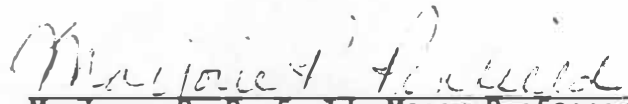
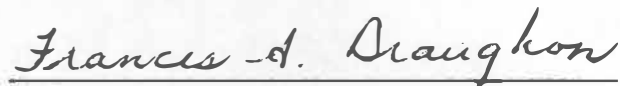


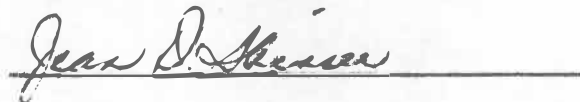
To the Graduate Council:

I am submitting herewith a thesis written by Marsha McNeil entitled "The Quality of Turkey as Affected by Ovens of Varying Energy Costs." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science.


Marjorie P. Penfield, Major Professor

We have read this thesis
and recommend its acceptance:


Francis A. Daughon


Jean D. Skinner

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

THE QUALITY OF TURKEY AS AFFECTED BY OVENS OF
VARYING ENERGY COSTS

A Thesis
Presented for the
Master of Science
Degree

The University of Tennessee, Knoxville

Marsha McNeil

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ABSTRACT

Energy conserving cooking procedures have been of recent interest to the consumer and the researcher. The introduction of convection and microwave ovens for consumers has been credited with potential energy savings. Therefore, an investigation was designed to compare the energy consumption of conventional, convection, and microwave ovens as boneless turkey roasts were cooked. Turkey was chosen because its consumption is increasing and it is a time and energy demanding muscle food to cook. The quality of the cooked roasts was evaluated by objective tests, an experienced sensory panel, and a consumer sensory panel.

The microwave oven cooked significantly faster ($P < 0.05$) than the other ovens. The convection oven consumed the most energy ($P < 0.05$) but had the most cooking power ($P < 0.05$) when compared to the other ovens. The relative efficiency of the convection and microwave ovens was greater ($P < 0.05$) than that of the conventional oven.

The evaporative and total cooking losses did not differ among treatments. The microwave roasts had the greatest ($P < 0.05$) drip loss. The conventional and convection roasts had lower ($P < 0.05$) percentages of fat-free dry weight than did the microwaved roasts. The expressible moisture index did not differ among treatments. The shear values of the convection roasts were lower than shear values of the microwave roasts but did not differ from those of the conventional roasts. The conventional and microwave roasts were similar in tenderness.

Riboflavin content of the cooked roasts, on a wet basis and dry basis did not differ. On a wet basis the conventional and on both a

wet and dry basis the microwaved roasts did not differ from the raw samples with respect to riboflavin content.

The 9-member, experienced sensory panel found no differences in doneness, appearance, juiciness, flavor, and overall acceptability but did find a difference in tenderness of the roasts cooked in the three ovens. The microwave-heated roasts were found to be tougher than the other roasts. A 72-member, consumer sensory panel also did not find any differences among the roasts in paired comparison tests for acceptability.

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CHAPTER I

INTRODUCTION

The oil embargo of 1973 generated an energy conscientiousness that has penetrated into many sectors of daily living. One such area of concern is related to energy requirements of preparation of food by traditional means such as cooking in a conventional oven. Convection and microwave ovens have been reported to require less energy than conventional ovens (Anon., 1979; Van Zante, 1973).

Conventional ovens usually have high energy consumptions and low relative efficiencies. Conventional ovens generally require preheating and lengthy cooking times. Heat escapes through the oven walls and whenever the oven door is opened. Further, conventional ovens may not have automatic timing devices, which terminate the heating process (McConnell, 1974). Conventional ovens require energy to operate in addition to that required for heating the food (Luetzeltschwab, 1980). Peart et al. (1980) reported that only approximately 14% of the energy available in the conventional oven is absorbed by the food being baked or roasted. The remaining energy heats the oven (46%) and is lost through the oven walls (26%) and vent (15%). In 1977, there were 54.4 million electric ovens, consuming an average of 376 kwh/oven yearly (Peart et al., 1980).

Microwave and convection ovens may have higher relative efficiencies than conventional ovens. McConnell (1974) found that the microwave

cooked 57 of 77 foods with less energy than did the conventional oven. In the microwave oven, there is minimal heating of the oven interior and the air in the cavity. There is no heat loss to the environment when the oven door is opened. Microwave ovens have automatic timers that terminate the heating process when the predetermined time expires. When based upon 100% use, McConnell (1974) found the microwave oven required 300 kwh annually. The energy consumption of the microwave has been evaluated by only a few independent researchers.

Energy savings with the convection oven, also, have not been fully explored. It has not been compared to the microwave oven for energy consumption (Rhee and Drew, 1977; Blanck, 1978).

The various heat treatments of the three ovens differ. Therefore, the quality of foods cooked in the three ovens also differs. Electricity is supplied to each oven and heats the food by various methods of heat transfer. The conventional oven heats primarily by conduction of hot air. The microwave oven cooks food by the penetration of microwaves, which produce heat within the food. The convection oven cooks food by circulating hot air evenly throughout the oven cavity.

With the increased use of microwave and convection ovens, consumers possibly are altering their cooking procedures for energy and time savings. Using energy conserving methods when cooking muscle foods, such as turkey, could result in reduced utility costs for the consumer (Mandigo and Janssen, 1982).

In recent years turkey consumption has increased in the United States (Berry et al., 1980). According to the USDA Agricultural Statistics (USDA, 1980), the per capita consumption, retail-weight equivalent,

for turkey in 1978 was 9.3 pounds and in 1979 it was 10.1 pounds. In 1980 the turkey consumption per capita was 10.6 pounds. In 1966 it had been 7.8 pounds (USDA, 1980). Generally, turkey is cooked in the conventional oven, which is a time and energy consuming process. Cipra et al. (1971) specifically pointed out that there have been few studies conducted concerning microwaving turkey.

Turkey contains riboflavin, which is a heat-labile vitamin. Riboflavin retention could be affected differently by various heat treatments. Watt and Murphy (1970) suggested the need for more investigation of the vitamin and mineral content of turkey.

The conservation of energy in regard to cooking methods has been advocated but not at the expense of the quality of the cooked food (Dennis and Schoenhals, 1978). Korschgen et al. (1980) have recommended the investigation of energy requirements of various cooking methods. The effect of energy conserving cooking methods on food quality is an area in need of further exploration.

Therefore, a study was undertaken to investigate the energy consumption of conventional, convection, and microwave ovens as boneless turkey roasts were cooked. The effects of the three heat treatments on the turkey quality were explored. The objectives of the study were:

1. To compare the relative efficiencies of the conventional, convection, and microwave ovens.
2. To compare objective characteristics such as rate of heat penetration, cooking losses (evaporative, drip, and total), total moisture, fat content, expressible moisture, and shear value of the turkeys cooked in the three ovens.

3. To compare the riboflavin contents of the raw and cooked turkey breasts.
4. To compare sensory characteristics such as doneness, appearance, juiciness, flavor, and tenderness of the turkeys cooked in the three ovens as evaluated by an experienced sensory panel.
5. To compare overall acceptability of the turkeys cooked in the three ovens as evaluated by a consumer panel.

CHAPTER II

REVIEW OF LITERATURE

I. Energy Consumption

One-fourth of the total annual energy consumed in the United States is used by the residential sector. Food preparation is one of the largest residential energy expenditures (Erickson, 1978). Berg (1973) stated that one-fifth of the national energy consumption goes to residential use and 11% of this energy is for food preparation. Hirst (1973) reported that consumer food preparation accounted for 30% of the 6,100 trillion BTU's expended in 1963 by the food chain. Food processing (33%) required more energy than did consumer food preparation.

For most consumers the energy requirements and economy of operating appliances used for food preparation are secondary considerations (Rhee and Drew, 1977). The energy utilization, efficiency, and initial and repair costs of an appliance, however, are becoming more important factors in evaluation of an appliance for purchase. Conservation of time is another factor associated with all aspects of food preparation. Changes in lifestyles and family structure have warranted the need for quick meal preparation (Drew and Rhee, 1978). Convection and microwave ovens have been credited with reducing cooking times.

National Family Opinion, Inc., (commissioned by the Appliance Manufacturer in 1978) surveyed 2,000 homeowners in order to review consumer attitudes toward appliances and energy consumption. Two-thirds of the families polled did not know the cost of operating major appliances.

Three-fourths did not know the cost of operating electric housewares. According to the survey, consumers were willing to spend slightly more for appliances in order to receive substantial energy reductions (Consdorf, 1978).

The Midwest Research Institute published an extensive survey dealing with appliance usage in urban-suburban populations (MRI, 1979). The objectives of the MRI project were to compile data on residential electrical energy, analyze factors influencing energy use, and determine national and regional appliance energy patterns. Ovens and ranges were among the major appliances studied and monitored for a year in private homes. The annual, average energy usages for range, electrical cooktop, and electrical ovens were 782, 553, 401 kw, respectively. Electrical household appliances use about 9% of the total annual energy consumption in the United States according to the MRI.

Microwave ovens and other specialized cooking appliances often are used in conjunction with electric or gas ovens, but not as a replacement (EPRI, 1979). The MRI survey revealed that separate electric ovens were owned less often than ranges with both oven and surface units (MRI, 1979).

II. Types of Ovens

Conventional Oven

In the conventional oven, the heat is radiated from the heating elements to the oven walls, and then to the oven air. The oven air heats

the outside of the food, and conduction transfers the heat inside the food. Because oven air has little movement and cools as it moves, preheating is required to maintain an even temperature throughout the oven. In order for heated air to come in contact with the food, pans should not be placed closely together (Anon., 1979).

The conventional oven has been used in many meat studies evaluating the quality of the cooked meat. It also has been a part of energy studies involving the convection and microwave ovens.

Convection Oven

The convection oven contains a fan that forces the hot air to flow evenly throughout the oven cavity. The constant flow of the hot air keeps the air surrounding the food at the same temperature at all times. Therefore, the oven racks can be filled completely. Generally no preheating is required and little hot air escapes to the environment (Anon., 1979, 1980a, Undated; Chalmers, 1979; Dow Consumer Products, 1980).

In 1973, Faberware marketed the first countertop convection oven for consumers (Dow Consumer Products, 1980). The convection oven is reported to reduce cooking times up to 30% (Anon., 1979, 1980a) and to make it possible to lower oven temperatures by 25-50 F degrees (Anon., 1980a).

No empirical energy research studies at the consumer level have been published on the convection oven. Walter H. Blanck, technical director of the Association of Home Appliance Manufacturers, recommended that new products such as the forced air convection oven be tested for true energy savings (Blanck, 1978). Furthermore, there are gaps in the

literature concerning the quality of foods cooked in the consumer convection ovens, and comparison of these foods to foods cooked in the conventional and microwave ovens.

Some research has been done concerning commercial convection ovens. For instance, McGinley (1982) reported a study involving cooking pork in the convection, microwave, and conventional ovens. The microwave oven required the least amount of energy to cook the pork, followed by the convection and then the conventional oven. The commercial convection oven used less energy to preheat and cooked at a lower temperature than did the conventional oven.

Microwave Oven

Microwave heating is a different type of cooking process than that of conventional and convection ovens. Microwave cooking is a dielectric heating process. The electromagnetic waves are nonionizing energy, which cause a temperature rise in the penetrated substances because of electromagnetic-field changes at high frequency. Polar molecules in the penetrated substances influence the heating. The microwaves are reflected, transmitted, or absorbed by the cooking container and the food. When the radiant energy is absorbed by the food, heat is produced. Heat production in the microwave, or lossiness, is caused by the movement of the charged particles in the food. The gyration of the dipole and polar molecules is caused by the rapid alternation of the high-frequency field in the oven. Frictional heat is produced as the charged particles vibrate which results in the cooking of the food. Conduction and convection processes transfer the heat throughout the food (Van Zante, 1968, 1973; Ziprin and Carlin, 1976).

Microwave ovens are credited with saving from 25 to 50% of the energy of conventional electric ovens (Ludvigson and Van Valkenburg, 1978). By 1985 with a projected market saturation of 50%, 32.3 billion kilowatt hours of electricity could be saved (Ludvigson and Van Valkenburg, 1978).

A survey was done in Arizona to describe use of the microwave, the microwave user, user expectations, and market potential (Gast et al., 1980). Vegetables were cooked more than other foods in the microwave. Reheating and defrosting were other main uses. Meats such as beef, including ground beef, chicken, and pork also were prepared. Overall, the microwave oven was used for convenience, and owners did not alter the types of food purchased or prepared.

Researchers at Litton concluded that a microwave can save a family of four varying amounts of energy; the more the microwave is used, the more energy is saved. Ludvigson and Van Valkenburg (1978) studied the energy required to prepare a basic 7-day menu for a family of four. The microwave was found to save more energy when used to replace oven cooking than when used as a substitute for surface cooking.

A similar study was done at the General Electric Company in Kentucky. It was shown that T.V. dinners and moderate quantities of foods such as desserts and meats can be cooked in the microwave with significant energy savings (Butel, 1975). Foods such as corn, broccoli, and other vegetables were reported to require more energy in the microwave than with the surface cooking method. A standard menu for a family

of four (USDA money-saving menu II) was cooked using a countertop microwave, a conventional oven, and combinations of the ovens. Only 60% of the foods on the menu could be cooked in the microwave. When comparing foods cooked only by the microwave with the same foods cooked conventionally, there was a 40% energy savings. When the microwave was used only for foods for which it was the most energy efficient and conventional cooking was used for the remainder of the meal, there was a 17% energy savings.

Energy savings also were noted by Lovingood and Goss (1980) when conventional oven cooking was supplemented with microwaving. Reductions in time, cost, and in annual operating time were observed when cooking the AHAM Standard Menu for Range Energy Testing.

Microwaving has been documented with as much as a 75% energy savings. However, there have been many discrepancies found in reports of microwave energy savings (Butel, 1975; Pollak and Foin, 1960; Drew and Rhee, 1978; Voris and Van Duyne, 1979). Voris and Van Duyne (1979) pointed out a need for more energy studies with microwave ovens in order to draw solid conclusions.

III. Energy Studies Involving Meats

Cooking meat causes denaturation and coagulation of proteins, melting of the fat, shifts in pH, changes in water-holding capacity, and chemical variations (Paul, 1972). These reactions affect the color, texture, and flavor of the cooked meat (Campbell et al., 1979). Water-holding capacity decreases as temperature increases, decreasing juiciness and tenderness. As the temperature increases, other changes

take place. Between 20 and 30°C, few changes occur. Between 30 and 50°C, the peptide chains unfold, cross linkages form, and the sarcoplasmic proteins begin to be denatured. Adenosine triphosphatase is inactivated completely. From 50 to 55°C, the myofibrillar and globular proteins coagulate and the collagen shrinks and changes partially to gelatin (Hamm, 1966). These changes that occur in meat during cooking are dependent upon the rate as well as the temperature of heating. Therefore, different cooking methods of meat may produce different results.

Bowers and Heier (1970) studied turkey breasts heated in a gas oven and turkey breasts cooked to several end points in a microwave. Heating curves were compared and cooking losses were determined. In the microwaved turkey, the large end had the highest and most rapid temperature rise of the five positions monitored in the meat. After removal from the oven, the temperature of the center position continued to rise, while the outer positions dropped in temperature. The temperatures at the two end positions in the conventionally gas-heated turkey also dropped after removal from the oven. After removal from the oven the temperature in all positions dropped within two minutes. Total cooking losses were less for the conventionally heated than for the microwaved turkey. No significant differences were found for degree of fragmentation of the muscle fibers or in sensory evaluation among any of the treatments.

Cipra and co-workers (1971) worked with precooking and reheating turkey in the microwave and gas ovens. The cooking times were found to be significantly less when microwaving. The post oven temperature rise averaged 3.0°C for the microwaved turkey but did not occur in the conventionally cooked meat. After removal from the oven, the standing period,

the time during which the temperature continued to rise and then fall, ranged from 10 to 21 min. Volatile and total cooking losses were greater for the microwaved turkey. The conventionally heated turkey had greater total moisture and expressible moisture values. Stale flavor in the conventional turkey was rated more intense than in the microwaved turkey by a sensory panel. No significant differences were found in shear values for the heat treatments.

Cipra and Bowers (1971) found microwaved reheated light turkey meat to have less of a stale and aldehyde-like aroma when compared to gas reheated light turkey meat. Microwaved samples had lower juiciness scores.

Even though a cooking method may be considered as energy saving, the food it produces must be desirable. When comparing conventionally cooked and microwaved meats, differences in the eating quality have been observed by many researchers (Rhee and Drew, 1977). Microwaving meat may result in meat that is different in color, flavor, and texture than conventionally cooked meats. However, some research has indicated that microwaved meat may be as acceptable as conventionally cooked meat (Harrison, 1980).

IV. Vitamin Content, Retention, and Analysis

Turkey contains riboflavin, which is a heat-labile, water-soluble vitamin. The riboflavin content of light meat roasted without the skin is 0.12 mg/85 g, on an as-is basis (USDA, 1977).

The effect of electronic cooking on vitamin retention has not been explored fully (Hall and Lin, 1981; Bowers and Fryer, 1972). The

available information is conflicting. Hall and Lin (1981) found more thiamin, which is also a heat-labile, water-soluble vitamin, in chicken broilers that were microwaved than in broilers cooked in an electric oven. Bowers and Fryer (1972) found that the type of oven did not significantly influence the thiamin retention. Van Zante and Johnson (1970) reported higher thiamin and riboflavin retentions in buffered aqueous solutions that were conventionally heated than in microwave-heated solutions.

High Pressure Liquid Chromatography (HPLC) can be used for the determination of the riboflavin content in raw and cooked meats. Ang and Moseley (1980) developed a chromatographic procedure for the determination of low levels of riboflavin among high levels of interfering substances in meat products. The riboflavin was extracted from the meat and then converted to lumichrome. A normal phase column was used. A chloroform-methanol (90:10%) mixture was used as the mobile phase. A fluorescence detector was used to detect the fluorescing lumichrome.

Riboflavin has a 6,7-dimethyl-9-(D-1'-ribityl)isoalloxazine structure. Lumiflavin can be formed by irradiation of riboflavin in an alkaline solution. The oxygen-constituent of the riboflavin side chain is removed and a chloroform soluble lumiflavin results (Sebrell and Harris, 1972). The amount of lumiflavin present in the meat samples is equivalent to the original riboflavin content.

V. Summary

Relative energy consumptions of the conventional, convection, and microwave ovens have not been fully investigated. The effects of the

three different modes of heat transfer upon the eating quality and nutritive content of foods, such as turkey, have not been compared at the consumer level.

CHAPTER III

PROCEDURE

I. Experimental Design

The statistical design consisted of a balanced, incomplete block (Table 1). One turkey, made into two roasts, was chosen randomly to be cooked in one session. Two roasts from each turkey constituted a block.

II. Turkey Procurement and Preparation

Fresh whole turkey breasts were obtained through The University of Tennessee Central Foods from Bil Mar Foods. The turkeys were grade A young breasts weighing 10-12 pounds. The turkeys, in their original wraps, were frozen and stored at -15°C in a freezer to simulate consumer practices. The storage time for the turkeys used in the first nine blocks did not exceed seven weeks. The turkeys for the consumer panel were stored for twelve weeks.

Each whole turkey breast was thawed for 24-36 hours in a refrigerator (4°C) and in a water bath (room temperature) for 1-2 hours before deboning (AHEA, 1980; Bowers and Fryer, 1972). Two boneless roasts were made from each whole breast by removing the meat from each side of the breast bone. The muscle was shaped, rolled, and secured with string. Samples were taken for total moisture and riboflavin determinations from the meat area next to the breast bone.

Table 1--Incomplete block^a design for assigning treatments to cooking period

Block (Cooking period)	Treatment		
	Conventional	Convection	Microwave
1	X		X
2		X	X
3	X	X	
4	X		X
5		X	X
6	X	X	
7		X	X
8	X	X	
9	X		X
10		X	X
11	X	X	
12	X		X

^aBlocks 1-9 were completed for energy, objective, and experienced sensory panel studies. Blocks 10-12 were completed for the consumer study.

III. Cooking Procedures

Conventional and Convection Ovens

The roasts were placed on racks in aluminum pans and covered with an aluminum foil tent. The oven was preheated to 163°C (325°F) (Berry et al., 1980). The oven temperatures were monitored by a copper-constantan thermocouple placed in the center of each oven.

The rate of heat penetration was monitored by two thermocouple probes placed in the two ends of the roast. The thermocouples were attached to a Honeywell Temperature Recorder (Goertz et al., 1960). When the temperature of the roast reached 77°C (170°F), the turkey roast was removed from the oven (AHEA, 1980). The probes were removed after a decline in the temperature of the roasts.

Microwave Oven

The turkeys were placed in glass dishes and covered with wax paper for microwave heating. The medium power level (990-1188 watts) was used. Power level was determined as outlined in Appendix A. During the second half of microwaving, the roast was turned over and the dish was rotated one-half turn (General Electric, 1977). The roasts were cooked to approximately 77°C (170°F).

A microwave thermometer was positioned in each end of the roast, and the temperature was recorded every three minutes. The post-oven temperature rise was recorded (Goertz and Stacy, 1960; Bowers and Heier, 1970).

IV. Energy Comparison

The conventional oven used was a self-cleaning Frigidaire Super Mode RSE-36L, 115/230 volts-120/240 cycles 60, and 10.8 kw. The convection oven was a Maxim oven with 120 volts, 1600 watts, and 60 Hz. The microwave was a General Electric model number JET 880VI, 1.25 kw, 60 Hz A.C. only and 120 volts, and for household use. The ovens used in the present study were considered to be representative of those used by consumers. General Electric, which made the microwave oven used, is one of the five largest manufacturers of microwave ovens, producing 13% of the domestic market (Anon., 1980b). Share of market data were not available for conventional or convection ovens.

Duncan appliance meters with Kh values of 3.6 and 0.33 were attached to the ovens. In order to compare the energy requirements of the three ovens, the relative efficiencies were determined by the following equation:

$$RE (\%) = \frac{\text{cooking power (w)}}{\text{power input (w)}} \times 100.$$

The cooking power was the energy required to actually cook the turkey. The power input was the energy required for cooking and operating the oven (Korschgen et al., 1980).

Collison (1980) hypothesized the energy expenditure during the cooking process to be the following:

1. Environmental losses, the energy necessary to maintain oven temperature without a food load, can be measured by using the Rotating Disc Method (Leutzelschuab, 1980).

2. Open door loss, energy necessary to reach temperature setting after door is opened for loading time, can be determined by recording whr needed to return oven to designated temperature.
3. Heat absorbed by food dish can be calculated by multiplying the specific heat of the dish by temperature rise of the oven.
4. Heat absorbed by the food is the remaining portion of the energy or the difference between the energy consumed and the energy lost and the energy required to heat the container.

Because the conventional and convection ovens are similar in operation, the wattage and cooking power of both were determined by the Rotating Disc Method (Leutzelschwab, 1980), which is outlined in Appendix B.

Cooking power of the microwave oven was determined by calorimetric computation for water loads, which is detailed in Appendix A. In order for H_2O to be a perfect absorber of microwaves, it has to be void of minerals. Distilled water absorbs microwaves at different rates than tap water. Therefore, distilled water was used with 1% NaCl added (Van Zante, 1973; Gerling, 1978).

V. Methods of Other Objective Evaluations

Cooking Losses

Cooking losses evaluated included drip, evaporative, and total. The roasts were weighed before cooking (Campbell et al., 1979). After the standing period following heating, the roasts were reweighed. Details of calculations for cooking losses are given in Appendix C.

Sampling

The cooked roasts were stored at 4°C after the weighing. The following day the skin was removed and samples were taken for objective and sensory tests. The roasts were sliced into four sections with an electric slicer. The first and fourth slices were 1.7-cm thick and cored for shearing. The second and third slices, 1.3 cm in thickness, were cubed for sensory testing. The meat remaining after sampling for coring and sensory was ground for the total moisture, fat, and expressible moisture determinations. Grinding was done with a grinder having a blade with 4-mm holes. The ground samples for riboflavin determination were further pulverized in a Waring blender for 30-60 sec.

Total Moisture, Fat, and Expressible Moisture

Total moisture was determined by placing 5-g duplicates of the ground raw and cooked turkey samples into pre-weighed Whatman extraction thimbles. The samples were dried in the vacuum oven for 6 hr at 60°C under 30 mm Hg. The samples were dried to a constant weight.

The dried samples then were extracted with petroleum ether (b.p. 37.4-50.0°C) on a Goldfish Fat Extraction Apparatus. After extraction, the samples were dried and weighed (Penfield, 1973; AOAC, 1974).

The expressible moisture index was measured by using the Haico Hydraulic Press. Three hundred milligrams of cooked, ground turkey samples were placed on Whatman No. 1 filter paper. Gradually, the samples were pressed with a force of 2272 kg over a period of 5 min (FSNFSA, 1979). The area of the pressed meat was measured with a planimeter. The ratio of the meat area to the juice was calculated and subtracted from one to

give the expressible moisture index (Brady and Penfield, 1981; Shaffer et al., 1973).

Shear Values

Cores, 1.90 cm in diameter, from the roasts were sheared with a Warner-Bratzler attachment to the Instron. A load cell of 50 kg was used. The chart and crosshead speeds were 100 mm and 50 mm, respectively. Eight shear values were measured per treatment. The force needed to shear the samples was recorded as force-distance curves. The height of each curve in kg was measured as an indicator of shear force.

Vitamin Assays

The vitamin assays consisted of extraction processes, chromatographic procedures, and recovery studies. Raw and cooked turkey meat both were extracted. Three samples per treatment were frozen and analyzed after each block.

Standard curves were determined using standard stock solutions of riboflavin (100 mg/ml). The riboflavin was converted to lumiflavin before injecting into the chromatograph (AOAC, 1974; Ang and Moseley, 1980). Appendix D is an outline of the chromatographic procedures. The recovery study showed that the method developed by Ang and Moseley (1980) and used in this study resulted in 98.00% recovery for raw turkey samples and 100% recovery for cooked turkey samples.

VI. Experienced Panel Sensory Evaluation

Sensory evaluation was performed by nine experienced panelists in the College of Home Economics sensory laboratory. The panelists were

female students, ages 22-27 years, in the College of Home Economics at The University of Tennessee who had had previous judging experience. A meeting was held to orient the panel to the purpose of the testing and to discuss the scorecard. A descriptive scaling test for doneness, appearance, juiciness, flavor, tenderness, and overall acceptability was used. The doneness and appearance were judged by sight before tasting. A 15-cm scale was anchored with bipolar terms (Goertz et al., 1960; Paul, 1972). Appendix E is a sample scorecard.

The samples were divided into 1.7-cm cubes and randomly selected for each panelist. Each panelist received two samples representing each treatment. The samples were served on white glass plates within 15 min after removal from the refrigerator under white light in individual sensory booths. Three-digit code numbers were randomly chosen for sample coding. The order of presentation was balanced.

VII. Statistical Analysis

The data from the objective testing and from the experienced sensory panel were analyzed statistically using the SAS statistical analysis package (SAS Institute, 1979). Proc GLM (General Linear Models) was used for analysis of variance and difference tests on the least squares means for all variables. Least squares means were used because of the balanced incomplete block experimental design. For objective measurements, differences attributable to the main effects of treatment (type of oven) and block were tested. For experienced sensory panel data main effects tested included treatment, block, and panelist. In addition two interactions, treatment x panelist and panelist x block, were studied.

VIII. Consumer Sensory Panel

Seventy-two panelists were recruited from faculty, students, and staff of the College of Home Economics and the Department of Food Technology and Science. Volunteers were recruited by mail (Appendix F) two weeks before the testing. Two days before the test a reminder was sent (Appendix G).

Two roasts from each of three turkeys were cooked for the consumer sensory panel. Each turkey was treated as an incomplete block as shown in Table 1. The three turkeys weighed 11.8-12.00 pounds and were the largest used in the study. They were not used for any other objective testing. The roasts were handled and cooked as previously described. The sampling procedure was the same as for the experienced panel except all of the turkey slices were used for sensory samples. A paired comparison test for preference was used. Three sets of samples were served, one at a time. Each set contained four samples, two 1.7-cm cubes from each roast. The cubes were randomly selected, and the order of presentation was balanced with respect to block and order within block. The samples were coded with three-digit random numbers. Water was stored in plastic pitchers and served at room temperature in paper cups. The turkey samples were served on white paper plates within 15 min of removal from refrigerator. Toothpicks were served with the samples as eating utensils. The testing conditions were similar to those for the experienced panel.

Instructions were posted in each booth (Appendix H). The panelists were requested to indicate which sample of each pair was more

acceptable to them (Appendix I). They also were instructed to rinse their mouths between samples.

After the third sample set, a questionnaire was distributed pertaining to demographics, frequency with which turkey was eaten, and availability of various types of ovens to the panelists. Appendix J is a replicate of the questionnaire.

The results of the multiple paired comparison tests were converted to ranking scores and significance determined by the method described by Kahan et al. (1973). This method is based on non-parametric techniques. The panel was characterized by determining the frequency of responses on the questionnaire.

CHAPTER IV

RESULTS AND DISCUSSION

I. Oven Temperatures and Heat Penetration of Roasts

The temperatures of the conventional and convection ovens were monitored during the cooking periods. The temperature of the conventional oven fluctuated less than that of the convection oven. The conventional oven generally deviated $\pm 2^{\circ}\text{F}$ from the oven setting of 325°F . In a convection oven the fan keeps the air circulating constantly, therefore, the cooler air is replaced and reheated (Anon., 1979). However, the temperature within the convection oven deviated $\pm 6\text{-}14^{\circ}\text{F}$.

The heat penetration curves for the roasts cooked in the conventional and convection ovens were similar (Figure 1). The temperatures rose gradually. In the microwave oven (Figure 1), the temperature rise of the roasts was more rapid than in the other two ovens. These findings are similar to what Bowers and Heier (1970) reported when cooking turkey breasts in gas-fired and microwave ovens.

The cooking time and the rate of heating, measured in min/kg, for the microwave oven were significantly different ($P < 0.05$) from those of the conventional and convection ovens (Tables 2 and 3). The microwave oven was faster in cooking the roasts than were the other two ovens, which did not differ. Cipra et al. (1971) reported microwaving turkey breasts pieces to be significantly faster than cooking identical pieces in a rotary gas oven. Korschgen et al. (1980) cooked beef rib roasts

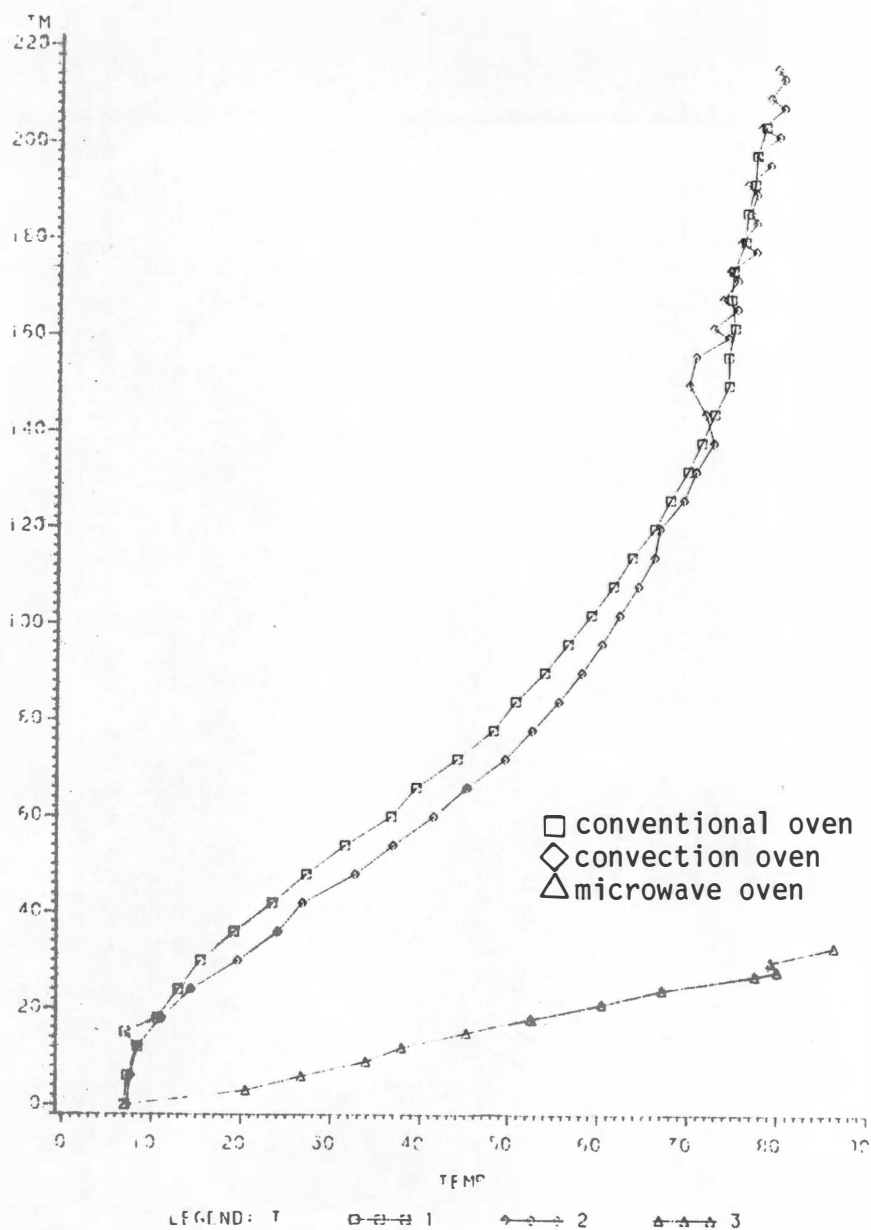


Figure 1--Heat penetration of turkey roasts cooked in the conventional, convection, and microwave ovens.^a

T = oven treatment.

T₁ = conventional oven.

T₂ = convection oven.

T₃ = microwave oven.

TM = cooking time, min.

Temp = temperature within roasts, C°.

^aMean of 6 roasts per oven treatment.

Table 2--Mean square values and significance of F ratios for cooking time and energy values for conventional, convection, and microwave ovens

Source of variation	df	Mean squares					
		Cooking time	Rate of heating Min/kg	Total whr	Rt. of consum. whr/kg	Cooking power	Relative efficiency
Total	17						
Treatment	2	43583.90 ^{***}	34298.91 ^{***}	9.37 ^{***}	6.61 ^{***}	1.21 ^{**}	298.10 ^{**}
Block	8	499.66	461.92	0.23	0.15	0.12	122.27
Error	7	737.90	403.80	1.88	0.20	0.10	27.90

^{**} P < 0.01.

^{***} P < 0.001.

Table 3--Least square means for the cooking time and energy values for conventional, convection, and microwave ovens^{a,b}

	Ovens		
	Conventional	Convection	Microwave
Cooking time, min	173.58b $\pm$ 12.26	182.16b $\pm$ 12.26	35.00c $\pm$ 12.26
Rate of heating, min/kg	155.97b $\pm$ 9.07	155.37b $\pm$ 9.07	33.13c $\pm$ 9.07
Total whr	1.67b $\pm$ 0.23	3.16c $\pm$ 0.23	0.55d $\pm$ 0.23
Rate of consumption, whr/kg	1.46b $\pm$ 0.20	2.65c $\pm$ 0.20	0.53d $\pm$ 0.20
Cooking power, whr	0.59b $\pm$ 0.14	1.25c $\pm$ 0.14	0.22b $\pm$ 0.14
Relative efficiency, %	31.64b $\pm$ 2.38	40.85c $\pm$ 2.38	44.46c $\pm$ 2.38

^aLeast square mean and standard error of 6 replications.

^bLeast square means within a row followed by like letters do not differ ($P > 0.05$).

weighing 2.2-2.6 kg and reported the rate of energy consumption of microwaving to be $2 \frac{2}{3}$ times faster than the conventional cooking method.

The standing time or period of post-oven temperature rise for the roasts cooked in the conventional and convection ovens ranged from 1 to 9 min. The post-oven temperature rise of 1°C was observed in only one of the six roasts cooked conventionally and in three of the six roasts cooked in the convection oven. The mean standing time for the microwaved roasts was 15.4 min (range 10-17 min) with a mean 5.3°C (range $2\text{-}17^{\circ}\text{C}$) post-oven temperature rise. These results are similar to that reported by Bowers and Heier (1970) who microwaved eight turkeys to 75°C . A mean 14.3 min standing time and a mean 10.2°C post-oven temperature rise was reported. A greater post-oven temperature rise is observed in microwaved turkey than in turkey cooked in other ovens because the internal cooking continues after removal from the oven.

II. Energy Comparison

The results of the energy comparison of the three ovens are presented in Tables 2 and 3. The total energy consumed, measured in whr, and the whr/kg differed significantly ($P < 0.05$) for all three ovens. The convection oven consumed the most energy, followed by the conventional oven and the microwave oven (Tables 2 and 3). The same differences were seen when energy consumed was expressed on a whr/kg basis (Tables 2 and 3). On a whr/kg basis, the convection oven required 81% more energy, and the microwave oven required 77% less energy than did the conventional oven. Korschgen et al. (1980) reported a 27% energy

saving with microwaving when compared to the conventional oven on a whr/kg basis. Cornforth et al. (1982) also reported microwaved frozen turkey to cook faster and require less energy than conventionally cooked frozen turkey.

The cooking power or total energy needed to cook the turkey was greater in the convection oven than in the conventional and microwave ovens, which did not differ. The relative efficiency of the conventional oven was lower ($P < 0.05$) than that of the convection and microwave ovens. Although the relative efficiency of the convection oven was more favorable than that of the conventional oven, it required more total energy to operate. The microwave oven was the most efficient and required the least amount of total energy to operate.

The construction of the conventional and convection ovens most likely influenced their performance. The conventional, self-cleaning oven was built with more insulation than was the convection oven.

Few empirical studies have been done concerning the relative efficiencies of the three ovens. A conventional oven was more efficient (39%) in cooking beef rib roasts than was a microwave (38%) in a study by Korschgen et al. (1980). In the same study the microwave cooking required less energy than did conventional cooking.

Collison (1980) theorized that the energy utilization of an oven during cooking includes environmental losses, open-door losses, energy absorbed by the food dish, and the energy absorbed by the food (Table 4). The performances of the conventional and convection ovens in the present study were evaluated in terms of Collison's theory. The microwave's

Table 4--Collison's analysis of energy utilization for the conventional and convection ovens^a

	Conventional oven ^b	Convection oven ^b
Environment losses, %	67.55b	61.87b
Open door losses, %	6.50b	2.10b
Energy absorbed by dish, %	0.0015b	0.0001b
Energy absorbed by food, %	25.52b	36.00b

^aMean within a row followed by like letters do not differ (P > 0.05).

^bMean of six values.

performance was not evaluated since its principle of operation is different than that of the other ovens. There were no significant differences found for the two ovens' performances when evaluated by Collison's theory. The placement of the thermocouples prevented the door of the convection oven from closing completely, which could have influenced its performance.

The time required for preheating the two ovens did differ significantly ($P < 0.5$) with the conventional oven requiring more time to preheat than the convection oven (Table 5). The energy required to preheat the two ovens did not differ significantly.

III. Objective Evaluations of Turkey Quality

Cooking loss percentages, based on weight of uncooked roast, were evaluated as evaporative, drip, and total (Tables 6 and 7). The evaporative losses were not significantly different (Table 7). The drip losses were greater ($P < 0.05$) for the microwaved roasts than for the roasts cooked in the other ovens. Even though there were differences in drip loss, total cooking losses did not differ.

Bowers and Heier (1970) found gas-heated turkey roasts to have less total cooking losses than microwaved roasts. The drip loss, in contrast to the present results, was less for the microwaved roasts than for the gas-heated roasts. Cipra et al. (1971) reported breast halves cooked in the microwave had higher evaporative and total cooking losses than did breast halves cooked in a rotary gas oven. Drip losses were greater for the gas-heated meat than for the microwaved meat. It

Table 5--Time and wattage required to preheat conventional and convection ovens^{a,b}

	Conventional oven	Convection oven
Time, min	6.97a	5.15a
Energy, whr	0.3801a	0.1444b

^aMean of six values.

^bMeans within a row followed by like letters do not differ ($P > 0.05$).

Table 6--Mean square values and significance of F ratios for objective tests of turkey roasts cooked in the conventional, convection, and microwave ovens

Source of variation	df	Mean squares				
		Evaporative losses	Drip losses	Total cooking losses	Fat free dry weight	Expressible moisture index
Total	17					
Treatment	2	25.84	25.56 ^{***}	36.93 [*]	16.11 ^{***}	0.009
Block	8	14.37	0.40	14.94	11.47 ^{***}	0.019 ^{**}
Error	7	12.68	0.82	8.73	1.33	0.006

* P < 0.05.

** P < 0.01.

*** P < 0.001.

Table 7--Least square means of objective test for turkey roasts cooked in the conventional, convection, and microwave ovens^a

	Oven		
	Conventional	Convection	Microwave
Evaporative loss, % ^b	23.76d ± 1.61	27.90d ± 1.61	24.94d ± 1.61
Drip loss, % ^b	2.10d ± 0.41	1.30d ± 0.41	5.03e ± 0.41
Total cooking loss, % ^b	25.81d ± 1.33	29.19d ± 1.33	29.97d ± 1.33
Fat-free dry weight, % ^c	30.42d ± 0.36	31.53de ± 0.36	31.88e ± 0.36
Expressible moisture index ^d	0.71d ± 0.02	0.72d ± 0.02	0.73d ± 0.02

^aLeast square means in a row followed by like letters do not differ (P > 0.05).

^bLeast square mean and standard error of 6 values.

^cLeast square mean and standard error of 2 values for each of 6 breasts.

^dLeast square mean and standard error of 3 values for each of 6 breasts.

should be noted that the microwave ovens used in these earlier studies did not have variable power levels. A higher power level was probably used to cook the turkey than was used in the present study. Voris and Van Duyne (1979), who used a lower power level, reported results similar to the present results for mean drip loss. Microwaved top round beef roasts weighing 3.4-4.7 pounds had greater mean drip loss than did those conventionally cooked.

The percentages fat-free dry weight of the conventional roasts ($P < 0.05$) were less than those of the microwaved roasts. The roasts heated in the convection oven did not differ significantly from the roasts cooked in the other two ovens in fat-free dry weight percentage either. Voris and Van Duyne (1979) also found no significant differences in mean percent moisture and fat contents of top round beef roasts cooked in the microwave and conventional ovens.

The expressible moisture index did not differ significantly due to oven treatment. Cipra et al. (1971), however, found lower expressible moisture in microwaved turkey than in conventionally cooked turkey.

IV. Shear Values

The shear values of the conventional roasts did not differ from the shear values of the convection and microwaved roasts (Tables 8 and 9). The convection oven roasts had lower ($P < 0.05$) shear values than did those heated in the microwave. Cipra et al. (1971) also reported no significant differences in shear values for turkey breast halves cooked in the microwave and conventional gas ovens. As in the present

Table 8--Mean square values and significance of F ratios for shear values for turkey roasts cooked in the conventional, convection, and microwave ovens

Source of variation	df	Mean squares
Total	143	
Treatment	2	16.71 ^{***}
Block	8	10.80 ^{***}
Error	133	2.18

^{***} $P < 0.001$.

Table 9--Least square means for shear values of turkey roasts cooked in the conventional, convection, and microwave ovens^{a,b}

	Oven		
	Conventional	Convection	Microwave
Shear value, kg	3.88bc $\pm$ 0.24	3.62b $\pm$ 0.24	4.39c $\pm$ 0.24

^aLeast square means within a row followed by like letters do not differ ($P > 0.05$).

^bLeast square mean and standard error of 8 values for each of 6 roasts.

study, Cornforth et al. (1982) reported that microwaved turkey had higher shear values than conventionally cooked turkey. The toughness was attributed to cooking the turkey breast to a higher internal temperature in the microwave oven than in the conventional oven.

V. Riboflavin Analysis

On a wet basis, the riboflavin content of the convection oven roasts was significantly different ($P < 0.05$) from that of the raw roasts (Tables 10 and 11). The convection oven roasts had less riboflavin than the other roasts. On a dry basis the conventional and convection roasts contained less ($P < 0.05$) riboflavin than the raw meat; the microwaved roasts did not differ in riboflavin content from the raw meat. However, the microwaved roasts did not differ significantly from the other cooked roasts. Bowers and Fryer (1972) analyzed microwaved turkey and turkey cooked in a gas oven for riboflavin retention. On a wet basis, the type of oven did not influence the retention. On a moisture and fat-free basis, the microwaved turkey retained less riboflavin than did the conventionally cooked turkeys. The power level of Bowers and Fryer (1972) was probably higher than the level used in the present study. The reduced power level probably favored increased retention of riboflavin in the present study.

VI. Experienced Sensory Panel

Differences in the scores reported by the experienced sensory panelists were attributable to treatment, block, and judge (Tables 12 and 13). There were no significant differences for doneness, appearance,

Table 10--Mean square values and significance of F ratios for riboflavin retention, wet and dry basis, of turkey roasts cooked in conventional, convection, and microwave ovens

Source of variation	df	Mean square	
		Wet basis	Dry basis
Total	80		
Treatment	3	.00001848	.00062723 ^{**}
Block	8	.00011700 ^{***}	.00129300 ^{***}
Error	69	.00001262	.00012971

^{**} P < 0.01.

^{***} P < 0.001.

Table 11--Least square means for riboflavin retention, wet and dry basis, for turkey roasts cooked in conventional, convection, and microwave ovens^{a,b}

	Riboflavin, ug/g			
	Conventional oven	Convection oven	Microwave oven	Raw
Wet basis	0.0046bc ± 0.00089	0.0041b ± 0.00089	0.0062bc ± 0.00089	0.0064c ± 0.00089
Dry basis	0.0151b ± 0.003	0.0125b ± 0.003	0.0187bc ± 0.003	0.0252c ± 0.003

^aLeast square means and standard error of 9 values for each of 6 roasts.

^bLeast square means within a row followed by like letters do not differ ($P > 0.05$).

Table 12--Mean square values and significance of F ratios for experienced sensory panel

Source of variation	df	Mean square					
		Doneness	Appearance	Juiciness	Flavor	Tenderness	Acceptability
Total	163						
Treatment (T)	2	26.67	43.86	98.61	29.88	77.00*	10.63
Block (B)	8	10.02*	16.80*	11.44	8.94	2.16	4.76
T x B ^a	7	8.65	13.06	33.04**	11.38	12.14	9.53
Panelist (P)	8	10.10*	23.71**	33.81**	14.17	24.88*	17.21*
T x P	16	4.70	9.13	16.50	17.21*	13.44	4.50
Error	122	4.33	7.05	9.65	9.04	10.32	8.04

^aError term for treatment.

* P < 0.05.

** P < 0.01.

Table 13--Least square means due to treatment for the experienced sensory panel^{a,b}

	Oven		
	Conventional	Convection	Microwave
Doneness ^c	6.6b ± 0.3	8.6b ± 0.3	8.6b ± 0.2
Appearance ^d	9.8b ± 0.4	9.4b ± 0.4	8.1b ± 0.4
Juiciness ^e	9.6b ± 0.5	7.0b ± 0.5	5.9b ± 0.5
Flavor ^f	7.5b ± 0.5	7.9b ± 0.5	8.9b ± 0.5
Tenderness ^g	10.5b ± 0.5	9.8b ± 0.5	7.8b ± 0.5
Acceptability ^h	10.0b ± 0.4	9.4b ± 0.4	8.8b ± 0.4

^aLeast square means and standard error of 9 values for 6 evaluations.

^bLeast square means within a row followed by like letters do not differ ($P > 0.05$).

^c1=very underdone; 15=very overdone.

^d1=very undesirable; 15=very desirable.

^e1=very dry; 15=very juicy.

^f1=no turkey flavor; 15=very intense turkey flavor.

^g1=very tough; 15=very tender.

^h1=not at all acceptable; 15=very acceptable.

juiciness, and overall acceptability attributable to oven treatment. The samples from all three ovens were rated in the middle of the scale for doneness. The scores for appearance were on the upper end of the scale, suggesting that all of the turkey samples were desirable with respect to appearance. The juiciness scores also were on the upper end of the scale, indicating that all of the turkey samples were juicy. The flavor scores were high indicating that all of the samples had intense turkey flavor. The overall acceptability scores were high on the scale suggesting that all of the samples were acceptable. The only attribute that was significantly different due to oven treatment was tenderness. The microwaved samples were tougher ($P < 0.05$) than were the samples from the other ovens. Bowers and Heier (1970) evaluated turkey samples for doneness, tenderness, and juiciness with a 5-member experienced panel. No significant differences were attributed to the oven treatments for the sensory parameters evaluated.

Several block and panelist differences were found in the present study (Table 12). These differences were complex and reflect the differences among the turkeys and the differences among the perceptions of the panelists (Appendix J; Tables 15 and 16).

VII. Consumer Sensory Panel

The consumer panelists responded to a questionnaire, the results of which were used to characterize the panel. The results are summarized in Appendix K. The majority of the panelists were women (75%). Their ages were mainly between 18 and 34 years of age. Most of the panelists

lived in single family dwellings (50%). The main source of meals was the home with food preparation done by the panelist or someone else in the home. Turkey was eaten by most panelists four times a year (29%). Turkey was cooked in the home by 86% of the panelists and in an electric conventional oven 92% of the time. Of the panelists, 100% owned a conventional oven, 26% owned a microwave, and 4% owned a convection oven. Of those who owned microwave and convection ovens, one panelist cooked turkey in a conventional-microwave oven combination.

Data from the consumer sensory panel are summarized in Table 14. Results of the total consumer sensory panel indicated no differences in preference attributable to treatment. Neither men nor women found differences, and differences within blocks were not found. Therefore, turkey roasts cooked in the conventional, convection, and microwave ovens were considered to be equally acceptable by a 72-member consumer panel. Many of the consumer panelists commented that the samples were similar in acceptability and differences were not obvious.

Table 14--Rank sums for acceptability of turkey samples cooked in conventional, convection, and microwave ovens as evaluated by a consumer panel

	Rank sum		
	Conventional oven	Convection oven	Microwave oven
Total panel ^a	145	144	143
Females ^b	111	107	106
Males ^c	34	37	37
Block 10 ^a	----	107	109
11 ^a	107	109	---
12 ^a	110	---	106

^a_n = 72.

^b_n = 54.

^c_n = 18.

CHAPTER V

SUMMARY AND CONCLUSIONS

An investigation was undertaken to compare the energy consumption and efficiency of the conventional, convection, and microwave ovens as boneless turkey roasts were cooked. The quality of the cooked turkey was evaluated by using objective and sensory tests.

The energy comparison showed the microwave oven cooked the roasts more quickly ($P < 0.05$) than did the other ovens. The rate of energy consumption also was faster for the microwave. The convection oven had the greatest ($P < 0.05$) cooking power of the ovens. The convection oven consumed the most total energy ($P < 0.05$), followed by the conventional and microwave ovens. The convection and microwave ovens had higher ($P < 0.05$) relative efficiencies than did the conventional oven.

When comparing the energy utilization of the conventional and convection ovens, there were no differences in environmental and open door losses or in the energy absorbed by the dish and the roasts. The time needed to preheat the conventional oven was more than that of the convection oven, however, there was no difference in the energy necessary to preheat the two ovens.

The oven temperature and heat penetration of the roasts were monitored. The temperature of the conventional oven fluctuated less than did that of the convection oven. The heat penetration curves for the roasts cooked in the conventional and convection ovens were similar and rose in a gradual pattern. The heating pattern in the microwaved roasts

was more rapid than in the other roasts. Longer standing times and greater post-oven temperature rises were observed with the microwaved roasts than with the other roasts.

Evaporative and total cooking losses were not significantly different for the three treatments. Drip losses were greater ($P < 0.05$) for the microwaved roasts than for the roasts cooked by the other treatments. The microwave oven roasts had greater percentages of fat-free dry weight than did the conventional roasts. The expressible moisture index did not differ ($P < 0.05$) due to the cooking process. Shear values for conventionally heated roasts were the same as those for roasts heated in convection and microwave ovens. Roasts heated in the convection oven had lower shear values than those heated in the microwave oven.

Riboflavin retention was the same for the oven treatments on a wet basis. The convection oven samples contain less riboflavin ($P < 0.05$) than did the raw samples. On a dry basis, the riboflavin content did not differ among the cooking methods. The microwaved samples were similar in retention to the raw samples.

The experienced panelists found no differences for doneness, appearance, juiciness, flavor, and overall acceptability among turkey roasts heated in three ovens. The microwaved samples, however, were considered to be tougher than were the other samples. The interactions of treatment and block and treatment and panelist were statistically evaluated and complex differences were identified.

A 72-member consumer panel did not find any differences in the overall acceptability of the turkey samples cooked in the three ovens.

The results of the energy comparison show the convection and microwave ovens to be more energy efficient in cooking boneless turkey roasts than the conventional oven. Even though the convection oven was more energy efficient than the conventional oven, it required more energy and time to cook the roasts. In terms of energy conservation the convection oven did not offer any advantage over the conventional oven for cooking turkey roasts. The microwave oven was the most energy efficient of the three ovens and used significantly less total energy to cook the roasts. Therefore, in this study the microwave oven was found to be the most energy sparing of the three ovens used to cook turkey roasts.

The different methods of heating in the ovens did have an effect upon the quality of the cooked turkey. There were differences in the results of the objective tests that can be attributed to the cooking method. However, there were no extreme differences in the results, and all three ovens cooked roasts which were generally acceptable products. The results of the two sensory panels also confirm that the conventional, convection, and microwave ovens produce acceptable turkey roasts.

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APPENDIXES

APPENDIX A

I. Determination of efficiency and cooking power of microwave oven for cooking water loads (Gerling, 1978; Van Zante, 1973).

To determine the efficiency with a water load:

1. Plug in watt-meter and oven.
2. Weigh out 50, 100, 275, 500, 2,000 g of water into appropriately sized beakers.
3. Weigh out 1% by weight of salt for each beaker.
4. Record initial temperature.
5. Stir with a wooden spoon before and after heating.
6. Heat in oven in order to cause a 25-degree temperature rise.
7. Measure temperature immediately after stirring.
8. Repeat three times for each load.
9. Repeat for different positions in the oven, at different times of day, and at the three power levels.
10. Calculate sensible heat (H)
$$H = m \times c \times t$$

m = mass, g

c = specific heat in cal/gram/°C

t = rise in liquid in °C
11. Multiple H x 1.16222 x 10⁻⁶ to convert from small calories to kwh.
12. Output = $\frac{\text{Calculated or measured kwh}}{\text{time to cook}} \times 3600 \text{ sec} \times \frac{10^3 \text{ W}}{\text{kwh}} = \text{watts}$

II. Determination of cooking power and relative efficiency of microwave oven for cooking turkey roasts.

1. Sensible heat of water in whr = $m \times c \times \Delta t \times 1.16222 \times 10^{-3}$

2. Determine rate of energy consumption.

$$\frac{\text{whr}}{\text{min}} = \frac{\text{Total watt hour for water load} - \text{sensible heat, whr}}{\text{time to cook water, min}}$$

3. Cooking power =

$$\frac{\text{whr to cook turkey}}{\text{rate of energy consumption}} = \left(\frac{\text{length of time to cook turkey}}{\text{rate of energy consumption}} \right)$$

4. Relative efficiency (%) = $\frac{\text{cooking power}}{\text{whr to cook turkey}} \times 100$

APPENDIX B

I. Rotating Disc Method for Determination of Wattage of Conventional and Convection Ovens (Leutzelschwab, 1980; Korschgen et al., 1980)

Procedure:

1. Attach watt-meter to oven.
2. Turn on oven. Time the revolution of the disc on the watt-meter. Use the black indicator mark on the disc for a signal to start and stop timing.
3. Determine oven wattage by multiplying Kh value (taken from meter) by 3,600 (number of seconds in an hour) and divide by the rotating time of the disc.
4. Time for one disc revolution = _____ seconds; wattage = $3,600 \times \frac{\text{Kh value}}{\text{seconds for one disc revolution}}$ = _____ watts of bake element.

II. Determination of Cooking Power and Relative Efficiency of Conventional and Convection Ovens

1. Operate oven without a load and record watthours and time.
2. Determine rate of energy consumption

$$\frac{\text{whr}}{\text{min}} = \frac{\text{total whr consumed}}{\text{time of test}}$$

3. Calculate cooking power (energy for cooking)

Cooking power =

$$\frac{\text{whr to cook turkey}}{\text{min}} - \left(\frac{\text{rate of energy consumption}}{\text{min}} \times \frac{\text{length of time to cook turkey}}{\text{min}} \right)$$

$$4. \text{ Relative efficiency (\%)} = \frac{\text{cooking power}}{\text{whr to cook turkey}} \times 100$$

APPENDIX C

Cooking Loss Data Collection and Determination
(Campbell et al., 1979)

Oven _____

A. Before cooking

1. weight of pan, g _____
2. weight of turkey, g _____
3. weight of pan and turkey, g _____

B. On removal from oven

1. weight of pan, turkey, drip, g _____
2. weight of pan and drip, g _____

C. Losses

1. loss due to evaporation, g (A3 - B1) _____
2. loss due to drip, g (B2 - A1) _____
3. total cooking loss, g (C1 + C2) _____

D. Losses as percentages of weight of uncooked roast

1. due to evaporation, % $(\frac{100 \times C1}{A_2})$
2. due to drip, % $(\frac{100 \times C2}{A_2})$
3. total loss, % (D1 + D2)

APPENDIX D

Vitamin Assay (AOAC, 1974; Ang and Moseley, 1980)

Extraction

The turkey samples were ground. Five-g of the ground sample were hydrolyzed with 0.1 N HCl (60 ml) at 121°C in an autoclave for 30 min. The pH of the solution was adjusted to 4.0-4.5 with 2 M sodium acetate (5 ml). Four ml of an enzyme solution of 5% Takadiastase and 10% papain were added to the sample. The sample was incubated at 42-45°C for 2.5-3 hr. Then 50% trichloroacetic acid (2 ml) was added and the sample was heated for 5 min on a steam bath. The sample volume was brought to 100 ml and it then was filtered through Whatman No. 40 filter paper. The sample was stored at 4°C until the next day. All sample solutions were worked with under subdued light.

Standard Curves

Riboflavin (100 mg/ml) standard stock solutions were made with 0.01 N HCl. Intermediate standard solutions (20.8 ug/ml) were prepared from the stock solutions.

In order to derive a standard curve aliquots (1-4 ml) of riboflavin intermediate standard solution was treated the same as the meat sample (see Riboflavin Determination).

The peak height, cm, was plotted against the micrograms of vitamin per injection.

Riboflavin Determination

Sample filtrate (10 ml) was pipetted into a 5-ml beaker and the pH adjusted to 10-12 with 10% NaOH. The solution was positioned 10 cm under a UV lamp for 30 min. One ml of glacial acetic acid was added to the beaker immediately after irradiation. The solution then was placed into a 60-ml separatory funnel and extracted with chloroform (10 ml). Anhydrous sodium sulfate was used to dry the chloroform extract. Injections of the aliquots of the chloroform extract (20 μ L) were injected.

High Pressure Liquid Chromatography

The liquid chromatograph used was a Waters Associates Model 6000A with a U6K Sepetumless injector device (Waters Associates, Inc., Milford, Mass.) equipped with a u-Porasil column. A solvent mixture of 90% chloroform and 10% methanol was used as the mobile phase. The flow rate was 1.0 ml/min. A fluorescence detector (Model 420-C and 420-E) fitted with a 280 nm excitation filter and a 425-nm cut off emission filter was used for detection. A 20- μ L sample injection syringe (Hamilton, Inc.) was used. Chromatograms were recorded on an Omniscribe recorder (Houston Instrument, Austin, Texas) with a chart speed of 0.2 in/min.

Riboflavin was identified on the basis of retention time by comparison with the standard. Vitamin content of the samples were calculated from peak height ratios using external standards.

Recovery Studies

One ml of the intermediate standard was added to the meat sample solution before the enzyme hydrolysis. Five replications were done.

APPENDIX E

SENSORY EVALUATION SCORE CARD^a

Name _____ Date _____

Please make a vertical line on each horizontal line to indicate your evaluation of each characteristic for this sample _____.

Look at the sample and evaluate the following characteristics.

DEGREE OF DONENESS

Very Under Done _____ Very Over Done

APPEARANCE

Very Undesirable _____ Very Desirable

Taste the sample to judge the following characteristics.

JUICINESS

Very Dry _____ Very Juicy

FLAVOR

No Turkey Flavor At All _____ Very Intense Turkey Flavor

TENDERNESS

Very Tough _____ Very Tender

OVERALL ACCEPTABILITY

Not At All Acceptable _____ Very Acceptable

MPP/nmd
NFS
3/82

^aOn original, lines were 15 cm in length.

APPENDIX F



NUTRITION
AND FOOD
SCIENCES

TO: College of Home Economics Faculty, Graduate Students, and Staff

FROM: Marsha McNeil, Graduate Student, NFS *mm*
Marjorie P. Penfield, Associate Professor, NFS *mpp*

DATE: June 16, 1982

RE: Volunteers for a Sensory Evaluation Panel

We currently are conducting a research project on factors that affect the eating quality of turkey. We are looking for 75 volunteers to help us with the last phase of the project. On Wednesday, June 30, we will be conducting a sensory evaluation panel in the Sensory Lab (Room 18 of the Home Economics Building). Volunteer panelists will be asked to complete a short questionnaire on their use of turkey and to taste several samples of turkey. The session should take no longer than 15 minutes.

Your participation in this project would be greatly appreciated. If you are willing to participate, please return the form below to M. Penfield, NFS Department. Please indicate the times that you would be available on the 30th. We will be testing from 9:00 to 11:00 a.m. and from 1:30 to 4:00 p.m. We will notify you of the time that you should come after all panelists are scheduled.

We hope that you will be willing to participate in this project.

Please supply the information requested and return to M. Penfield, NFS Dept., by June 25.

Name: _____

Campus address _____

Campus phone _____

Please check all times that you could
come on Wednesday, June 30.

9:00 a.m. _____ 1:30 p.m. _____

9:30 a.m. _____ 2:00 p.m. _____

10:00 a.m. _____ 2:30 p.m. _____

10:30 a.m. _____ 3:00 p.m. _____

11:00 a.m. _____ 3:30 p.m. _____

4:00 p.m. _____

THE UNIVERSITY
OF TENNESSEE
COLLEGE OF
HOME ECONOMICS
KNOXVILLE 37996-1900
615 974 - 5445
615 974 - 3491

APPENDIX G



NUTRITION
AND FOOD
SCIENCES

TO: _____

FROM: Marsha McNeil, Graduate Student, NFS
Marjorie P. Penfield, Associate Professor, NFS

DATE: June 25, 1982

RE: Your participation in the sensory evaluation panel on turkey.

Thank you for volunteering to participate in the sensory panel on turkey.
Please come to Room 18 of the Home Economics Building on June 30 at the time
listed below.

Time for sensory panel: _____

If you find that you cannot come at the above time, please call us. Thank
you.

THE UNIVERSITY
OF TENNESSEE
COLLEGE OF
HOME ECONOMICS
KNOXVILLE 37996-1900
615 · 974 · 5445
615 · 974 · 3491

APPENDIX H

THANK YOU FOR AGREEING TO PARTICIPATE
IN THIS SENSORY EVALUATION STUDY.

You will receive three sets of samples to test today. The samples will be followed by a short questionnaire. When you are ready for your first set of samples open the hatch.

When you finish with the first set, place the tray in the hatch and close it. Your second set then will be placed in the hatch for you. Repeat this process for the second and third sets.

When you return the third set the questionnaire will be placed in the hatch for you to complete. Place the questionnaire in the hatch when you have answered all questions.

APPENDIX I

DEPARTMENT OF NUTRITION AND FOOD SCIENCES

Turkey Preference Scorecard

Panelist number _____

Set number _____

On your plate you have two samples of turkey. Taste the sample on the left first. Rinse your mouth with water. Taste the sample on the right. Indicate which of the two samples is more acceptable to you by placing a check in the appropriate blank below.

SAMPLE CODE

SAMPLE PREFERRED

Comments:

APPENDIX J

Table 15--Least square means due to block for the experienced sensory panel^{a,b}

Block	Doneness	Appearance	Juiciness	Flavor	Tenderness	Acceptability
1	9.1b ± 0.5	7.9b ± 0.7	6.5b ± 0.8	8.1b ± 0.8	9.5b ± 0.8	9.1b ± 0.7
2	6.8c ± 0.5	7.6b ± 0.7	9.0b ± 0.8	7.7b ± 0.8	9.1b ± 0.8	9.4b ± 0.7
3	7.7bc± 0.5	8.4bc± 0.7	6.3b ± 0.8	9.4b ± 0.8	9.2b ± 0.8	8.7b ± 0.7
4	8.6b ± 0.5	9.8c ± 0.7	7.7b ± 0.8	7.5b ± 0.8	9.7b ± 0.8	8.8b ± 0.7
5	6.8c ± 0.5	10.0c ± 0.7	8.6b ± 0.8	7.3b ± 0.8	9.5b ± 0.8	9.5b ± 0.7
6	8.4b ± 0.5	8.6c ± 0.7	7.4b ± 0.8	8.2b ± 0.8	8.7b ± 0.8	9.1b ± 0.7
7	7.7bc± 0.5	9.8c ± 0.7	7.3b ± 0.8	9.2b ± 0.7	10.0b ± 0.8	10.0b ± 0.7
8	8.4b ± 0.5	9.9c ± 0.7	7.3b ± 0.8	8.3b ± 0.7	9.3b ± 0.8	10.3b ± 0.7
9	7.8bc± 0.5	9.8c ± 0.7	7.2b ± 0.8	7.4b ± 0.7	9.4b ± 0.8	9.6b ± 0.7

^aLeast square mean and standard error of 9 judges for 6 evaluations.

^bLeast square means within a column followed by like letters do not differ (P > 0.05).

Table 16--Least square means due to judge for the experienced sensory panel^{a,b}

Judge	Doneness	Appearance	Juiciness	Flavor	Tenderness	Acceptability
1	9.1b ± 0.5	9.3cde ± 0.7	6.4bd ± 0.8	7.0b ± 0.7	11.2b ± 0.8	9.7cd ± 0.7
2	9.0be ± 0.5	10.4bc ± 0.7	8.2c ± 0.8	9.1b ± 0.7	9.9cd ± 0.8	9.7cd ± 0.7
3	7.2d ± 0.5	8.7cde ± 0.6	5.4d ± 0.8	9.1b ± 0.7	9.4bcd ± 0.7	10.5bc ± 0.6
4	8.1bde ± 0.5	8.0de ± 0.7	6.3bd ± 0.8	7.4b ± 0.7	7.8c ± 0.7	8.6d ± 0.7
5	7.9bde ± 0.5	8.7cde ± 0.7	7.9bc ± 0.8	9.3b ± 0.7	8.9cd ± 0.8	9.3cd ± 0.7
6	6.8d ± 0.5	7.7e ± 0.7	7.7c ± 0.8	8.1b ± 0.7	9.3cd ± 0.8	8.5d ± 0.7
7	7.6de ± 0.5	8.3de ± 0.7	7.8c ± 0.8	8.4b ± 0.7	7.9c ± 0.8	8.8cd ± 0.7
8	7.8bde ± 0.5	9.7bcd ± 0.7	7.6b ± 0.8	7.2b ± 0.7	8.9cd ± 0.8	8.3d ± 0.7
9	7.7de ± 0.5	11.2b ± 0.7	10.1c ± 0.8	7.6b ± 0.7	10.9bd ± 0.8	11.2b ± 0.7

^aLeast square mean and standard error of 9 values for 6 evaluations.

^bLeast square means within a column followed by like letters do not differ ($P > 0.05$).

APPENDIX K

SUMMARY OF RESPONSES TO TURKEY QUESTIONNAIRE

Sex:

18 Male
54 Female

Age:

1 Less than 18 years
23 18-24 years
23 25-34 years
16 35-44 years
9 Over 45 years

Type of residence:

36 Single-family dwelling
29 Multiple-family dwelling (duplex, apartment, townhouse)
1 Mobile home
3 Dormitory, fraternity
3 Rented room
0 Other, please specify _____

What is the main source of your meals (please check only one):

1 Cafeteria
62 Home (prepared by yourself or someone else)
0 Home of friends and relatives
7 Snack shops/fast-food restaurants
2 Full-service restaurants
0 Other, please specify _____

Check the time period which best describes the frequency with which you eat turkey. (Please check only one.)

1 One or more times per week
12 One or two times per month
17 Six times per year
21 Four times per year
20 Two times per year
1 Never

Do you or does someone else cook turkey in your home?

62 YES
10 NO

If yes, what type of oven is most often used to cook the turkey?

57 Conventional electric
4 Conventional gas
0 Convection
0 Microwave
1 Other, please specify _____

Do you have a conventional gas or electric oven in your home?

72 YES
0 NO

Do you have a microwave oven in your home?

19 YES
53 NO

Do you have a convection oven in your home?

3 YES
69 NO

VITA

Marsha Anne McNeil was born in Knoxville, Tennessee, on August 14, 1958. She attended Mooreland Heights Elementary School and Young High School, both in Knoxville. In 1976, she began her college career at Salem College in Winston-Salem, North Carolina. In 1977, she entered The University of Tennessee, Knoxville, and graduated in 1980 with a Bachelor of Science in Home Economics with a major in Food Science. She began working toward a Master of Science degree in Food Science in 1980 at The University of Tennessee, Knoxville, and graduated in August 1982. During her graduate studies, she was a graduate research assistant. The author is a member of Phi Tau Sigma, Omicron Nu, and the Institute of Food Technologists.