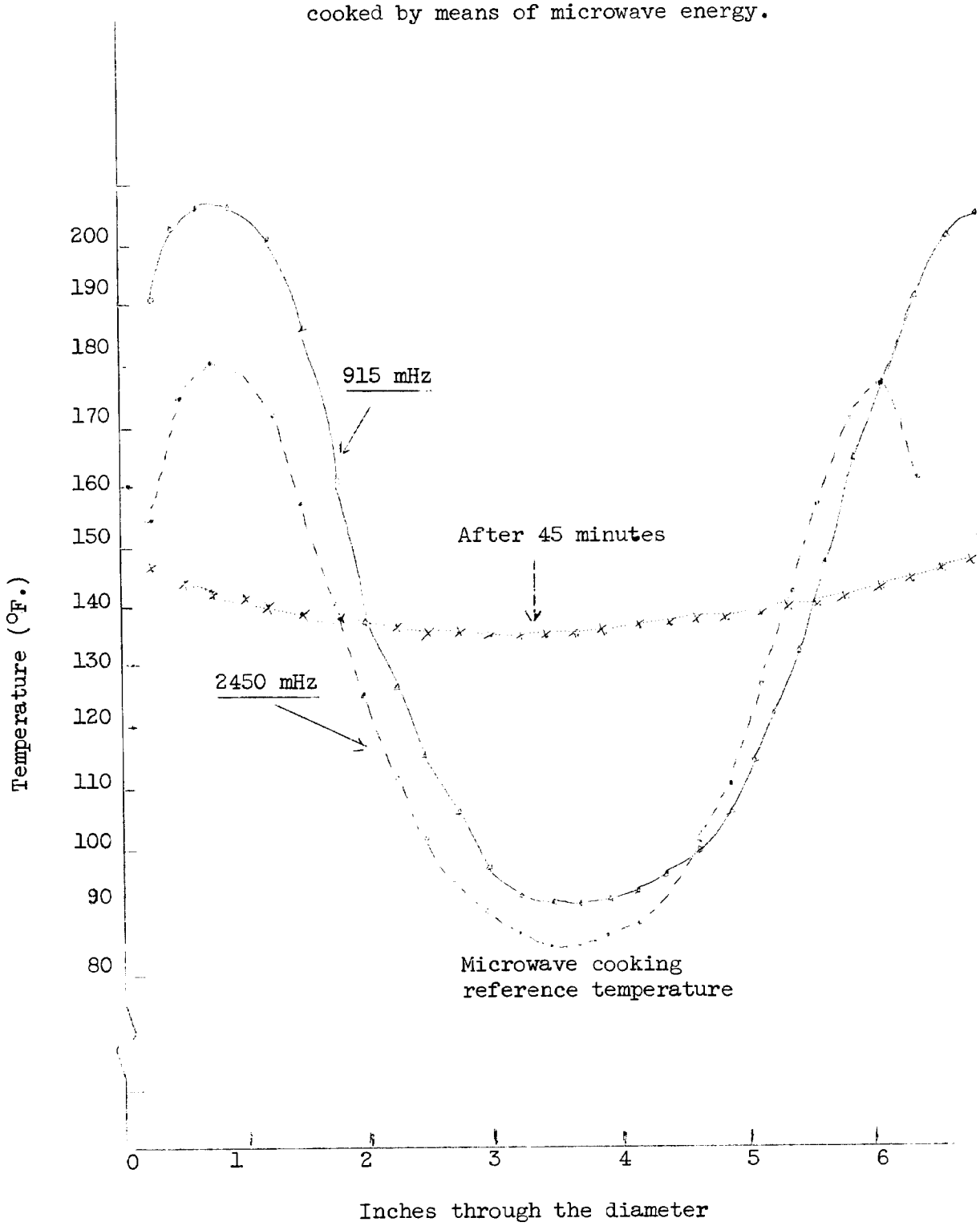
Figure 1. Temperature pattern in 7-rib roast of beef cooked by means of microwave energy.



DR. WANDERSTOCK: Thank you, Dr. Decareau for bringing this most interesting information to us. We now move on to an entirely different aspect of meat cookery relative to what actually happens in the muscle fibers when meat is cooked. Dr. R. L. Hostetler of Texas A & M University will present the paper.

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