

NUTRITIVE LOSSES ATTRIBUTABLE TO
MICROWAVE COOKERY

by

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INTRODUCTION

Changes in home, institutional, and commercial processing and preparation of foods have brought to the attention of many that food composition tables need reevaluation. Baldwin et al. (1976) stated that "increasing nation-wide concern for nutrition cannot be directed realistically unless up-to-date information is available on the influence of new processing and preparation procedures on nutritive value and quality of foods." Because of the new processing and preparation procedures, Watt and Murphy (1970) believed that a number of food commodities and conventional food products such as beef, poultry products, grain products, mixes, fruits, vegetables, and institutional products need to be reanalyzed nutritionally to update food composition tables used by government agencies, food industries, and food researchers.

One of the changes taking place in homes, institutions, and industries is the use of microwave ovens. According to a survey conducted for the American Can Company, microwave ovens have changed the head of the household's approach to meal planning and preparation (Murray, 1977). Thirty-three per cent of the 500 respondents to the survey questions claimed that foods cooked more quickly and 19% said foods thawed more quickly when a microwave oven was used. Thirty-five percent indicated less menu planning is needed. Thirteen percent said that they prepare different types of food than they had prepared in the past with a conventional range and 12% used more leftovers. Eighty percent indicated changes in their approach to food preparation.

The survey also asked owners of microwave ovens which foods they prepared most frequently in their microwave ovens; the response was 51%

for vegetables, 39% for bacon, 38% for potatoes, 38% for hot sandwiches, 33% for hot dogs, 29% for leftovers, and 26% for soups and eggs. Pork, spareribs, steaks, and roasts were prepared by 26% of the respondents, and stews and casseroles were prepared by 23%. Bread, toast, rolls, buns, and muffins were mentioned by 25% of the respondents.

Large scale feeding operations and industry also are using microwave ovens. In institutions, microwave ovens are used mainly to reheat conventionally prepared foods and to thaw and warm precooked frozen foods (Lorenz, 1976). More institutions such as elementary and secondary schools, colleges and universities, recreational and labor camps, hospitals and nursing homes, military feeding operations, and welfare institutions would be using microwave ovens if the nutritional implications of microwave cookery were studied to resolve the doubts that potential users have in the method (Kahn, 1970). Some present or future uses of microwave energy in industry are defrosting meat and fish, pasteurizing milk and ham, sterilizing foods in plastic bags, baking bread and rolls, proofing doughnuts, inhibiting mold in bakery products, drying potatoe chips, and blanching vegetables (Lorenz, 1976).

Because microwave cookery is becoming increasingly popular, even though skepticism exists about the nutritional adequacy of the food, this report will consist of a review of the literature relative to the nutritive losses attributable to microwave cookery. The objective is to summarize results of research experiments on meat, poultry, vegetables, baked products, and institutionally prepared foods cooked by microwaves.

Information is presented in two parts. Part I includes a short discussion of principles and techniques of microwave cookery and general

effects of microwaves on selected food components. In Part II details of specific studies are tabulated by food products.

A computerized literature search was performed through a computer terminal located in Farrell Library at Kansas State University to find the research articles for Part II. The abstract systems used were Food Science and Technology (1969-1979/July), Biological Abstracts (1974-1979/Oct.), and Chemical Abstracts (1972-1979/July). For earlier research, indexes and abstracts from as far back as 1945 were searched manually.

PART I

MICROWAVE COOKERY

To understand the effects of microwaves on nutritive quality of food, some background on the principles and techniques used in microwave cooking is needed. The microwave oven is a box or cavity, generally rectangular in shape (Copson, 1962), designed to heat food by non-ionizing radiation. Within the box or cavity is a magnetron tube, or generator, which is used to change electricity into microwaves (Fenton, 1957). Microwaves are short electromagnetic waves, about 12.7 cm in length (Moore, 1978), that fall between light and radio waves in frequency (Van Zante, 1973). Four frequencies used for microwave heating, under the rules of the Federal Communications Commission, are 915 MHz, 2450 MHz, 5800 MHz, and 22,125 MHz (Copson, 1962). The wavelength frequency most commonly used for microwave cookery is 2450 MHz, although 915 MHz also is used. The wavelength determines the energy available for food preparation. A short wavelength (2450 MHz) provides more energy than a longer wavelength (915 MHz), Van Zante, 1973.

Microwave energy interacts with matter in three basic ways: reflection, transmission, and absorption (Schiffmann, 1971). Metals reflect microwaves, which is why a microwave cavity has metallic walls. The metallic walls are designed to reflect microwaves so that food can intercept energy from many directions. Glass, paper, and some plastics can be used as cooking utensils in a microwave oven, because microwaves can be transmitted through them with little or no energy loss, whereas oils, water, and water containing foods absorb microwave energy and convert it to heat (Schiffmann, 1971).

The heating principle of microwave cookery involves molecules within the food acting as miniature dipoles and oscillating about their axes (attributable to microwave penetration). Heat is generated from the intermolecular friction created by the molecules attempting to go to the proper positive or negative poles (Goldblith, 1966).

The dipole molecular action is one of the many factors that affects cooking time. Molecules of foods vary in their ability to oscillate, decreasing or increasing the dipole molecular action. Foods containing a high percentage of water are subject to much dipolar activity, and therefore, cook easily (Van Zante, 1973).

Another factor affecting cooking time is the depth of penetration of the microwaves. Microwaves are capable of penetrating food from $2\frac{1}{2}$ to 3 inches (Fenton, 1957), but if the food is frozen, microwave penetration can be much greater. However, the effects of microwave absorption are greater than the effects of microwave penetration, and because the absorption rate of water is much higher than that for ice, the thawed food will cook faster than the unthawed food (Napleton, 1967). The frequency also influences the depth of penetration. The longer the wavelength (lower frequency), the greater the penetration of microwaves and the longer the cooking time.

The mass, size, and shape of food cooked in a microwave oven is important in determining cooking time. The dimension of food is important because the denser and larger the food, the longer it takes to cook by microwave energy. Also, various shapes affect cooking time. Roasts shaped in a cylindrical form or meatloaves shaped like a doughnut will cook more rapidly and evenly than irregular shaped roasts and loaves (Baldwin, 1977).

The evenness of cooking is also an important consideration when cooking in a microwave oven. Bone in meat can facilitate uneven cooking, because calcium and other minerals in bone reflect microwaves. This reflection of microwaves causes rapid heating. Bone also casts shadows, which slow down the heating process of the meat (Van Zante, 1973). Meat just inside a fat covering cooks more rapidly than meat not surrounded by fat. Because of its low specific heat, fat tissue cooks more rapidly than lean muscle (Baldwin, 1977 and Kalafat, 1973). This also suggests that ground meat in which the fat, connective tissue, and lean meat are uniformly distributed will cook more evenly than intact muscle (Napleton, 1967).

Utensils used in a microwave oven also influence the evenness of cooking. Van Zante (1961) found that foods cooked in a circular pan cook more evenly than those cooked in a square pan. In a square pan, microwaves become concentrated in the corners causing hot spots. Containers that will not absorb, reflect, or refract microwaves are ideal for uniform cooking in a microwave oven (Van Zante, 1973). Metal foil also can be used advantageously to facilitate even cooking, because it acts as a shield preventing microwave penetration. Thinner portions of a roast, poultry wings and drumsticks, and the outside corners of square cake pans are examples where metal foil can be used successfully (Van Zante, 1973).

EFFECTS OF MICROWAVE ENERGY ON FOOD COMPOSITION

The following information is from studies found in the literature on the effects of microwave energy on selected food components as compared to other methods of cookery. Food components included in the discussion are moisture, amino acids and protein, carbohydrates, lipids, vitamins, and minerals.

Moisture

Frequently moisture loss is greater for foods cooked by microwaves than for foods cooked by conventional methods. Data for pork, beef, and poultry supporting this statement were reported by Apgar et al. (1959), pork; Bowers et al. (1974a), pork; Bowers et al. (1974b), poultry; and Moore et al. (1980), beef.

When vegetables (green beans, broccoli, peas, potatoes, or spinach) were cooked in a microwave oven without water, moisture losses were greater than when they were cooked with water in a microwave oven or by conventional methods (Eheart and Gott, 1964). Lorenz (1976) explained that when researchers use large amounts of water to cook vegetables in a microwave oven, the process of cooking is similar to conventional cooking in which the conduction and convection of heat from the water cooks the vegetables rather than the vegetables being cooked by microwaves. Lanier and Sistrunk (1979) found that sweet potatoes prepared electronically received lower ($P < 0.05$) sensory moisture ratings than those prepared by conventional home methods or by commercial canning procedures.

[Baked products also have a tendency to lose more moisture when cooked electronically than when cooked by conventional methods. Yellow cakes (Street and Surratt, 1961) and white and devil's food cakes (Neuzil and Baldwin, 1962) were less ($P < 0.01$) moist when baked in a microwave oven than when baked in a conventional oven. When Street and Surratt (1961) added liquid (40g per 212g of batter) to yellow cake batter baked by microwaves, the baked cake was equal in moisture content

to a conventionally-baked batter (without additional liquid), but the microwave-baked cake had undesirable tunnels.

Amino acids and protein

Frozen ground beef or lamb patties were cooked by pan-broiling, oven-broiling, or microwaves (with and without pre-browning). The patties were thawed during the cooking process or at room temperature to an internal temperature of 2.8°C . There was no consistent trend in the amount of lysine lost that was attributable to either thawing or cooking method. A major percentage of the lysine was retained in all drained patties with only negligible amounts in the drip (Causey et al., 1950).

Baldwin et al. (1976) found that the free amino acid content tended to be greater in conventionally cooked beef, lamb, or pork roasts than in those meats cooked in two microwave ovens (2450 MHz, 220 or 115 volts). Valine and leucine were higher ($P < 0.05$) in all conventionally-cooked roasts than in the microwave-cooked roasts. Free amino acid content of beef round roasts was similar in roasts cooked in moist heat by conventional or electronic methods, except for glutamic acid, leucine, and threonine, which were greater ($P < 0.05$) in the conventionally cooked roasts (Korschgen and Baldwin, 1978).

Raw, headless shrimp defrosted by a water method used predominately in the fishing industry, lost more protein by leaching into the water than shrimp defrosted by microwaves in a 915 MHz conveyORIZED multi-mode applicator.

Tsen et al. (1977) compared the effects of conventional baking, microwave baking, and steaming on the protein efficiency ratio (PER) of regular and fortified breads (defatted soy flour or lysine). All conventionally

baked breads had a lower ($P < 0.05$) PER than breads baked by microwaves or by steam. Lysine has a role in the browning process; conventional baking produced a browner crust than was obtained with microwave baking or steaming, so more of the lysine was destroyed.

Carbohydrates

Understanding how cooking methods affect carbohydrate content of foods is important in establishing an appropriate diet for persons with diabetes mellitus (a major public health problem). However, no research was found on the effects of microwaves on the carbohydrate content of human foods after processing and preparation. Jones and Griffith (1968) did compare conventional drying to microwave drying of herbage used for animal food to study the effects of drying on the soluble carbohydrate content. Their results indicated higher soluble carbohydrate in herbage dried by microwaves.

Lipids

Fat content of meat loaves or of beef, pork, or lamb roasts did not differ significantly between products cooked by microwaves and those cooked by conventional methods (Kylen et al., 1964; Noble and Gomez, 1962). However, Ziprin and Carlin (1976) found that fat content of meat loaves containing soy flour or a soy concentrate cooked by microwaves was higher ($P < 0.01$) than the fat content of loaves cooked conventionally.

Janicki and Appledorf (1974) prepared ground beef patties obtained from a commercial fast food franchise by broiling, grill frying, microwave cookery, or by reheating in a microwave oven after being broiled, then frozen. Patties cooked by microwaves contained the least total crude fat

and the largest ratio of unsaturated to saturated fatty acids, which suggested to the authors that persons on a low fat diet might use microwave cookery to help decrease the fat content of their diets, and to retain the highest ratio of unsaturated to saturated fatty acids. However, significant decreases in cholesterol occurred during cooking of all patties, except for patties cooked by microwaves.

Data on the fatty acid composition of deep-fat fried chicken that was frozen, then reheated indicated that chicken reheated in a microwave oven contained less myristic, palmitic, and stearic acids (all saturated acids) and palmitoleic (an unsaturated acid) than did chicken reheated in a conventional oven. Refried chicken contained less of those fatty acids than did chicken reheated in either a microwave or a conventional oven (Berry and Cunningham, 1970).

Schiller et al. (1973) compared lipid changes in egg yolks and cakes cooked by conventional methods or by microwaves at 915 or 2450 MHz. Oxidation (Thiobarbituric acid value, TBA) was greater ($P < 0.01$) in yolks cooked in a conventional oven than it was in yolks cooked by the two microwave frequencies. Oxidation also was greater ($P < 0.01$) in yolks cooked in a microwave oven at 2450 MHz than in yolks cooked by microwaves at 915 MHz; the greater the energy exerted, the greater the fat oxidation, but even greater was the effect of the longer heating time in the conventional oven. TBA values were lowest in cakes baked in the conventional oven, which suggests that the ingredients in cakes may protect the egg yolk from fat oxidation, because yolks cooked alone in a conventional oven had the highest TBA values.

Vitamins

Changes in vitamin content, as a result of microwave cookery, have been reported for several of the B-vitamins, ascorbic acid and carotene (a precursor of vitamin A) in food systems such as red meat, poultry, vegetables, and baked products. Only a few reports were found for each of the vitamins and food systems, attributable to the fact that extensive research has not been performed on any of the vitamins.

Reports that are available on loss of B-vitamins (thiamin, riboflavin, niacin, pyridoxine, and pantothenic acid) in foods cooked by microwave or conventional methods have shown no consistent trends in the amount of nutrients lost during cooking. Reports by Causey et al. (1950a, 1950b, and 1950c) showed no consistent trends in the loss of thiamin, riboflavin, or niacin in pork, beef, or lamb patties or loaves. Although there were no significant losses of thiamin, riboflavin, or niacin in pork patties cooked by microwaves or conventional methods, the beef patties showed a significantly lower retention of thiamin and riboflavin when cooked by microwaves than when cooked conventionally. Drip from the lamb patties cooked by microwaves contained more thiamin than drip from the lamb patties cooked conventionally, but no consistent trends were found in the amount of riboflavin loss attributable to cooking methods.

In other studies similar losses were found when meat was cooked by microwave or conventional methods. Apgar et al. (1959) cooked pork patties, roasts, and chops by microwave or conventional methods and found that the thiamin content was similar for the two cooking methods. Noble and Gomez (1962) found that the retention of riboflavin was similar for lamb roasts and bacon cooked electronically and conventionally. Even when the bacon

was cooked electronically for a longer period of time in a triple serving (9 slices) as compared to a single serving (3 slices) the riboflavin content did not differ significantly.

Bowers et al. (1974b) compared pork loin cooked by microwaves or conventionally and found no differences in the pyridoxine (B_6) content of the meat that was of practical importance. Baldwin et al. (1976) also found similar losses of thiamin, riboflavin, and niacin when the longissimus dorsi muscle of beef or pork and a deboned leg of lamb were cooked by microwaves or conventional methods. When comparing effects of moist-heat microwave cookery and conventional oven braising on thiamin, riboflavin, and niacin content of round roasts of beef, Korschgen and Baldwin (1978) found no significant differences between the two cooking methods. However, beef cooked by microwaves retained more ($P < 0.05$) thiamin and riboflavin than that cooked by conventional braising; equal amounts of niacin were retained by beef cooked by the two methods.

Research with poultry also showed that there were no significant differences in the thiamin content as a result of cooking with microwaves or by a conventional method. Bowers and Fryer (1972) reported that pectoralis major muscles of tom turkeys did not differ significantly in thiamin content when cooked in a microwave oven or in a conventional oven. In the same study they found that the type of oven did not affect the riboflavin content of turkey on a wet basis or as percentage retention; however, on a moisture-free, fat-free basis the riboflavin content was higher ($P < 0.05$) for turkey cooked in a conventional oven than for turkey cooked in a microwave oven. Even when Armbruster et al. (1975) baked chicken covered or uncovered with household film in a 915 MHz or in a

2450 MHz microwave oven, no significant differences were found in the riboflavin content of the meat.

Wing and Alexander (1972) found that retention of vitamin B₆ in cooked chicken was higher ($P < 0.05$) when cooked by microwaves (91%) than when cooked conventionally (83%). Bowers et al. (1974) also found turkey retained more ($P < 0.05$) vitamin B₆ on a cooked weight basis when baked in a microwave oven than when baked conventionally, but on a dry weight basis there was no significant difference.

The few studies found on the effects of microwave cookery on the thiamin content of vegetables were diversified. Thomas et al. (1949) found that pressure cooking resulted in significantly greater thiamin and riboflavin retention in broccoli and cabbage than did boiling or microwave cooking, and pressure cooked carrots and potatoes retained the same amount of thiamin and riboflavin as was retained when those vegetables were boiled or baked conventionally or by microwaves. The authors believed that water-soluble vitamins, such as thiamin and riboflavin, were affected more by the amount of water used and cooking time than they were by the cooking method per se.

Stevens and Fenton (1951) reported that although the time for microwave cooking of peas was one-third the time required for stewpan cooking, thiamin and riboflavin retention by the peas did not differ significantly between the two cooking methods. Armbruster et al. (1975) found that the thiamin content of peas was not affected significantly by household plastic film covers when cooked in a 915 MHz or a 2450 MHz microwave oven.

Lanier and Sistrunk (1979) prepared sweet potatoes by baking, boiling, steaming, microwaves, or commercial canning and found that roots baked

conventionally or electronically retained equal amounts of riboflavin and niacin, whereas the commercially canned roots contained the least amounts of those vitamins.

In the search made for this report, only one article was found on the effects of microwave cookery on B-vitamins in baked products. That was an experiment performed by Proctor and Goldblith (1948). In their experiment, commercial mixes for gingerbread, devil's food cake, or white cake baked in a microwave oven retained more thiamin and less riboflavin than when baked in a conventional oven. As the baking time in the microwave oven was increased from 1.0 to 1.25 to 1.5 min, the thiamin retention decreased from 87.9 to 81.1 to 77.9%; respectively.

Research on thiamin and riboflavin losses in foods prepared in model food service operations have shown that holding time has the greatest affect on B-vitamin content and B-vitamin retention in food. Kahn and Livingston (1970) found that freshly prepared food dishes that were cooked in a microwave oven or those same foods that were frozen then reheated in a microwave oven retained more thiamin than was retained by the same products reheated in infrared ovens or by immersing in a boiling water bath. Their data indicated that increasing the holding time of the freshly prepared foods in a laboratory water bath to simulate conventional handling decreased the thiamin content and percentage retention more than any of the other reheating methods. Ang et al. (1975) also found that increasing the holding time of freshly prepared food dishes decreased ($P < 0.05$) the thiamin content and percentage retention as compared to the freshly prepared dishes with no holding time, but increased holding time did not affect significantly the riboflavin content or percentage retention of the

same foods. They also found that the freshly prepared foods that were frozen, then reheated by microwave or infrared ovens regained more ($P < 0.05$) thiamin than products reheated in a convection oven or in a steamer. There were no significant differences in the loss of riboflavin attributable to cooking treatments.

Ang et al. (1978) performed another study on the effects of convection, infrared, steam, and microwave reheating on the thiamin and riboflavin content of commercially frozen fried chicken and char-broiled beef-soy patties. They found that chicken retained equal amounts of riboflavin when cooked by all four methods. However, beef-soy patties retained more ($P < 0.05$) riboflavin when reheated by microwave or convection methods than when reheated by the other two methods, with infrared reheating being the most destructive. The opposite was true for thiamin retention. The microwave and infrared treatments were the most detrimental to the thiamin retention of the beef-soy patties which the authors attributed to intense surface heating in the infrared oven and localized intense hot spots in the microwave oven.

Another way in which microwave heating and its effect on B-vitamins have been studied is through the use of buffer solutions. Goldblith et al. (1968) exposed thiamin buffer solutions to model systems in a 2450 MHz microwave oven in which the time and temperature of the solutions were controlled. There was no destruction of thiamin attributable to the microwave energy per se, but increased heat exposure did affect the amount of thiamin in the solutions. Van Zante and Johnson (1970) reported that thiamin chloride and riboflavin in citrate in buffer solutions (pH 5.7) exposed to microwaves retained slightly less thiamin and riboflavin than did the same solution heated in a conventional oven. However, they

considered the difference of no practical importance, because vitamins are more stable in foods than in buffer solutions.

Like the B-vitamins, some studies have shown that the greatest contributors to the loss of ascorbic acid are the use of large amounts of water and increased cooking time. However, carotene and folacin have not been shown to be as water soluble or as sensitive to heat as is ascorbic acid. Chapman et al. (1960) studied the effects of increased cooking time on the ascorbic acid and carotene content of fresh and frozen broccoli cooked by microwaves and found that for every 3 min of increased cooking time there was a 3.6% decrease in ascorbic acid, but no significant loss of carotene. Martin et al. (1960) found similar results when broccoli was cooked in boiling water and by microwaves without water. As the cooking time increased the ascorbic acid decreased in the broccoli cooked by both microwave or conventional methods.

Eheart and Gott (1965) cooked broccoli and green beans by a stirfry method, a microwave method, and two conventional methods (covered and uncovered) in varied amounts of water and found that ascorbic acid retention was highest when the vegetables were cooked in small amounts of water.

Thomas et al. (1949) found that both, amount of water and time exposed to heat, affected the ascorbic acid content of broccoli, cabbage, carrots, and potatoes.

Overall, research by Campbell et al. (1958), Gordon and Noble (1959), Bowmen et al. (1975), and Mabesa and Baldwin (1979) has found that vegetables retain more ascorbic acid when cooked in a microwave oven than when cooked by conventional methods, while Causey and Fenton (1951), Stevens and Fenton (1951), Martin et al. (1960), Kylen et al. (1961), and Eheart

and Gott (1964) found no significant differences between ascorbic acid content in vegetables cooked by a microwave or conventional method.

Lanier and Sistrunk (1979) found that sweet potatoes baked by a microwave oven or cooked commercially retained less ascorbic acid than when baked conventionally, but found no significant difference in the carotene content between the sweet potatoes baked by the various methods.

Klein et al. (1979) also found no significant differences in the folacin content of spinach, green peas, green beans, and broccoli cooked in a microwave oven without water or in 100 ml of water on a gas range.

Some research by Moyer et al. (1947), Samuels et al. (1948) and Procter and Goldblith (1948) has indicated that blanching by microwaves may be beneficial in decreasing the amount of ascorbic acid lost as compared to blanching by conventional methods with water. Eheart (1967) also found that on a wet basis the ascorbic acid content of broccoli blanched by microwaves for two minutes was significantly higher than broccoli blanched by two conventional methods (100 or 77°C for 3 or 10 min, respectively), but on a dry basis there was no significant difference between the vegetables blanched by microwaves and the vegetables blanched at 100°C for 3 min.

Eheart and Odland (1973) experimented with adding ammonium hydroxide to broccoli blanched by microwaves and concluded that on a wet basis the broccoli blanched by microwaves retained more ascorbic acid than the broccoli blanched in boiling water, but on a dry basis there was no significant difference. According to a study by Moyer and Stotz (1947), neither the method of blanching (microwaves, water, or steam) nor the variations in time or temperature affected significantly the amount of carotene found in peas.

Minerals

Limited information is available at this time on the effects of microwave cookery on the mineral content of foods. Baldwin et al. (1976) studied sodium, chloride, phosphorus, and iron contents of and percentage retention in beef and pork longissimus dorsi muscles and deboned leg of lamb cooked by microwave or conventional methods. They found no significant differences in the mineral contents of the meats cooked in the two types of ovens. However, when considering percentage retention, phosphorus and iron retention was higher ($P < 0.05$) in the conventionally cooked beef than in beef cooked by microwaves. Drip from the conventionally cooked pork contained larger ($P < 0.05$) amounts of all four of the minerals, and drip from the conventionally cooked beef and lamb contained larger ($P < 0.05$) amounts of phosphorus and iron than when those same meats were cooked by microwaves.

Korschgen and Baldwin (1978) assayed sodium, iron, phosphorus, and potassium content of round roasts of beef after being cooked by moist-heat in a microwave oven and by conventional braising and found that the only significant difference in mineral content of the cooked meat was the phosphorus content, which was higher ($P < 0.05$) in meat cooked by microwaves (2416 mcg/g) than in meat cooked by conventional braising (2108 mcg/g). Also, the percentage retention of phosphorus and potassium was higher ($P < 0.05$) in beef cooked by microwaves than when cooked conventionally. The only significant difference between the drip of the meat cooked by microwaves and that cooked conventionally was in the percentage retention of iron, which was greater ($P < 0.05$) in the drippings of the meat cooked by microwaves.

CONCLUSIONS

The following conclusions are based on the literature reviewed:

- 1) Generally there are greater losses of moisture when foods (meat, poultry, vegetables, and baked products) are cooked by microwaves than when cooked by conventional methods.
- 2) No consistent trends are apparent on the effects of microwaves versus conventional cookery on protein losses in meat, but microwave cooking does seem to improve the protein efficiency ratio of breads over conventional methods, which is attributed to a decrease in the browning process.
- 3) Research is needed on the effects of microwaves on the carbohydrate content of foods.
- 4) The lipid content of meat and poultry seems to be affected slightly by microwave energy with implications of decreasing fat oxidation in eggs and baked products.
- 5) Water soluble vitamins (B-vitamins and ascorbic acid) are affected more by the amount of water used for cooking and the length of cooking time than by the type of oven used. Carotene does not seem to be affected by the cooking method.
- 6) No consistent trends are apparent for microwave cookery and mineral losses when compared with conventional cookery, partly because of a shortage of research.

Overall, when comparing one study to another, one must consider the variables in research techniques such as cooking time, internal temperature and post-temperature rises, type of oven used (frequencies, voltage, and cooking power), and the amount of water used, if any. Also, the year

the research was done must be considered, because microwave ovens are changing constantly. Because of the different techniques, comparison of research reports is difficult, which suggests that techniques used by researchers need to be more consistent if research in microwave cookery is to be useful.

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PART II

BAKED PRODUCTS

Authors:

Proctor, B. E. and Goldblith, S. A., Dept. of Food Technology,
Massachusetts Institute of Technology, Cambridge, MA.

Reference:

Radar energy for rapid food cooking and blanching, and its effect
on vitamin content. Food Technol. 2:95-104. 1948.

Nutrients:

Thiamin and riboflavin

Treatments:

Commercially packaged devil's food, gingerbread, and white cake mixes
were baked by two methods:

In a microwave oven for a pre-determined amount of time

In a conventional gas oven at 190°C

Gingerbread cakes were baked by several methods:

In a microwave oven for 1½, 1¼, or 1 min

Results:

Cakes baked in the microwave oven contained a greater amount of
thiamin and a smaller amount of riboflavin than cakes baked by the
conventional method. The thiamin content of the gingerbread baked
by microwaves decreased as the cooking time increased. Also, the
thiamin content was less in the gingerbread cooked in a conventional
oven than in the gingerbread cooked in a microwave oven.

Baked Products (continued)

Authors:

Schiller, E. A., Pratt, D. E., and Reber, E. F., Dept. of Foods and Nutr., Purdue Univ., West Lafayette, IN.

Reference:

Lipid changes in egg yolks and cakes baked in microwave ovens. Am. Dietet. Assn. J. 62:529-533. 1973.

Nutrient:

Lipids

Treatments:

Cakes were baked by three methods:

In microwave oven, 2450 MHz for 2.75 min

In microwave oven, 915 MHz for 4.0 min

In conventional oven, 173°C for 22 min

Results:

Thiobarbituric acid numbers were higher ($P < 0.05$) for cakes baked in the microwave oven operating at 915 MHz (0.644) than for cakes baked in the conventional oven (0.497). However, all methods resulted in higher oxidation levels in baked cakes than in batters (0.173). The difference between the thiobarbituric acid numbers for the cakes baked in either the 915 MHz or the 2450 MHz microwave oven was not significant.

Baked Products (concluded)

Authors:

Tsen, C. C., Reddy, R. K., and Gehrke, C. W., Dept. of Grain Science and Industry, Kansas Agric. Exp. Sta., Kansas State Univ., Manhattan, KS. and Exp. Sta. Chem. Lab., Univ. of Missouri, Columbia, MO.

Reference:

Effects of conventional baking, microwave baking, and steaming on the nutritive value of regular and fortified breads. J. Food Sci. 42: 402-406. 1977.

Nutrient:

Protein

Treatments:

Commercial wheat flour and defatted soy flour were used to prepare bread dough. Some of the dough was fortified with 0.2% L-lysine monohydrochloride. The loaves (weighing 125g each) were baked by three methods:

Conventionally for 19 min at 218°C

Steaming for 25 min

Electronically for 8 min at 0.3 kW and 0.2 milliamperes operating at a frequency of 2450 ± 50 MHz

Results:

The protein efficiency ratio (PER) for conventionally baked bread was less ($P < 0.05$) than for breads baked by microwaves or by steam. The addition of lysine and soy flour improved the PER significantly ($P < 0.05$) suggesting that wheat bread is deficient in lysine.

BUFFER SOLUTIONS

Authors:

Goldblith, S. A., Tannenbaum, S. R., and Wang, D., Dept. of Nutr. and Food Sci., Massachusetts Institute of Technology, Cambridge, MA.

Reference:

Thermal and 2450 MHz microwave energy effect on the destruction of thiamin. *Food Technol.* 22:1266-1268. 1968.

Nutrient:

Thiamin

Treatments:

A thiamin buffer solution was subjected to:

Conventional thermal energy

101.5°C for 50 min

108.5°C for 25 min

Microwave energy (2450 MHz)

102.8°C for 50 min

33.0°C for 30 min

0.0°C for 45 min

Results:

Microwave energy at 2450 MHz was not destructive to thiamin other than that attributable to heat (102.8°C for 50 min). The thiamin exposed to 0.0°C for 45 min and 33.0 for 30 min showed no destruction attributable to microwave energy.

Buffer Solutions (concluded)

Authors:

Van Zante, H. J. and Johnson, S. K., Dept. of Household Equipment,
Iowa State Univ., Ames, IA.

Reference:

Effect of electronic cookery on thiamin and riboflavin in buffered
solutions. Am. Dietet. Assn. J. 56:133-135. 1970.

Nutrients:

Thiamin and riboflavin

Treatments:

The buffer solutions were prepared by dissolving thiamin chloride and
riboflavin in a 0.02 M citrate buffer solution with a pH equal to 5.7.
The concentrations of riboflavin and thiamin were 2 or 10 mg per liter
and 8 or 40 mg per liter, respectively. Individual samples were heated
by an electronic oven and by a conventional oven to an internal tem-
perature of 170° or 185°F.

Results:

Both spectrophotometric and microbiologic analysis, used to analyze
vitamin retention in the buffer solutions, showed only a slight dif-
ference in the riboflavin or thiamin level between the two cooking
methods. The retention of vitamins was slightly higher in the con-
ventionally cooked buffer solution, but the differences were of no
practical importance. Thiamin retention was higher ($P < 0.05$) at 185°F.
Riboflavin retention was higher ($P < 0.05$) at 170°F as indicated by
microbiological analysis.

EGG YOLKS

Authors:

Schiller, E. A., Pratt, D. E., and Reber, E. F., Dept. of Foods and Nutr., Purdue Univ., West Lafayette, IN.

Reference:

Lipid changes in egg yolks and cakes baked in microwave ovens. Am. Dietet. Assn. J. 62:529-533. 1973.

Nutrient:

Lipids

Treatments:

Samples (50g) of egg yolk with and without added linoleic acid were cooked to a final temperature of 80°C by three methods:

In a conventional electric oven at 190°C

In a microwave oven operating at 915 MHz

In a microwave oven operating at 2450 MHz

Results:

TBA values were greater ($P < 0.01$) for egg yolks cooked in conventional ovens as compared to yolks cooked by microwaves. Oxidation levels were greater for yolks cooked in a microwave oven at 2450 MHz than for yolks cooked in a microwave oven at 915 MHz.

FISH

Authors:

Bezanson, A.,¹ Learson, R.,² and Teich, W.,³ ¹Food Engineering Consultant, Southborough, MA., ²Research Food Technologist, National Marine Fisheries Service, Atlantic Fishery Products Technology Center, Gloucester, MA., ³Principal Engineer, Raytheon Company, Microwave and Power Tube Division, New Products Center, Waltham, MA.

Reference:

Defrosting shrimp with microwaves. Microwave Energy Appl. Newsletter 6(4):3-8. 1973.

Nutrient:

Protein

Treatments:

Raw headless shrimp of the intermediate sizes used for breeding were defrosted by typical industrial water-defrosting procedures for one or two hours and by microwave-defrosting, which was carried out in a 915 MHz conveyorized multi-mode applicator.

Results:

The percent protein (18.6) in the shrimp defrosted by microwaves did not differ significantly from the frozen control (18.7). However, the average percent of protein in the water-defrosted shrimp (16.3) was significantly less, which was attributed to protein leaching into the water.

FOODS PREPARED FOR FOOD SERVICE OPERATIONS

Authors:

Ang, C. Y. W., Chang, C. M., Frey, A. E., and Livingston, G. E.,
Food Sci. Assoc., Inc., Dobbs Ferry, NY.

Reference:

Effects of heating methods on vitamin retention in six fresh and frozen prepared food products. J. Food Sci. 40:997-1003. 1975.

Nutrients:

Thiamin, riboflavin, ascorbic acid, and carotene

Treatments:

Each food product (mashed potatoes, pot roast/gravy, peas/onions, beans/franks, diced carrots, and fried fish portions) underwent the following treatments:

Freshly prepared with no holding time; $\frac{1}{2}$ hr holding; $1\frac{1}{2}$ hr holding time; and 3 hr holding time

Frozen-heated in convection oven and held $\frac{1}{2}$ hr

Frozen-heated in infrared oven and held $\frac{1}{2}$ hr

Frozen-heated in steamer and held $\frac{1}{2}$ hr

Frozen-heated in microwave oven and held $\frac{1}{2}$ hr

Results:

Generally, the thiamin content was greatest in the freshly prepared products not subjected to hot-holding, followed by the freshly prepared products held for 30 min. Microwave and infrared reheated products subjected to hot-holding for 30 min retained the greatest amount of thiamin as compared to the convection and steamer methods.

There were no significant losses of riboflavin in any of the products prepared by any of the treatments. The microwave and infrared reheating treatments were the most detrimental to the ascorbic acid content of the mashed potatoes. The carotene level was similar for carrots given all treatments.

Foods Prepared For Food Service Operations (continued)

Authors:

Ang, C. Y. W., Basillo, L. A., Cato, B. A., and Livingston, G. E.,
Food Sci. Assoc. Inc., Dobbs Ferry, NY.

Reference:

Riboflavin and thiamine retention in frozen beef-soy patties and
frozen fried chicken heated by methods used in food service operations.
J. Food Sci. 43:1024-1025, 1027. 1978.

Nutrients:

Thiamin and riboflavin

Treatments:

Frozen fried chicken was heated by the following methods:

In a convection oven on aluminum pans for 20-25 min to an internal
temperature of 71.1°C

In a convection oven for 20-25 min and then held in a food warmer
for $\frac{1}{2}$, $1\frac{1}{2}$, or 3 hr, maintaining an internal temperature of 71.1 to
 82.2°C

In an infrared oven for 14-15 min to an internal temperature of
 71.1 with the chicken being turned over after 7 min and held in a
food warmer for $\frac{1}{2}$ hr, maintaining an internal temperature of 71.1
to 82.2°C

Steam-heated for 25-33 min and then held in a food warmer for $\frac{1}{2}$
hr, maintaining an internal temperature of 71.1 to 82.2°C

In a microwave oven on paper trays for 10-11 min to an internal
temperature of 71.1°C with frequent turning and relocating of the
chicken and then held for $\frac{1}{2}$ hr, maintaining an internal temperature

of 71.1 to 82.2°C

Frozen raw and char-broiled beef-soy patties made from 70% beef, water, fortified textured soy protein, corn and wheat flour, soy flour, onions, dried whey, salt, and caramel coloring were cooked or heated by several methods.

Raw patties:

Cooked in a convection oven for 7.5-8.5 min on aluminum pans to an internal temperature of 73.9-76.7°C

Cooked in a convection oven for 7.5-8.5 min to an internal temperature of 73.9-76.7°C and held $\frac{1}{2}$, $1\frac{1}{2}$, or 3 hr, maintaining an internal temperature of 71.1-82.2°C

Char-broiled patties:

Heated in a convection oven for 8 min and held in a food warmer for $\frac{1}{2}$ hr, maintaining an internal temperature of 71.1-82.2°C

Heated in an infrared oven for 7 min and held $\frac{1}{2}$ hr, maintaining an internal temperature of 71.1-82.2°C

Steam-heated for 7-10 min and held $\frac{1}{2}$ hr, maintaining an internal temperature of 71.1-82.2°C

Heated in a microwave oven for 7 min with frequent turning and relocating of the beef patties and then held $\frac{1}{2}$ hr, maintaining an internal temperature of 71.1-82.2°C

Results:

The fried chicken heated by microwaves retained the largest ($P < 0.05$) percentage of thiamin compared to the other methods used and the chicken held for 3 hr retained the least amount of thiamin. There were no significant losses of riboflavin attributable to heating

method or holding time. The riboflavin retained in the beef patties was lowest ($P < 0.05$) in the infrared- or steam-heated patties with the infrared oven being the most destructive, while the microwave oven was the least destructive to riboflavin. The lowest ($P < 0.05$) retention of thiamin was found in the convection-cooked patties held for 3 hr and those that were infrared-heated. Steam or microwave heating also caused a significant loss ($P < 0.05$) of thiamin compared to raw patties, but there was no significant difference between steam- or microwave-heated patties and those patties heated by convection even though the convection-heated patties retained the most thiamin.

Foods Prepared For Food Service Operations (concluded)

Authors:

Kahn, L. N. and Livingston, G. E., Food Sci. Program, Columbia Univ.,
New York, NY.

Reference:

Effect of heating methods on thiamin retention in fresh or frozen
prepared foods. J. Food Sci. 35:349-351. 1970.

Nutrient:

Thiamin

Treatments:

Beef stew, chicken a la king, shrimp newburg, and peas in cream sauce
were prepared and treated by the following methods:

Freshly prepared and held for 1, 2, or 3 hr at 82.2°C

Freshly prepared, frozen at -23.3°C and reheated to 90°C using
three methods:

A microwave oven (Radarange Mark VI-Ten with an output of 650W)

An infrared oven (Minute King IR-40 quartz plate unit)

Boiling water immersion

Commercial samples of each product were cooked by microwave and
infrared heating.

Results:

The frozen products cooked by microwaves retained the most thiamin.
Thiamin content of the commercially prepared foods was similar to
that obtained for the experimental samples. Increasing the holding
time of the freshly prepared foods decreased thiamin retention of all
foods.

MEAT AND MEAT PRODUCTS

Authors:

Apgar, J., Cox, N., Downey, I., and Fenton, F., State College of Home Econ. and Agri. Exp. Sta., State Univ. of New York, Cornell Univ., Ithaca, NY.

Reference:

Cooking pork electronically. Am. Dietet. Assn. J. 39:321-326. 1961.

Nutrients:

Thiamin and fat

Treatments:

Pork patties, roasts, and chops were prepared by the following methods:

In a conventional oven at 175.6°C to an internal temperature of 87.8°C

In a home-type microwave oven (450W), without browning, to an internal temperature of 87.8°C

In a home-type microwave oven (450W), with browning, to an internal temperature of 87.8°C

In an institutional oven, without browning, to an internal temperature of 87.8°C

Results:

The thiamin content of roasts and patties cooked by microwave and conventional methods was similar, but there were differences ($P < 0.05$) in the chops cooked by the various methods. Chops cooked with the browning unit in the home microwave oven retained more thiamin than chops cooked in the institutional oven, which in turn retained more thiamin than chops prepared by the home microwave oven without a

browning unit and the conventional method. Differences were small, only 0.2 to 0.4 mg. Roasts cooked conventionally had a lower ($P < 0.05$) fat content. No other significant differences were found between the fat content of the patties and chops cooked by the different methods.

Meat and Meat Products (continued)

Authors:

Armbruster, G. and Haefele, C., Div. of Nutr. Sci., Cornell Univ.,
Ithaca, NY.

Reference:

Quality of foods after cooking in 915 MHz and 2450 MHz microwave
appliances using plastic film covers. J. Food Sci. 40(4):721-723.
1975.

Nutrient:

Riboflavin

Treatments:

Chicken was cooked by the following methods:

In a microwave oven (915 MHz) covered with Saran Wrap

In a microwave oven (915 MHz) uncovered

In a microwave oven (2450 MHz) covered with Saran Wrap

In a microwave oven (2450 MHz) uncovered

Results:

A Saran Wrap cover did not affect significantly the riboflavin
content of the chicken cooked in a 915 MHz or in a 2450 MHz microwave
oven.

Meat and Meat Products (continued)

Authors:

Baldwin, R. E. and Tettambel, J. E., Dept. of Food Sci. and Nutr.,
Univ. of Missouri, Columbia, MO.

Reference:

Nitrogen content of rib-eye steaks heated by microwaves and a conventional method. Microwave Energy Appli. Newsletter 7(3):3-4. 1974.

Nutrient:

Protein

Treatments:

Beef rib-eye steaks were cooked by two methods:

Conventionally at 177°C to an internal temperature of 66°C

Electronically (2450 MHz) to an internal temperature of 66°C

Results:

The microwave cooked steaks contained more ($P < 0.01$) nitrogen per unit of cooked meat than the conventionally cooked steaks. Even though the cooking losses were greater for the microwave cooked meat, the presence of nitrogen in the drip was less ($P < 0.01$) than when the meat was cooked conventionally.

Meat and Meat Products (continued)

Authors:

Baldwin, R. E., Korschgen, B. M., Russell, M. S., and Mabesa, L.,
Dept. Foods and Nutr., Univ. of Missouri, Columbia, MO.

Reference:

Proximate analysis, free amino acid, vitamin, and mineral content of
microwave cooked meat. J. Food Sci. 41:762-765. 1976.

Nutrients:

Protein, fat, thiamin, riboflavin, niacin, iron, phosphorus, sodium,
and chloride

Treatments:

Beef, pork, and lamb were cooked by three methods:

Microwave oven (2450 MHz) operating at 220V with 1054W cooking
power and a three minute cycle

Microwave oven (3450 MHz) operating at 115V with 492W cooking power
and a six minute cycle

Conventional gas oven ($163 \pm 3^{\circ}\text{C}$)

All roasts were cooked uncovered to an internal temperature of 70°C .

Results:

Protein content of meat cooked by microwaves was greater than the protein content of meat cooked conventionally, but the difference was significant ($P < 0.05$) only between the beef cooked by the microwave 115V and the conventional method. Drippings from the pork cooked conventionally contained a higher percentage of fat than pork cooked by the 115V microwave oven. The 220V microwave produced drippings

with the greatest percentage of fat as compared to the other methods when cooking lamb. The oven type did not affect significantly the amount of fat found in the drippings from the cooked beef. The free amino acid content was greater ($P < 0.05$) in meat cooked by the conventional method. Thiamin, riboflavin, and niacin retained in the beef and niacin retained in the pork were higher ($P < 0.05$) when meat was prepared by the microwave 220V or conventional oven. Lamb cooked by the conventional method had a higher ($P < 0.05$) sodium content than lamb cooked by the two microwave methods. Overall, conventionally cooked meats retained a greater ($P < 0.05$) percentage of their minerals than meat cooked by microwaves, particularly phosphorus and iron.

Meat and Meat Products (continued)

Authors:

Bowers, J. A., Fryer, B. A., and Engler, P. P., Dept. Foods and Nutr.,
Kansas State Univ., Manhattan, KS.

Reference:

Vitamin B₆ in pork muscle cooked in microwave and conventional ovens.
J. Food Sci. 39:426-427. 1974.

Nutrient:

Vitamin B₆

Treatments:

Pork muscle from a loin section were cooked by the following methods:

In a microwave oven (Amana Radar Range, Model RR-2), 75°C internal
temperature

In a microwave oven (Amana Radar Range, Model RR-2), 85°C internal
temperature

In a conventional gas oven set at 177°C, 75°C internal temperature

In a conventional gas oven set at 177°C, 85°C internal temperature

Results:

On a moisture free basis, there was a difference ($P < 0.01$) in the
vitamin B₆ content between the electronically and conventionally
cooked pork. However, on a cooked weight basis, there was no signifi-
cant difference in vitamin B₆ content of pork muscle cooked in the two
ovens or between the two oven temperatures. Also, on a moisture free
basis, no significant difference was found between the two oven tem-
peratures.

Meat and Meat Products (continued)

Authors:

Causey, K., Hausrath, M. E., Ramstad, P. E., and Fenton, F., School of Nutrition and State College of Home Econ., Cornell Univ., Ithaca, NY.

Reference:

Effect and nutritive value of frozen ground meat. I. Pork. Food Res. 15:237-248. 1950.

Nutrients:

Thiamin, riboflavin, and niacin

Treatments:

Frozen pork patties were thawed by three methods:

During cooking

At room temperature (18.3 to 23.8°C) to an internal temperature of 2.8°C

Under running cold tap water (4 to 13.5°C) to an internal temperature of 2.8°C

Frozen pork loaves were thawed by the first two methods.

Patties were cooked by four methods:

Pan-broiling, 85°C internal temperature

Oven-broiling at 302°C, 85°C internal temperature

Microwave oven without pre-browning, 87.8°C internal temperature

Microwave oven with pre-browning, 87.8°C internal temperature

Loaves were cooked by two methods:

Baked in gas oven at 176.6°C, uncovered, to an internal temperature of 87.8°C

Baked in a microwave oven, 85°C internal temperature

Results:

There were no significant differences in the thiamin retention of the pork patties cooked by the various methods. The average thiamin retention was 85% and 63% for the patties and loaves, respectively. Loaves that were thawed at room temperature and cooked by the microwave method retained 10% more thiamin and 8% less riboflavin than those cooked by the other three methods. The percent of riboflavin and niacin retained in the patties cooked by the four methods was not significantly different. The loaves that were thawed at room temperature and cooked by microwaves had a higher retention of niacin in the drip than the loaves thawed and cooked by the other three methods. Loaves prepared by the other three methods showed no significant differences in the percent of niacin retained.

Meat and Meat Products (continued)

Authors:

Causey, K., Hausrath, M. E., Ramstad, P. E., and Fenton, F., School of Nutrition and State College of Home Econ., Cornell Univ., Ithaca, NY.

Reference:

Effect of thawing and cooking methods on palatability and nutritive value of frozen ground meat. II. Beef. Food Res. 15:249-255. 1950.

Nutrients:

Thiamin, riboflavin, and lysine

Treatments:

Ground beef patties, thawed during cooking or at room temperature (18.3 to 23.8°C) to an internal temperature of 2.8°C, were cooked by the following methods:

Pan-broiling, 74°C internal temperature

Oven-broiling, 74°C internal temperature

Microwave oven without pre-browning, 96.6°C internal temperature

Microwave oven with pre-browning, 80°C internal temperature

Results:

The room thawed, unbrowned, microwave-cooked patties had a lower retention of thiamin compared to the other methods used to thaw and cook the beef patties. The patties cooked by microwaves lost more thiamin in the drip than the other methods used. There was a trend toward a smaller retention of riboflavin in beef patties cooked by the microwave methods, but the only loss that was considered significant was the loss of riboflavin in the unbrowned, microwave-cooked patties that were thawed during cooking. There was no consistent trend in the amount of lysine lost attributable to either the thawing or cooking methods.

Meat and Meat Products (continued)

Authors:

Causey, K., Hausrath, M. E., Ramstad, P. E., and Fenton, F., School of Nutrition and State College of Home Econ., Cornell Univ., Ithaca, NY.

Reference:

Effect of thawing and cooking methods on palatability and nutritive value of frozen ground meat. III. Lamb. Food Res. 15:256-261. 1950.

Nutrients:

Thiamin, riboflavin, and lysine

Treatments:

Lamb patties that were thawed during cooking or at room temperature were cooked by the following methods:

Pan-broiling, 85°C internal temperature

Oven-broiling, 85°C internal temperature

Microwave oven without pre-browning, 95.6°C internal temperature

Microwave oven with pre-browning, 90.6°C internal temperature

Results:

More thiamin was found in the drip of microwave-cooked lamb patties than in patties cooked by conventional methods. There was no consistent trend in the amount of riboflavin or lysine lost attributable to either the thawing or cooking methods.

Meat and Meat Products (continued)

Authors:

Janicki, L. J. and Appledorf, H., Food Sci. Dept., Univ. of Florida,
IFAS, Gainesville, FL.

Reference:

Effect of boiling, grill frying, and microwave cooking on moisture,
some lipid components and total fatty acids of ground beef. J. Food
Sci. 39:715-717. 1974.

Nutrients:

Moisture, fat, and cholesterol

Treatments:

Ground beef patties approximately six inches in diameter, $\frac{1}{4}$ inch thick,
and 107.5g in weight were cooked by four methods:

Broiled to commercial doneness on a Model BK-1001 broiler for 50 sec

Grill fried to commercial doneness on a Model TG-72 special

McDonald's grill at 375°C for 4 min

Cooked by microwaves in a Menumaster System 70/50 microwave oven
(2450 MHz) at two heating cycles for 45 sec in between which the
patties were turned

Broiled, placed in plastic bag, and frozen at -25°C for subsequent
reheating in a microwave oven at two heating cycles, 45 and 30 sec,
respectively

Results:

Greater ($P < 0.05$) losses were found in the microwave reheated patties.
The patties cooked by microwaves showed the greatest crude fat loss.
The microwave reheated method did not significantly alter the amount

of crude fat in the patties. All cooked patties had lower ($P < 0.05$) cholesterol content than the raw patties except for the patties cooked by microwaves. However, there were no significant differences in cholesterol content among the four methods. C16, C18:1, and C18:2 underwent the greatest compositional changes in all cooking methods used when compared to other fatty acids considered in the experiment. C16 was affected the greatest by the microwave reheated method. The percent of C18:1 and C18:2 increased following all cooking treatments. Microwave-treated patties contained the largest ratio of unsaturated to saturated fatty acids.

Meat and Meat Products (continued)

Authors:

Korschgen, B. M. and Baldwin, R. E., Dept. Food Sci. and Nutr., Univ. Missouri-Columbia, Columbia, MO.

Reference:

Moist-heat microwave and conventional cooking of round roasts of beef. J. Microwave Power 13:257-262. 1978.

Nutrients:

Moisture, fat, protein, thiamin, riboflavin, niacin, sodium, phosphorus, iron, potassium, and essential amino acids

Treatments:

Round roasts of beef were cooked by two methods:

In a conventional oven, covered, in 50 ml of water with the oven set at $135 \pm 3^{\circ}\text{C}$ to an internal temperature of 98°C

In a microwave oven (115V, 2450 MHz) in 50 ml of water on a high setting (550W) for 10 min and at simmer (250W) to an internal temperature of 98°C

Results:

No significant differences were found in the moisture, fat, or protein content of the meat or the drippings of the meat prepared by microwave or conventional methods. The thiamin, riboflavin and niacin contents of the meat cooked by either method was similar, but the percentage retention of thiamin and riboflavin was greater ($P < 0.05$) in the beef cooked by microwaves. The microwave-cooked meat retained 25% of its thiamin and 90% of its riboflavin while the conventionally cooked meat retained 15% and 81% of its thiamin and riboflavin, respectively.

There were no significant differences in the thiamin or riboflavin content in the drippings of the meat prepared by either method, but the niacin content was greater ($P < 0.05$) in the drippings of the conventionally prepared meat. The phosphorus content of the beef cooked by microwaves was greater ($P < 0.05$) than the phosphorus content of the beef cooked conventionally. The percentage retention of both phosphorus and potassium was higher ($P < 0.05$) in the beef cooked by microwaves than the meat cooked by the conventional method. There were no significant differences in the mineral content of the drippings except for iron which was greater ($P < 0.05$) in the microwave-cooked meat than in the meat cooked conventionally.

Meat and Meat Products (continued)

Authors:

Kylen, A. M., McGrath, B. H., Hallmark, E. L., and Van Dyne, F. O.,
Dept. of Home Econ., Univ. of Illinois, Urbana, IL.

Reference:

Microwave and conventional cooking of meat. Thiamin retention and palatability. Am. Dietet. Assn. J. 45:139-145. 1964.

Nutrients:

Fat and thiamin

Treatments:

Beef and pork roasts and beef and ham loaves were cooked conventionally in a gas oven or in a microwave oven.

Results:

The fat content was similar for both methods of cooking except for the beef loaves cooked by microwaves, which had a slightly lower percentage of fat. The thiamin retained in the conventionally cooked beef roasts was relatively high and the thiamin retained in the beef roast drippings was low. The reverse was true for the beef roasts cooked by microwaves. Therefore, there was no significant difference in the total percentage of thiamin retained from the beef roasts cooked by either method. Also, there was no significant difference in the total percentage of thiamin retained in the pork roasts and beef and ham loaves attributable to the cooking methods.

Meat and Meat Products (continued)

Authors:

Lushbough, C. H., Heller, B. S., Weir, E., and Schweigert, B. S.,
American Meat Institute Foundation, and Dept. of Biochemistry, Univ.
of Chicago, Chicago, IL.

Reference:

Thiamine retention in meats after various heat treatments. Am.
Dietet. Assn. J. 40:35-38. 1962.

Nutrient:

Thiamin

Treatments:

The following methods were used to cook beef round:

Electric oven

93°C oven temperature

149°C oven temperature

204°C oven temperature

Microwave oven

Autoclaved at 121°C for 4 or 16 hr

Ground, commercially processed at 116°C for 90, 113, or 132 min

Results:

The inner and outer portions of the beef rounds cooked in the electric oven and the microwave oven were similar in thiamin retention. The commercially processed meat retained less thiamin (42%) than the meat cooked conventionally or by microwaves (75-100%). The autoclave methods retained the least amount of thiamin (0-5.4%) of the methods used.

Meat and Meat Products (continued)

Authors:

McMullen, E. A. and Cassilly, J. P., Dept. Home Econ., Central Michigan Univ., Mount Pleasant, MI.

Reference:

Thiamin and riboflavin retention in meats cooked uncovered and in oven film. Home Econ. Res. J. 5(1):33-39. 1979.

Nutrients:

Thiamin and riboflavin

Treatments:

Choice grade arm pot roasts of beef, pork loin roasts, and turkey breasts were cooked by six methods:

In a conventional oven (gas or electric), uncovered, at 163°C with a cooking time of 30 min per lb of meat

In a conventional oven (gas or electric), covered in oven film, at 163°C with a cooking time of 30 min per lb of meat

In a microwave oven (General Electric, Model #J856002WH), uncovered with a cooking time of 6 min per lb of meat

In a microwave oven (same as above), covered in oven film, with a cooking time of 6 min per lb of meat.

Results:

There were no significant differences in the retention of thiamin or riboflavin in the meats cooked uncovered or covered in oven film. Also, the type of oven made no significant difference in the amount of thiamin or riboflavin retained by all the meats.

Meat and Meat Products (continued)

Authors:

Moore, L. J., Harrison, D. L., and Dayton, A. D., Dept. Foods and Nutr. and Dept. of Statistics, Kansas Agri. Exp. Sta., Kansas State Univ., Manhattan, KS.

Reference:

Differences among top round steaks cooked by dry or moist heat in a conventional or a microwave oven. J. Food Sci. 45:777-781. 1980.

Nutrient:

Moisture

Treatments:

Top round beef steaks were cooked by four methods:

In an electric rotary hearth oven set at 177°C, on a wire rack in a shallow pan, to 65°C with no post-oven temperature rise (dry heat)

In an electric rotary hearth oven set at 177°C, in an oven film bag, to 58°C, and allowed to stand 10 min to reach an internal temperature of 65°C (moist heat)

In a microwave oven (Sharp R-8200) at the roast setting (approximately 422W), on a Pyrex casserole lid in a Pyrex pie plate, to 59°C and allowed to stand 10 min to reach an internal temperature of 65°C (dry heat)

In a microwave oven (Sharp R-8200) at the roast setting (approximately 422W), in an oven film bag, placed on a Pyrex casserole lid on a Pyrex pie plate, to 55°C and allowed to stand 10 min to reach an internal temperature of 65°C (moist heat)

Results:

The total moisture in the microwave-cooked steak was less ($P < 0.001$) than in the steaks cooked conventionally.

Meat and Meat Products (continued)

Authors:

Noble, I. and Gomez, L., School of Home Econ., Univ. of Minnesota,
St. Paul, MN.

Reference:

Vitamin retention in meat cooked electronically. Thiamine and riboflavin in lamb and bacon. Am. Dietet. Assn. J. 41:217-220. 1962.

Nutrients:

Thiamin, riboflavin, and fat

Treatments:

Lamb roasts from choice carcasses were cooked by two methods:

In a microwave oven set on "LO" for 10 min, turned, and cooked on the "LO" setting with the browning unit on until the internal temperature reached 73°C

In a conventional oven set at 149°C to an internal temperature of 79°C

Three samples of bacon were analyzed:

At raw stage

After broiling 3 slices (76g) in a microwave oven for 1 min 5 sec

After broiling 9 slices (228g) in a microwave oven for 2 min 30 sec with the oven set on "HI"

Results:

There were no significant differences in thiamin and riboflavin retention of either the lamb roasts cooked by a microwave oven or by a conventional oven, or in the quantities found in the drippings. Also, there was no significant difference in thiamin or riboflavin retention

of the bacon cooked as a single serving (3 slices) or as three-servings (9 slices). There was no significant difference in the fat content of the lamb roast or bacon cooked by the microwave or conventional methods.

Meat and Meat Products (continued)

Authors:

Proctor, B. E. and Goldblith, S. A., Dept. of Food Technology,
Massachusetts Institute of Technology, Cambridge, MA.

Reference:

Radar energy for rapid food cooking and blanching, and its effect on
the vitamin content. Food Technol. 2:95-104. 1948.

Nutrients:

Thiamin and riboflavin

Treatments:

Hamburger patties were cooked by two methods:

In a microwave oven for 1 min

Fried for 5-6 min

Haddock was baked by two methods:

In a microwave oven for 40 sec

In a conventional oven for 12 min at 260°C

Frankforters were cooked by two methods:

In a microwave oven for 30 sec

Grilled

Results:

Thiamin and riboflavin retention were less for fried hamburgers than
for hamburgers baked in a microwave oven, partially attributable to
grease spattering. Thiamin and riboflavin losses were considerable for
both methods of cooking haddock, but the microwave oven method pro-
duced a slightly greater loss. The frankforters prepared by microwaves

retained more thiamin (71.8%) than the grilled (57.6%) frankforters. Equal amounts of riboflavin were retained in the frankforters cooked by microwave oven or grilled.

Meat and Meat Products (continued)

Authors:

Thomas, M. H., Brenner, S., Eaton, A., and Craig, V., Food Res. Div., Quartermaster Food and Container Institute for the Armed Forces, Chicago, IL.

Reference:

Effect of electronic cooking on nutritional value of foods. Am. Dietet. Assn. J. 25:39-45. 1945.

Nutrients:

Thiamin, riboflavin, and niacin

Treatments:

Beef patties were cooked by three methods:

In a microwave oven, singly, for 70 sec

In a microwave oven, 6 at a time, for 4 min

Grilled for 20-30 min

Pork patties were cooked by three methods:

In a microwave oven, singly, for 85 sec

In a microwave oven, 6 at a time, for 5 min

Grilled for 20-30 min

Beef roasts were baked by two methods:

In a microwave oven for 13 min

In an electric oven for 121 min

Results:

No significant differences were found in the niacin or riboflavin content of the beef patties, pork patties, or beef roasts prepared by the different cooking methods. More niacin, riboflavin, and

thiamin were found and recovered in the juices from the multiple cooked patties than in juices from singly prepared patties, which was attributable to a longer cooking time for multiple cooked patties. Thiamin content of the beef patties was affected more by the methods of cooking than the thiamin content of the pork patties, however, both the pork and beef patties cooked by microwaves retained more thiamin than when those patties were grilled. Roasts prepared in the electric oven retained more thiamin than the roasts prepared in the microwave oven.

Meat and Meat Products (concluded)

Authors:

Ziprin, Y. A. and Carlin, A. F., Food and Nutr. Dept., Iowa State Univ., Ames, IA.

Reference:

Microwave and conventional cooking in relation to quality and nutritive value of beef and beef-soy loaves. J. Food Sci. 41:4-8. 1976.

Nutrients:

Moisture, fat, and thiamin

Treatments:

Meat loaves containing 0, 15% soy flour, or 15% soy concentrate were cooked by several methods:

In two General Electric ranges to a final internal temperature of 74°C with the preheated oven set at 163°C

In three microwave ovens (one Tappan, 220V and two Amana, 115V), 2450 MHz, for 9.5 min, turned 90 degrees, and cooked another 9.5 min to an internal temperature of 74°C

Results:

Microwave ovens decreased the thiamin retention in the meat loaves more ($P < 0.01$) than conventional ovens. Thiamin retention was 65-69% for loaves cooked in the microwave ovens and 75-82% for loaves cooked in the conventional ovens, calculated on a dry basis. On a moist basis, the thiamin content of all loaves was similar. The addition of soy did not affect thiamin retention. The average fat content of all the loaves cooked by microwaves was greater ($P < 0.01$) than the loaves cooked conventionally. There was no significant difference in

the fat content between the types of loaves prepared. The microwave cooking reduced the moisture content to 58%, whereas the conventional cooking reduced the moisture content to 64%, a reduction of 14 or 5%, respectively.

POULTRY

Authors:

Berry, J. G. and Cunningham, F. E., Dairy and Poultry Sci. Dept.,
Kansas State Univ., Manhattan, KS.

Reference:

Factors affecting the flavor of frozen fried chicken. Poultry Sci.
49:1236-1242. 1970.

Nutrient:

Fatty acids

Treatments:

Broilers (2 to 2½ lb) were fried in deep-fat at 300°F to an internal
temperature of 185°F and frozen and stored by three methods:

Household freezer at -10°C until the end of trial

Blast freezer at -30°C overnight

Liquid-nitrogen freezer at -50°C for 45 min

The chicken was reheated by three methods:

Household oven preheated to 425°F for 30 min

Microwave oven for 2 min for 2 pieces of chicken

Refrying in deep-fat (300°F) for 7 min

Results:

The conventional oven was the most desirable for maintaining a constant fatty acid composition considering the fact that myristic, palmitric, palmitoleic, and stearic acids decreased least in the samples reheated by the conventional method as compared to the microwave method and the refrying method, which had the greatest losses.

Poultry (continued)

Authors:

Bowers, J. A. and Fryer, B. A., Dept. Foods and Nutr., Kansas State Univ., Manhattan, KS.

Reference:

Thiamin and riboflavin in cooked and frozen, reheated turkey: gas vs microwave ovens. Am. Dietet. Assn. J. 60:399-401. 1972.

Nutrients:

Moisture, thiamin, and riboflavin

Treatments:

Eight treatments were used on the pectoralis major muscles of turkey:

Gas oven

Roasted in rotary oven set at 177°C to an internal temperature of 80°C

Roasted, frozen (-17.5°C) for 5 weeks, thawed 2 hr at 25°C to an internal temperature of $3^{\circ}\text{C} \pm 3^{\circ}\text{C}$, and reheated at 177°C to an internal temperature of 55°C

Roasted, held at 0°C for 24 hr in refrigerator and reheated at 177°C to an internal temperature of 55°C

Roasted, frozen (17.5°C) for 5 weeks, thawed 2 hr at 25°C to an internal temperature of $3^{\circ}\text{C} \pm 3^{\circ}\text{C}$

Microwave oven

Roasted to 68°C , post-oven temperature rise of 12°C

Roasted, frozen (-17.5°C) for 5 weeks, thawed 2 hr at 25°C to an internal temperature of $3^{\circ}\text{C} \pm 3^{\circ}\text{C}$, and reheated to 40°C , post-oven temperature rise of 15°C

Roasted, held at 0°C for 24 hr in refrigerator and reheated to 40°C , post-oven temperature rise of 15°C

Roasted, frozen (-17.5°C) for 5 weeks, and thawed 2 hr at 25°C to an internal temperature of $3^{\circ}\text{C} \pm 3^{\circ}\text{C}$

Results:

There was no significant difference in the thiamin content of the turkeys attributable to the type of oven used. On a moisture-free, fat-free basis there was more ($P < 0.05$) riboflavin in the muscle heated by a gas oven than by a microwave oven. On a wet basis or as percentage retention, there was no significant difference between the riboflavin content of the gas- or microwave-cooked turkey.

Poultry (continued)

Authors:

Bowers, J. A., Fryer, B. A., and Engler, P. P., Foods and Nutr. Dept.,
Kansas State Univ., Manhattan, KS.

Reference:

Vitamin B₆ in turkey breast muscle cooked in microwave and conventional ovens. Poultry Sci. 53:844-846. 1974.

Nutrient:

Vitamin B₆

Treatments:

Four treatments were used to cook turkey breasts:

Microwave oven (Amana RadaRange, Model RR-2), 75°C end point temperature

Microwave oven (same as above), 85°C end point temperature

Conventional electric oven, 75°C end point temperature

Conventional electric oven, 85°C end point temperature

Results:

On the basis of cooked weight, the turkey breasts cooked in the microwave oven had a higher ($P < 0.01$) vitamin B₆ content than the samples cooked in the conventional oven, but there was no significant difference between the two methods when the vitamin B₆ content was calculated on a dry weight basis.

Poultry (continued)

Authors:

Engler, P. P. and Bowers, J. A., Foods and Nutr. Dept., Kansas State Univ., Manhattan, KS.

Reference:

Vitamin B₆ in reheated, held, and freshly cooked turkey breast. Am. Dietet. Assn. J. 67:42-44. 1975.

Nutrient:

Vitamin B₆

Treatments:

Four treatments were used to determine the effect of roasting and reheating on turkey breasts:

Roasting

Roasting, refrigerating (6°C) 24 hr, then reheating in an electric oven

Roasting, refrigerating (6°C) 24 hr, then reheating in a microwave oven

Roasting, slicing, and holding at 93°C for 60 min and then at 79.5°C for 15 min

Results:

On a cooked weight basis, there was no significant difference in vitamin B₆ content of the four methods, but on a moisture-free, fat-free basis, the freshly roasted turkey breast retained more vitamin B₆ than the other treatments. No significant difference in vitamin B₆ was found between the turkey reheated by the electric oven or by the microwave oven.

Poultry (concluded)

Authors:

Wing, R. W. and Alexander, J. C., Univ. of Guelph, Guelph, Ontario, Canada.

Reference:

Effect of microwave heating on vitamin B₆ retention in chicken. Am. Dietet. Assn. J. 61:661-664. 1972.

Nutrients:

Vitamin B₆ and moisture

Treatments:

Fifteen chicken breasts were divided into 30 pieces and placed in three groups to be analyzed:

After cooking in a microwave oven for 1.5 min at 2450 MHz

After baking in a conventional oven at 162.7°C to an internal temperature of 88°C

Raw

Results:

The chicken breasts cooked by microwaves had a higher ($P < 0.05$) vitamin B₆ content than the chicken cooked by the conventional method, possibly attributable to a shorter cooking time, 1.5 min for the microwave method compared to 45 min for the conventional method. The chicken cooked by microwaves retained less ($P < 0.05$) moisture (65.5%) than the chicken cooked conventionally (67.5%).

VEGETABLES

Authors:

Armbruster, G. and Haefele, C., Div. of Nutritional Sciences,
Cornell Univ., Ithaca, NY.

Reference:

Quality of foods after cooking in 915 MHz and 2450 MHz microwave
appliances using plastic film covers. J. Food Sci. 40(4):721-723.
1975.

Nutrients:

Ascorbic acid and thiamin.

Treatments:

Peas were cooked by the following methods:

In a microwave oven (915 MHz) covered with Saran Wrap

In a microwave oven (915 MHz) uncovered

In a microwave oven (2450 MHz) covered with Saran Wrap

In a microwave oven (2450 MHz) uncovered

Results:

A Saran Wrap cover did not affect significantly the thiamin and
ascorbic acid content of peas cooked at wavelength frequencies of
915 MHz or 2450 MHz.

Vegetables (continued)

Authors:

Bowman, F., Berg, E. P., Chuang, A. L., Gunther, M. W., Trump, D. C., and Lorenz, K., Dept. Food Sci. and Nutr., Colorado State Univ., Fort Collins, CO.

Reference:

Vegetables cooked by microwave vs. conventional methods. Microwave Energy Appl. Newsletter 8(3):3-8. 1975.

Nutrient:

Ascorbic acid

Treatments:

Fresh broccoli, cauliflower, green beans, and spinach and frozen broccoli, cauliflower, green beans (cut, Brand A or B), peas (two types of loose-pack, light-pervious or light-impervious), leaf spinach (Brand A or B) and chopped spinach were cooked in various amounts of water and cooked for various amounts of time in a microwave oven or in a saucepan.

Results:

There were no significant differences in ascorbic acid between 13 of the 16 vegetables cooked by microwaves or in boiling water. Only frozen peas (light-impervious package), frozen leaf spinach (Brand B), and frozen chopped spinach cooked in a microwave oven retained more ($P < 0.05$) ascorbic acid than did the boiled vegetables. More ascorbic acid was found in the vegetable solids and less in the cooking liquids of vegetables cooked by microwaves as compared to those cooked in a saucepan, but if the percent of reduced ascorbic

acid in the vegetable solids was added to the amount dissolved in the cooking liquids there would have been no significant differences between the two cooking methods.

Vegetables (continued)

Authors:

Campbell, C. L., Lin, T. Y., and Proctor, B. E., Dept. of Food Technology, Massachusetts Institute of Technology, Cambridge, MA.

Reference:

Microwave vs. conventional cooking. I. Reduced and total ascorbic acid in vegetables. Am. Dietet. Assn. J. 34:365-369. 1958.

Nutrient:

Ascorbic acid

Treatments:

Fresh cabbage was cooked by several methods.

Microwave cooking:

Without water for 5 min

With water (350 ml) for 4 min

In moist cloth for 5 min

In parchment (300 ml water) for 4 min

Conventional cooking:

Open pot (400 ml water) for 30 min

Covered pot (400 ml water) for 25 min

Double boiler (0 ml water) for 35 min

Pressure cooker (125 ml water) for 3 min

Fresh and frozen broccoli and frozen peas were cooked by three methods:

In a microwave oven using a Radarange, Model 1161 with a power output of 1500-1600 W.

Using conventional cookery with various amounts of water and with various amounts of cooking times.

Using conventional cookery plus one hr at 185°F in steam bath.

Results:

When comparing the ascorbic acid content of the cabbage cooked by all four microwave methods to all four conventional methods, the microwave methods produced products significantly higher in ascorbic acid content than the conventional methods. The percentage retention of ascorbic acid in fresh and frozen broccoli was greater in microwave cooking than in conventional cooking. There was no significant difference in the ascorbic acid retention of the peas cooked by the microwave or conventional methods. Additional heating of the peas and broccoli in a steam bath decreased the ascorbic acid retention markedly.

Vegetables (continued)

Authors:

Causey, K. and Fenton, F., School of Nutrition and New York State
College of Home Econ., Cornell Univ., Ithaca, NY.

Reference:

Effect of reheating on palatability, nutritive value, and bacterial
count of frozen foods. I. Vegetables. Am. Dietet. Assn. J. 27:
390-395. 1951.

Nutrients:

Ascorbic acid, thiamin, and riboflavin.

Treatments:

Frozen cut green beans, swiss chard, broccoli, diced carrots, and
shredded beets were reheated to an internal temperature of 180-185°F
by the following methods:

Maxon Whirlwind oven, 300°F, on Pyrex plates, covered with
aluminum foil

Household electric oven, 400°F, on Pyrex plates, covered with
aluminum foil

Top of covered Pyrex double boiler over a gas burner

Boiling water, in Pliofilm bag

Dielectric oven, in Pliofilm bag on Pyrex plate

Results:

No significant differences in the ascorbic acid retention occurred that
were attributable to the reheating treatments. The thiamin and ribo-
flavin retained in the cooked vegetables were less than one-tenth of the
daily allowances, therefore the percentage retentions were not calculated.

Vegetables (continued)

Authors:

Chapman, V. J., Putz, J. O., Gilpin, G. L., Sweeney, J. P., and Eisen, J. N., Human Nutrition Res. Div., USDA.

Reference:

Electronic cooking of fresh and frozen broccoli. J. Home Econ. 52: 161-165. 1960.

Nutrients:

Ascorbic acid and carotene

Treatments:

Fresh and frozen broccoli were cooked by microwaves and by boiling. Fresh broccoli (heads and stems) was cooked by microwaves for 3, 6, 9, or 12 min. Frozen broccoli (heads and stems) was cooked by microwaves for 6, 9, 12, or 15 min.

Results:

Overall, the fresh and frozen broccoli cooked by microwaves retained more ascorbic acid than the boiled broccoli. Ascorbic acid retention for fresh broccoli ranged from 97% for 3 min of cooking to 80% for 12 min of cooking, with a 5% decrease in retention for every 3 min increase in cooking time. Ascorbic acid retention in frozen broccoli ranged from 98% for 6 min of cooking to 83% for 12 min of cooking, with a 3.6% decrease in retention for every 3 min increase in cooking time. None of the cooking methods used for fresh broccoli produced a measurable loss of carotene. Carotene levels were lower for the frozen broccoli than for the fresh broccoli, but the difference could not be considered significant, because there was such a wide variation in the carotene content of the raw vegetables.

Vegetables (continued)

Authors:

Eheart, M. S. and Gott, C., Univ. of Maryland, College Park, MD.

References:

Conventional and microwave cooking of vegetables. Am. Dietet. Assn. J. 44:116-119. 1964.

Nutrients:

Ascorbic acid and carotene

Treatments:

Part 1. Green beans, broccoli, peas, potatoes, and spinach were cooked by microwaves or conventionally (with and without water).

Part 2. Frozen, pre-thawed, and loose-packed peas were cooked in a microwave oven and by a conventional method to compare ascorbic acid retention.

Results:

No significant differences in ascorbic acid retention were found between vegetables cooked in a microwave oven with or without water. Also, no significant differences in ascorbic acid retention were indicated for peas, broccoli, or potatoes cooked by microwave or conventional methods. However, the spinach did retain more ascorbic acid when cooked in the microwave oven than when cooked conventionally. No significant difference in ascorbic acid content was reported when comparing the pre-thawed blocks or loose-packed frozen peas to the frozen blocks. The total amount of carotene in the raw peas was retained by both the microwave and conventional methods.

Vegetables (continued)

Authors:

Eheart, M. S. and Gott, C., Dept. of Foods and Nutr., Univ. of Maryland,
College Park, MD.

Reference:

Chlorophyll, ascorbic acid and pH changes in green vegetables cooked by
stir-fry, microwave, and conventional methods, and a comparison of
chlorophyll methods. Food Technol. 19:867-870. 1965.

Nutrient:

Ascorbic acid

Treatments:

Fresh broccoli and green beans were cooked by four methods:

Broccoli

Stir-fry with 360g vegetables in 240 ml water for 10 min

Microwaves with 300g vegetables in 240 ml water for 11 min

Conventional, uncovered with 300g vegetables in 1200 ml
water for 15 min

Conventional, covered with 300g vegetables in 150 ml water
for 20 min

Green beans

Stir-fry with 360g vegetables in 180 ml water for 15 min

Microwaves with 300g vegetables in 240 ml water for 10 min

Conventional, uncovered with 300g vegetables in 1200 ml
water for 20 min

Conventional, covered with 300g vegetables in 150 ml water
for 20 min

Results:

Ascorbic acid retention was the highest when both vegetables were cooked in a small amount of water. Broccoli cooked by the stir-fry method retained as much ascorbic acid as broccoli cooked in a small amount of water. The stir-fry method, the microwave method, and the use of large amounts of water (conventional, uncovered method) produced green beans with similar amounts of ascorbic acid retention, which was significantly less than the green beans cooked conventionally, covered.

Vegetables (continued)

Author:

Eheart, M. S., Agri. Res. Sta. and the College of Home Econ., Univ. of Maryland, College Park, MD.

Reference:

Effect of microwave vs. water-blanching on nutrients in broccoli.
Am. Dietet. Assn. J. 50:207-211. 1967.

Nutrient:

Ascorbic acid

Treatments:

Broccoli was blanched by three methods:

In 100°C water for 3 min

In 77°C water for 10 min

In a microwave oven for 2 min

Results:

On a wet basis, the ascorbic acid content of the broccoli blanched by microwaves was higher ($P < 0.01$) than that of the broccoli blanched by the other two methods. On a dry basis, there was no significant difference in ascorbic acid content between the microwave-blanched broccoli and the 100°C water-blanched broccoli, but the microwave-blanched and 77°C water-blanched broccoli differed ($P < 0.01$).

Vegetables (continued)

Authors:

Eheart, M. S. and Odland, D., Agri. Expt. Sta., Univ. of Maryland,
College Park, MD.

Reference:

Use of ammonium compounds for chlorophyll retention in frozen green
vegetables. J. Food Sci. 38:202-205. 1973.

Nutrient:

Ascorbic acid

Treatments:

Broccoli was treated by the following methods.

Pretreatments:

Blanched 3 min in boiling water

Blanched 2 min in a microwave oven in a loosely-closed baggie
containing 50 ml of 0.24 M NH_4OH

Cooked 7 min in a microwave oven in a loosely-closed baggie
containing 50 ml of 0.24 M NH_4OH

Cooking treatments:

H_2O -blanched vegetables were conventionally cooked in 150 ml
 H_2O for 11 min, covered

Microwave-blanched vegetables were cooked covered in 40 ml H_2O
in a microwave oven for 6 min

Microwave pre-heated vegetables were covered and reheated in
40 ml H_2O in a microwave oven for $1\frac{1}{2}$ min and then an additional
 $1\frac{3}{4}$ min

Results:

On a wet basis, broccoli blanched and/or cooked with NH_4OH in a microwave oven retained more reduced ascorbic acid than the broccoli blanched in water. On a dry basis, there was no significant difference in reduced ascorbic acid among the broccoli cooked by the three methods.

Vegetables (continued)

Authors:

Gordon, J. and Noble, I., School of Home Econ., Univ. of Minnesota,
St. Paul, MN.

Reference:

Comparison of electronic vs. conventional cooking of vegetables.
Flavor, color, and ascorbic acid retention. Am. Dietet. Assn. J.
35:241-244. 1959.

Nutrient:

Ascorbic acid

Treatments:

Cabbage, cauliflower, and broccoli were cooked by three methods:

In boiling water

In pressure saucepan (15 lb)

In microwave oven

Results:

Overall, the vegetables cooked by the microwave oven retained more ascorbic acid than vegetables cooked by the conventional methods. The vegetables cooked in boiling water retained the least amount of ascorbic acid of the three methods used and had the greatest amount of ascorbic acid dissolved in the cooking liquid.

Vegetables (continued)

Authors:

Hard, M. M. and Ross, E., State College of Washington, Pullman, WA.

Reference:

Dielectric scalding of spinach, peas, and snap beans for freezing preservation. Food Technol. 10:241-244. 1956.

Nutrient:

Ascorbic acid

Treatments:

Spinach, peas, and snap beans were blanched by three methods:

Steaming-scalding

Dielectric-blanching

Water-scalding

The vegetables were cooled by dip, spray, or air-cooled methods for 0.5, 0.75, or 5.0 min, respectively.

Results:

The vegetables blanched by the dielectric scald-air cool treatment retained a higher percentage of reduced ascorbic acid than all of the other methods used. However, overall there was no practical difference among the treatments used in the experiment.

Vegetables (continued)

Authors:

Klein, B. P., Lee, H. C., Reynolds, P. A., and Wangles, N. C., Dept. of Food and Nutr., Univ. of Illinois, Urbana, IL.

Reference:

Folacin content of microwave and conventionally cooked frozen vegetables. J. Food Sci. 44(1):286-288. 1979.

Nutrient:

Folacin

Treatments:

Frozen leaf spinach, green peas, green beans, and broccoli were cooked by two methods:

In a conventional gas oven in 100 ml of water

In a 2450 MHz Litton Minutemaster microwave oven (585 W) in no water

Results:

No significant difference was found between the folacin content of the vegetables cooked by microwaves and the vegetables cooked by the conventional method.

Vegetables (continued)

Authors:

Kylen, A. M., Charles, V. R., McGrath, B. H., Schleter, J. M., West, L. C., and Van Duyne, F. O., Dept. of Home Econ., Univ. of Illinois, Urbana, IL.

Reference:

Microwave cooking of vegetables. Ascorbic acid retention and palatability. Am. Dietet. Assn. J. 39:321-325. 1961.

Nutrient:

Ascorbic acid

Treatments:

Broccoli, cabbage, cauliflower, peas, green beans, soybeans, and spinach were cooked by conventional or microwave methods with various amounts of water and various cooking times.

Results:

There were no significant differences in the ascorbic acid content of the fresh or frozen vegetables cooked by microwave or conventional methods.

Vegetables (continued)

Authors:

Lanier, J. J. and Sistrunk, W. A., Dept. of Horticultural Food Science,
Univ. of Arkansas, Fayetteville, AR.

Reference:

Influence of cooking method on quality attributes and vitamin content
of sweet potatoes. J. Food Sci. 44:374-376. 1979.

Nutrients:

Ascorbic acid, pantothenic acid, niacin, riboflavin, and carotene

Treatments:

Sweet potatoes were cooked by five methods:

Baking for 75-90 min at 190°C

Boiling for 40-60 min at 99°C

Steaming for 40-70 min at 99°C

In a microwave oven for 18-35 min (Litton Microwave Oven, 2450 MHz)

Commercial canning for 35 min at 116°C

Results:

The ascorbic acid retention was lower ($P < 0.05$) in the sweet potatoes cooked by microwaves or commercially than in the sweet potatoes baked conventionally. The sweet potatoes baked conventionally or by microwaves retained the highest levels of pantothenic acid and niacin, and sweet potatoes canned commercially retained the least. Cooking methods did not affect significantly the carotenoid content of the sweet potatoes. Conventional baking was the only method that affected ($P < 0.05$) the riboflavin content of the sweet potatoes.

Vegetables (continued)

Authors:

Mabesa, L. B. and Baldwin, R. E., Dept. Food Sci. and Nutr., Univ. of Missouri-Columbia, Columbia, MO.

Reference:

Ascorbic acid in peas cooked by microwaves. J. Food Sci. 44:932-933. 1979.

Nutrients:

Ascorbic acid and moisture

Treatments:

Frozen peas were cooked by five methods:

Simmered with 100g water for 8.0 min on a surface burner.

Cooked 8.0 min with 100g water in a domestic microwave oven (115V, 550W cooking power, 2450 MHz)

Cooked 6.5 min without water in a domestic microwave oven (115V, 550W cooking power, 2450 MHz)

Cooked 6.0 min in 100g water in an institutional microwave oven (220V, 1150W cooking power, 2450 MHz)

Cooked 5.0 min without water in an institutional microwave oven (220V, 1150W cooking power, 2450 MHz)

Results:

Cooking without water resulted in peas with a lower percentage of moisture than peas cooked with water. All methods of cookery, except the institutional method (without water) lost significant ($P < 0.05$) amounts of ascorbic acid. The peas cooked by microwaves retained more ascorbic acid than the peas cooked by the conventional method except

for peas cooked in the domestic microwave oven in 100g water. When comparing peas cooked with and without water in the microwave ovens, (domestic or institutional) the ascorbic acid retention was higher ($P < 0.05$) in peas cooked without water.

Vegetables (continued)

Authors:

Martin, M. E., Sweeney, J. P., Gilpin, G. L., and Chapman, V. J.,
Human Nutrition Res. Div., Agri. Res. Service, USDA, Washington, DC.

Reference:

Factors affecting the ascorbic acid and carotene content of broccoli.
J. Agric. Food Chem. 8:387-390. 1960.

Nutrient:

Ascorbic acid

Treatments:

Frozen broccoli was cooked by boiling in 236g water for 1, 5, 10, 15,
or 20 min or in a microwave oven without water for 0 or 15 min.

Results:

Both conventional and microwave cooking caused similar losses in
reduced ascorbic acid. As the cooking time increased, the reduced
ascorbic acid content decreased.

Vegetables (continued)

Authors:

Moyer, J. C. and Stotz, E., New York State Agri. Exp. Sta., Geneva, NY.

Reference:

The blanching of vegetables by electronics. Food Technol. 1:252-257.
1947.

Nutrients:

Ascorbic acid and carotene

Treatments:

Peas were blanched by several methods:

Radio frequency power at 160, 170, 180, 190, 200, and 210°F

Water, 210°F for 0.3, 1.0, and 3.0 min

Steam, 210°F for 0.5, 1.5, and 3.0 min

Three methods were used to blanch potatoes:

Microwave oven at 212°F for 3 min

Microwave oven at 212°F for 3 min and cooled on tray in slow air
movement at -10°F

Microwave oven at 212°F for 3 min and cooled in carton at -10°F

Results:

Peas blanched by radio frequency power retained a higher percentage of ascorbic acid than peas blanched by water or steam. There was no significant difference in the carotene content of the peas blanched by radio frequency power, water, or steam. Rapid cooling increased the ascorbic acid retention of potatoes blanched by radio frequency power over the slow cooling method.

Vegetables (continued)

Authors:

Proctor, B. E. and Goldblith, S. A., Dept. of Food Technology,
Massachusetts Inst. of Technol., Cambridge, MA.

Reference:

Radar energy for rapid food cooking and blanching, and its effect on
the vitamin content. Food Technol. 2:95-104. 1948.

Nutrient:

Ascorbic acid

Treatments:

Spinach, broccoli, carrots, peas, or green beans were blanched by
three methods:

In a microwave oven

In boiling water

By steam

Results:

None of the vegetables subjected to blanching by the microwave oven
lost any significant amount of ascorbic acid. The spinach blanched
by boiling water lost almost all of its ascorbic acid to the blanching
water. The microwave oven was superior to the boiling water or
steam blanching methods in retaining ascorbic acid in all of the
vegetables used in the experiment.

Vegetables (continued)

Authors:

Samuels, C. E. and Weigand, E. H., Oregon Agri. Exper. Sta., Oregon State College, Corvallis, Oregon.

Reference:

Radio frequency blanching of cut corn and freestone peaches. Fruit Prod. J. & Am. Food Mfr. 28:43-44, 61. 1948.

Nutrient:

Ascorbic acid

Treatments:

The raw corn underwent three blanching treatments:

Unblanched

Boiling water for 2 min

Microwave-blanching for 3 min using hot water or air as its media

The blanched corn was cooled by two methods:

Under running water for 15 sec

By placing on a tray on a 20⁰F air blast for 5 min

Results:

The ascorbic acid content was decreased by only 10% (water cooled) and 0% (air cooled) when blanched by microwaves in an air media as compared to 35% (water cooled) and 23% (air cooled) for water-blanching corn. The use of a hot water media instead of an air media decreased the ascorbic acid content of the blanched corn.

Vegetables (continued)

Authors:

Stevens, H. B. and Fenton, F., State College of Home Econ., Cornell Univ., Ithaca, NY.

Reference:

Dielectric vs stewpan cookery. Comparison of palatability and vitamin retention in frozen peas. Am. Dietet. Assn. J. 27:32-35. 1951.

Nutrients:

Ascorbic acid, thiamin, and riboflavin

Treatments:

Two methods were used to cook frozen peas:

Microwave oven

Stewpan

Frozen peas were cooked to three degrees of doneness by microwaves:

Underdone, 2 min 35 sec

Done, 2 min 55 sec

Overdone, 3 min 25 sec

Results:

There were no significant differences in the retention of ascorbic acid, thiamin, or riboflavin in the frozen peas cooked in a microwave oven or in a stewpan. Also, no significant differences were found in the retention of ascorbic acid in frozen peas cooked to different degrees of doneness in a microwave oven.

Vegetables (concluded)

Authors:

Thomas, M. H., Brenner, S., Eaton, A., and Craig, V., Food Res. Div.,
Quartmaster Food and Container Institute for the Armed Forces, Chicago,
IL.

Reference:

Effect of electronic cooking on nutritive value of foods. Am. Dietet.
Assn. J. 25:39-45. 1949.

Nutrients:

Ascorbic acid, carotene, riboflavin, and thiamin

Treatments:

Broccoli, cabbage, and carrots, were cooked by microwaves, boiled, or
pressure cooked. Potatoes were boiled in a microwave oven, in a
saucepan, or in a pressure saucepan. The potatoes also were baked
singly or in multiple amounts in a microwave oven or in a conventional
oven.

Results:

The retention of water soluble vitamins decreased as the amount of
water and time exposed to heat increased. Pressure cooking was
generally the least destructive (of the three methods) to the water
soluble vitamins. The carotene content of the vegetables was not
significantly affected by the cooking methods.

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NUTRITIVE LOSSES ATTRIBUTABLE TO
MICROWAVE COOKERY

by

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B. S., Kansas State University, 1978

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

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MASTER OF SCIENCE

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ABSTRACT

The use of microwave energy for food preparation is increasing in homes, institutions, and industries. Because of the increased use of microwave ovens, research has been done to compare the effects of microwave energy on food composition to those foods prepared by conventional methods.

Losses of moisture (one component of foods) are frequently greater in microwave-cooked foods than in foods cooked conventionally. This has been found to be true in red meats, poultry, vegetables, and baked products.

Free amino acids tend to be greater in conventionally cooked beef, lamb, and pork roasts than in meats cooked by microwaves. However, conventionally baked breads tend to have a lower protein efficiency ratio than breads baked by microwaves attributable to the fact that conventionally baked breads have a browner crust than crusts from breads baked by microwaves. Because lysine has a role in the browning process, more lysine is destroyed.

No consistent trends have developed in research which compares the fat content of meats cooked by microwave or conventional methods. However, studies have shown that meats (beef and chicken) baked by microwaves contain a larger ratio of unsaturated to saturated fatty acids than meats cooked conventionally. Also, research has implicated that fat oxidation in egg yolks and cakes is less when baked by microwaves than when baked in a conventional oven.

Changes in vitamin content (B-vitamins and ascorbic acid) and carotene, a precursor of vitamin A, have been reported in foods cooked

by microwaves. However, oven type does not seem to be the major contributing factor to vitamin losses in foods (red meat, poultry, vegetables, and baked products). The amount of cooking liquid used, the length of cooking time, and the length of holding time seems to play the most significant role in vitamin losses.

No consistent trends are apparent for microwave cookery and mineral losses when compared with conventional cookery, partly because of a shortage of research in this area.

Overall, if techniques used by researchers were more consistent, drawing conclusions on the effects of microwave cookery would not be so difficult.