Microwave Cooking: An Overview

RUTH E. BALDWIN

Department of Food Science and Nutrition, University of Missouri, Columbia, Missouri 65211

(Received for publication August 16, 1982)

ABSTRACT

Microwave ovens can be expected to continue as a method of cooking and reheating foods, and versatility will improve as needs become evident. Microwaves cause heating when polar materials absorb them, but confer no special qualities on the food. Lethal effects on microorganisms and trichinae are due to heat. Speed and evenness of heating are influenced by composition and mass of food as well as features of the appliance. Although there is variability depending on these factors, microwave ovens have considerable potential for energy saving. Foods cooked by microwaves are as nutritious and, in some instances, more nutritious than those cooked conventionally. Safety to the users of microwave ovens is assured by strict Government regulations.

It is estimated that usage of microwave ovens in homes exceeds a 20% saturation level in the United States. Ownership is not confined to the affluent but extends through all income groups (31). Commercial microwave oven usage for 1981 was anticipated to be 67,400 units (26). Commercial microwave ovens are employed in a wide variety of situations including carry-out businesses, taverns and bars, snack stands and fast food operations, full menu, seated foodservice establishments, restaurants serving luxury menu items, and catering and commissary food services (33).

Microwaves are applied both for cooking and for reheating precooked chilled products. Of the advantages of microwave ovens, Snyder (33) cited energy saving for some foods, provision of high quality food during off-peak operation when foods might otherwise deteriorate due to being held hot, and labor saving potential. Reduced food waste is another aspect of small batch cooking by microwaves as opposed to holding cooked foods hot (32). Other advantages cited by Franzese (14) include increased employee morale due to reduced peak work loads, labor reduction, reliability and increased flexibility.

MICROWAVES: DEFINITION AND CAPABILITIES

Microwaves are a form of non-ionizing electromagnetic energy generated by a magnetron tube. Electromagnetic energy travels in waves classified by the rate, or frequency, of recurrence of cycles. The frequencies used for cooking and processing food are among those assigned by the Federal Communications Commission for industrial, scientific and medical uses (3). Hence, some equipment used for medical purposes, such as diathermy treatments, operate on the same frequencies as microwave ovens (2). The present trend is toward exclusive use of frequency of 2450 MHz for microwave ovens.

In contrast to ionizing radiation, microwaves have insufficient energy to ionize atoms or molecules (21). In this respect, microwaves are comparable to visible light, infrared waves and radio and television waves. Ionizing radiation, such as X-rays and gamma rays, can cause cellular changes and effects which are cumulative.

Microwaves cause heating only when they are absorbed (14). Polar molecules absorb microwaves and are set in motion as they attempt to align with the microwaves which are vibrating according to their frequency. Those with a frequency of 2450 MHz vibrate at a rate of 2450 million times per second. This rapid movement of polar molecules results in heat developing within the product. Materials which transmit microwaves, such as glass, china, paper and most plastics, do not heat. This is also true for materials, such as metals, which reflect microwaves (14). Non-polar molecules absorb heat from polar molecules which heat due to absorption of microwaves. For example, a glass container will absorb heat from the food that is cooked by microwaves.

EFFECTS OF MICROWAVES ON FOOD INGREDIENTS

Foods exposed to microwaves, undergo the usual changes induced by heat. Microwaves cause no effect other than those due to rapid heating. Overcooking can occur in a matter of seconds. Because of the speed of microwave heating and because penetration of microwaves is limited and varies according to food composition (3), deviation from the usual cooking procedures may be necessary.

1Contribution from the Missouri Agricultural Experiment Station. Journal Series Number 9162. Approved by the Director.
Mass, geometry and composition of the food are more influential with microwave than with conventional heating. As mass increases, there is a concomitant increase in the time required for attaining the desired temperature. However, small, thin, less dense portions of food may overcook before other areas reach the desired temperature. Measures which permit equilibration of temperature throughout food products require more consideration with microwave than with conventional cooking.

Rapid steam formation makes venting essential for products with skins and removal of shells necessary. Cooking sufficiently for stable structure formation may lag behind expansion in volume of some baked products. Unless the mass is such that cooking beyond 15 or 20 min is required, there is insufficient time for browning which is characteristic of many foods cooked conventionally. Also, the speed of cooking does not provide sufficient time, in a favorable temperature range, for achieving optimum tenderness in some meats.

From a nutritional standpoint, foods cooked by microwaves can be expected to be as nutritious as those cooked by conventional methods (5,25). Waterless cooking, which is feasible with many vegetables, is conducive to retention of ascorbic acid in foods cooked by microwaves (26). In addition to the influence of amount of water, reduced time of cooking has a favorable effect on retention of thiamine, particularly in vegetables (35).

Because of its speed, small batch cooking by microwaves (24) or, in the case of hospital meals, plateting of food from chilled components which are heated quickly by microwaves (9) offer distinct advantages over holding foods hot. Both nutritive value and palatability are degraded by the latter practice (9).

Literature pertaining to effects of microwaves on nutritive value of food has been reviewed by Lorenz (25), Decareau (9), Livingston (24) and Cross and Fung (5).

**MICROBIOLOGICAL ASPECTS OF MICROWAVE HEATING**

A preponderance of data supports the theory that microwaves cause only thermal effects on microorganisms. Investigations have included a variety of bacteria in both model systems (18,23) and in foods, such as custards, scrambled eggs and beef patties (10).

The possibility that microwaves exert nonthermal effects continues to be suggested. Culkin and Fung (6) found a lower survival of microorganisms in the coolest part of the soup heated by microwaves. Rose (30) noted, however, that uneven heat build-up in test materials may result in changes due to heat which are not registered as such by the temperature monitoring procedures employed.

Temperature achieved, length of time held at various temperatures (4), moisture content, and physiological state of the cells, all influence the lethality of either microwave or conventional heating. Factors influencing microwave heating, composition, mass and geometry of the food, are not always addressed as, for example, in the recommendations for home pasteurization techniques (7). As stated by Fruin and Guthertz (16), the cumulative time-temperature pattern of microwave heating will differ from that of conventional heating even though the medium is identical. Dahl et al. (8) recommended that guidelines in addition to time and internal temperature be developed for cook/chill foodservice. They found similar reductions in microorganisms (Streptococcus faecium) in beef loaf and potatoes heated 80 and 85 s even though internal temperatures varied from 66 to 95°C.

Literature concerning thermal and nonthermal effects of microwaves on microorganisms was summarized by Fung and Cunningham (17). Certain unexplained phenomena and the tendency for microorganisms to align when in the presence of microwaves (20) will continue to stimulate interest in nonthermal effects of microwaves. It is doubtful, however, that such effects will ever be demonstrated to have practical application in the food industry.

**CONTROVERSY REGARDING TRICHINAE**

Trichiniae were found to survive in pork chops heated to 77°C when chops were thawed by microwaves after 18 h of frozen storage followed by charbroiling or when they were precooked by microwaves followed by deep fat frying (22). The survival may have been due to uneven heat distribution throughout the meat. Current recommendations for microwave cooking (1) are for pork to be cooked to an internal temperature of 77°C throughout the entire mass. Covering the meat during cooking and allowing time for equilibration of temperature after cooking are measures which are conducive to uniform heat distribution. No trichinae would be encountered with pork which had been frozen at 5°F for 20 d, -10°C for 10 d or -20°F for 6 d.

**ENERGY SAVING ASPECTS OF MICROWAVE HEATING**

Microwave ovens vary in efficiency from 30 to 47%. Efficiency varies with the mass of the food being heated and its composition and characteristics. Commercial ovens average around 45% efficiency (33). It is possible, depending on the food composition and mass and type of conventional heating being compared, to achieve as much as 75% energy saving by microwave heating (27). Microwave ovens are exempt from energy cost and efficiency labeling because of the low energy requirement for operation. Yet, there are notable exceptions in which conventional methods are more energy sparing, as, for example, in cooking certain vegetables (19). Even here, quantity and the method being compared influence findings.

**FEDERAL REGULATIONS**

Government regulations assure the safety of microwave cooking appliances. According to an amendment to Public Law 90-602, emission of microwaves from any surface of the oven must not exceed a power density of 1 mW/cm² before sale or 5 mW/cm² after it has been put to use (11).
In addition, microwave energy obeys the Inverse Square Law. Thus, energy, if emitted, diminishes by the square of the distance from the source (21).

Further, Government regulations require microwave ovens to have a minimum of two safety interlocks, one of which is concealed. In the event of electrical failure of a component of the oven, the interlocks must remain effective (11). Should the interlocks fail, the oven must be rendered inoperative (12). As an additional safeguard, the viewing port of the oven must be covered to prevent entry of objects from the outside (11). The most recent ovens to have a minimum of two safety interlocks, one of which is concealed. In the event of electrical failure of a microwave system, the interlocks must remain effective (11). Should the interlocks fail, the oven must be rendered inoperative (12). As an additional safeguard, the viewing port of the oven must be covered to prevent entry of objects from the outside (11). The most recent regulations require microwave ovens, other than those meeting very stringent requirements, to be labeled warning against operation if the door does not seal perfectly (13).

Few, if any, cooking appliances are regulated as strictly as microwave ovens. Even so, care should be exercised by using only grounded electrical outlets and by adhering to safety precautions normally observed when operating an electrical appliance. Worn door gaskets should be replaced and ovens should be kept clean.

MICROWAVE OVENS VS. CARDIAC PACEMAKERS

Cardiac pacemakers with proper shielding are highly resistant to interference from microwaves (21). Pacemakers which are encapsulated in plastic are susceptible to interference not only from microwaves but also from sources such as electrosurgical equipment, electric motors, electric razors, elevators, radars, regulated electric heaters, heating pads, regulated ovens, portable communicators and telephones (3). With due consideration of these facts and the stringent Government regulations regarding emission of energy from microwave ovens, generalized posting of warning signs concerning operation of microwave ovens is not recommended by the Bureau of Radiological Health (21,29).

TRENDS FOR THE FUTURE

Microwave ovens have a bright future. Snyder (33) recommended that components be built on a modular basis to facilitate removal and servicing. It is likely that this and other features, such as combined thermal-microwave capabilities (34), will become common place as demands dictate. Understanding the capabilities of microwave heating will become general as the numbers of these appliances increase both in homes and in foodservice operations.

REFERENCES

energy consumption in commercial foodservice. J. Microwave Power


Calendar

1983

March 14-16, 1983---SECOND NATIONAL DAIRY CONFERENCE, Madison, WI. For more information contact: Cathy Ziegert, Meetings Secretary, ASAE, 2550 Niles Road, St. Joseph, MI 49085, 616 429-0300.

March 20-23, 1983---AMERICAN CULTURED DAIRY PRODUCTS INSTITUTE ANNUAL MEETING AND CONFERENCE, KURDS KLINIC, Rockville, MD. For more information contact: C. Bronson Lane, ACDPI, P.O. Box 7813, Orlando, Florida 32854.

March 21-25---MID-WEST WORKSHOP IN MILK AND FOOD SANITATION, The Ohio State University. For information contact: John Lindamood, Department of Food Science and Nutrition, 2121 FYffe Road, The Ohio State University, Columbus, OH 43210.

March 24, 1983---IOWA ASSOCIATION MILK, FOOD & ENVIRONMENTAL SANITARIANS. Little Amana, Iowa. Contact Bill Lorraine, ISU, Department of Food Technology, Ames, IA 50011.

April 11-13---DAIRY AND FOOD INDUSTRIES SUPPLY ASSOCIATION, 64th ANNUAL MEETING, Boca Raton Hotel and Club, Boca Raton, FL. For more information: Dairy and Food Industries Supply Association, 6245 Executive Blvd., Rockville, MD 20852, 301-984-1444.

April 13-14, 1983---FOOD MICROBIOLOGY UPDATE. Orange County Cooperative Extension Office, Anaheim, CA. Topics covered include sampling, new trends and methods for detection, enumeration, and identification of microorganisms, microbial aspects of food processing methods, pathogens, and the significance of microorganisms in food. Contact Paulette De Jong, Food Science and Technology, University of California, Davis, CA 95616, 916 752-1478.

April 13-14, 1983---FOOD MICROBIOLOGY UPDATE. Orange County Cooperative Extension Office, Anaheim, CA. Topics covered include sampling, new trends and methods for detection, enumeration, and identification of microorganisms, microbial aspects of food processing methods, pathogens, and the significance of microorganisms in food. Contact Paulette De Jong, Food Science and Technology, University of California, Davis, CA 95616, 916 752-1478.

April 20-22---SOUTH DAKOTA ENVIRONMENTAL HEALTH ASSOC. ANNUAL MEETING. Howard Johnsons, Sioux Falls, SD. For more information contact: Morris V. Forstine, SD State Dept. Health, 1320 S. Minnesota Ave., Room 101, Sioux Falls, SD 57105.

April 20-22, 1983---FOOD MICROSTRUCTURE ANNUAL MEETING in conjunction with Scanning Electron Microscopy 1983. For more information contact: Dr. Om Johari, SEM Inc., P.O. Box 66507, AMF O’Hare (Chicago), IL 60066, 312-529-6677.

April 26---ILLINOIS ASSOCIATION OF MILK, FOOD AND ENVIRONMENTAL SANITARIANS SPRING MEETING. For more information contact: Clem J. Honer, 1 S 760 Kenilworth Ave., Glen Ellyn, IL 60137.

April 27, 1983---SOUTHERN CALIFORNIA FOOD PROCESSORS SANITATION WORKSHOP FOR THE FOOD PROCESSING AND FOOD SERVICE INDUSTRIES. Presented by the University of California Cooperative Extension with assistance from industry trade associations and food industry personnel. Inn at the Park, Anaheim, California. For more information contact: Paulette De Jong, Food Science and Technology, University of California, Davis, CA 95616, 916 752-1478.

May 16-20, 1983---INTERNATIONAL DAIRY FEDERATION SYMPOSIUM, Denmark. For more information contact: Canadian National Committee International Dairy Federation, 549 Sir John Carling Building, Ottawa K1A 0C5 Canada, 613-994-9537.

May 23-25, 1983---TRACE ANALYSIS OF FOODS: Flavor Problems and Contaminants. Univ. of Mn, St. Paul, MN. For more information contact: Gary Reineccius, Department of Food Science and Nutrition, University of MN, St. Paul, MN 55108.

June 1-3, 1983 "Roles of Cereals and Legumes in the Food Supply" three day symposium sponsored by the Nutritional Sciences Council of Iowa State University. For more information contact: Dr. J. Dupont, Dept. of Food and Nutrition, Iowa State University, Ames, IA 50011.

June 8, 1983 Nebraska Dairy Industries Association Annual Spring Dairy Outing, Beatrice, NE. For more information contact: T.A. Evans, Executive Secretary, 134 Filley Hall, East Campus, UN-L, Lincoln, NE 68583.

June 13-14, 1983 Conferences on the Human-Animal Bond, University of Minnesota, Contact: Center to Study Human-Animal Relationships and Environment I-117 Health Sciences Unit A 515 Delaware St. S.E., Minneapolis, MN 55455.

June 17-18, 1983 Conferences on the Human-Animal Bond, University of California, Irvine. Contact: California College of Medicine A121 Medical Sciences I, Irvine, CA 92717.

July 16-23, Microwave Workshop, Kansas State Univ. For more information contact: Dr. Daniel Fung, Call Hall, KSU, Manhattan, KS 66506, 913-532-5654.

July 3-8, 1983---67TH ANNUAL SESSION OF THE INTERNATIONAL DAIRY FEDERATION, Oslo, Norway. For further information, contact Harold Wainess, Secretary U.S. National Committee of the IDF (USNAC), 464 Central Avenue, Northfield, IL 60093, 312-446-2402.

July 9-14, 1983 Annual Education Conference, National Environmental Health Association, Holiday InnScope, Norfolk, VA. Contact: Leon F. Vinc, Director of Health, City of Middletown, Middletown, CT 06457-1300.

August 1-5, 1983 "Biotechnology; Microbial Principles and Processes for Fuels, Chemicals and Ingredients" Massachusetts Institute of Technology Cambridge, MA 02139. Contact: Director of Summer Session, MIT, Room E19-356, Cambridge, MA 02139.

Aug. 7-11, 1983---70TH ANNUAL MEETING OF IAMFES. Marriott Pavilion, St. Louis, MO. For more information contact: Kathy R. Hathaway, IAMFES, PO Box 701, Ames, IA 50010, 515-232-6699.

Aug. 7-11, 1983---23rd ANNUAL MEETING, THE HOSPITAL, INSTITUTION, AND EDUCATIONAL FOOD SERVICE SOCIETY. Fairmont Hotel, New Orleans, LA. HIEFFES Expo '83 will be open on August 9 and 10. For more information contact: Carolyn Isch, Assistant Executive Director, HIEFFES, 4410 West Roosevelt Road, Hillside, IL 60162, 312-449-2770.

Aug. 14-19, 1983---5th WORLD CONFERENCE ON ANIMAL PRODUCTION, Nihon Toshi Center, Tokyo, Japan. For more information: The 5th WCAP Conference Secretarial, c/o National Institute of Animal Industry, Tsukuba Norimandchi, PO Box 5, Ibaraki 305, Japan.

1984

August 3-9, 1984---IAMFES ANNUAL MEETING, Edmonton, Alberta, Canada.

Classified Ads

For Sale

Single Service milk sample tubes. For further information and a catalogue please write, Dairy Technology Inc., PO Box 101, Eugene, OR 97401.