VARIABLE POWER AND MICROWAVE TECHNOLOGY AND THE QUALITY OF SELECTED FOODS

by

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ABSTRACT

Custard, cake, beef patties, potatoes, frozen broccoli, and frozen chicken pot pie were cooked or heated at 100% (High), 70% (Medium High) or 50% (Medium) power in a transformer microwave oven or an inverter microwave oven. Separate batches of each food were prepared for instrumental and sensory evaluation.

Cooking at 50% (Medium) power produced less smooth custards and broccoli woodier in texture than at other power levels. More moist potatoes, harder in texture, and beef patties more tender at center resulted from cooking at 70% (Medium High) power. Cooking at 100% (High) power produced less set custards and less consistent temperature in pot pie, along with more tender cakes, juicier beef patties, and potatoes whiter in color.

Within particular foods, there were also significant differences by oven type. In the inverter oven, at 50% (Medium) power, custards were more set and less tender, while broccoli had a fresher flavor and potatoes a softer texture than the same foods cooked in a transformer

microwave. At 70% (Medium High) power, the transformer microwave produced a potato less white than that cooked in the inverter oven. High (100%) power inverter-microwaved custard was less creamy than its transformer-cooked counterpart; broccoli and cake cooked in the inverter microwave at this power level had a fresher flavor and a weaker chocolate flavor, respectively.

There were not overall differences in quality in foods cooked at different power levels in the two oven types. However, for certain foods, there were advantages for the selected cooking conditions.

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DEDICATION

This paper is dedicated to

John Anthony Nettleton,

provider of the catalyst whereby I went to graduate school.

"Did you ever ask yourself the question," Lady Muriel began, à propos of nothing, "what is the chief advantage of being a Man instead of a Dog?"

"No, indeed," I said: "but I think there are advantages on the Dog's side of the question as well."

"No doubt," she replied... "but, on Man's side, the chief advantage seems to me to consist in having pockets!"

Lewis Carroll, *Sylvie and Bruno*

"You k'n hide de fire, but what're you gwine ter do wid de smoke?"

Uncle Remus

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CHAPTER I

INTRODUCTION

Microwave ovens were introduced for home use in the United States in the mid-1950's (Pickett, Arnold, and Ketterer, 1985). From an initial uncertain beginning, acceptance has grown; today, more than 80% of the households in the United States have a microwave oven (Appliance, 1990). Manufacturers have responded to consumer acceptance of microwave ovens with a proliferation of oven types, styles, and capabilities.

Microwave ovens are now available with a variety of features, cavity sizes, and output wattages. The consumer who wishes to purchase a microwave oven is therefore faced with many choices. As a general rule, smaller or compact microwave ovens have lower maximum output wattage, but they can be space-saving. Larger ovens use more counter area but have a higher maximum output wattage and more features. The consumer would do well to decide in advance how the microwave oven purchased will be used. If the primary use will be reheating small quantities of food or warming baby food, an oven with lower maximum output wattage may be sufficient as well as more economical. If, however, the oven will be used for more cooking and heating tasks, or in oven will be used for more cooking and heating tasks, or in a large household, more features and a higher output wattage will be desirable.

A common feature of microwave ovens is variable power. That is, output wattage can be adjusted downward from the maximum level. This study employed three power levels: 100% (High), 70% (Medium High), and 50% (Medium). Food quality was assessed after cooking for each level.

Output wattage in this study was either of cycled delivery for variable power (the most common type of variable power in microwave ovens in the U. S.) in the transformer oven or continuous delivery in the inverter oven. A randomized incomplete block design was used to test the effect of output wattage level and continuous or cycled wattage delivery on six foods: custard, chocolate cake, ground beef patties, potato, frozen broccoli, and frozen chicken pot pie. Foods selected represented different types of food systems. Each food was prepared twice at the power levels previously stated, using each microwave technology for both sensory and instrumental evaluation. Instrumental evaluation measured post heating temperature rise, weight/evaporative loss during heating, and tenderness where applicable. A trained sensory panel conducted sensory evaluation on each food according to attributed that were food-type dependent.

Microwave ovens for this study were donated by the Sharp Electronics Corporation (Mahwah, New Jersey). The Sharp R3A81 and the Sharp R300A microwave ovens are of identical size and shape. Each possesses an internal carousel or turntable, so that the food revolved as it was heated. Each oven cavity has a capacity of 0.7 cubic feet with an acrylic interior; each required 120 V of electricity for operation.

The R3A81 is a cycled output wattage microwave oven of the type familiar to most consumers. Testing by the manufacturer rated this oven's maximum output wattage at 600 W. The R300A is a continuous output wattage microwave oven rated at 620 W maximum according to manufacturer testing. The control microwave for this study was the R3A81.

Justification

The purpose of this research was to determine the effect of differing output wattage, as controlled by power level setting, on food quality. A second purpose was to determine heated/cooked food quality by oven type.

Many foods may be cooked or heated in one microwave oven. The consumer wants to achieve consistently good results when heating or cooking numerous food systems or system combinations. If a food overcooks or is otherwise lessened in acceptability at a particular power level, a consumer will not utilize the microwave oven to prepare that food unless alternate instructions are found. Manufacturers and consumers may be able to modify cooking or heating instructions based on the results of the selected food systems of this study.

The study also evaluated oven technology of the transformer ("cycled" variable power) or inverter (continuous, true variable power) type. The hypothesis was that method of energy production will alter the quality of certain foods when cooked or heated in one oven type as opposed to the other. The results are important to manufacturers of the ovens and to the food industry processing the foods commonly heated/cooked in the microwave oven. Consumers and authors of microwave oven cookbooks or instruction brochures will also make use of this information.

Hypotheses

H_o: There are no significant differences in quality between foods cooked or heated at one power level in a transformer microwave oven and the same power level in an inverter microwave oven.

H_o: There are no significant differences in quality between foods cooked or heated at different power levels within the same microwave oven.

CHAPTER II

REVIEW OF LITERATURE

General Operation Principles

The chief advantage of microwave ovens is the ability to heat foods quickly. In a conventional oven, energy is given to food molecules in the form of heat, transferred by air currents and radiant energy. In a microwave oven, energy is transferred by electromagnetic radiation, or microwaves (Turpin, 1989). The heat of a conventional oven warms foods by conduction, convection, and radiation. Microwave heating involves the transfer of the electromagnetic radiation, or microwaves, to a dipolar molecule, usually water. In a microwave oven, water dipoles in a food follow a rapidly oscillating electrical field. The vibration rate of dipolar water molecules affected by microwave heating will thus be extremely rapid. The temperature of the water, and so of the food, will therefore increase quickly (Ohlsson, 1983).

The quick-heating ability of microwave energy is restricted to a penetration depth of up to 7.4 cm (2.9 inches) (Harrison, 1980). Beyond that, microwave heating of the food relies upon conduction. The surface of the foods heated in a microwave oven is cooler than the temperature of the food 2-3 cm. below the surface (International Microwave Power Institute, 1987). The "negative temperature gradient" exists because the ambient temperature in a microwave oven is only slightly above room temperature. As the food heats, heat is transferred from the hotter food to the cooler air surrounding it (Decareau, 1973).

One effect of a negative temperature gradient is the lack of browning and crisping in foods prepared in a microwave oven. Decareau (1973) stated that shortened cooking times and negative temperature gradient are the chief factors in the absence of browning and crisping. The Maillard browning reaction, which results in crisp, browned baked goods and roasted meats, is a reaction between reducing sugars and certain amino acids; the reaction requires time and higher ambient temperature than that produced in a microwave oven. An intermediate product, hydroxymethylfurfural, is polymerized, producing the melanoidin pigments responsible for browning. The lack of browning in microwave ovens has also been attributed to minimal surface dehydration and the negative temperature gradient (Food Engineering, 1981). The cooking time in a microwave oven is usually insufficient to achieve necessary surface dehydration. Without dehydration, and at low ambient temperature, food surfaces will not attain the greater-than-155° C (300° F) level necessary for "carbonization or caramelization"; in other words, crisping and/or browning. Andrews (1989) concurred, but reported that lack of surface heat was due to microwave wavelength. In 1957, Fenton characterized such wavelength as "about five inches long". Andrews did not specify a length, but declared that microwaves were too long to result in the increased surface heating which would occur at higher infrared frequencies (producing shorter wavelengths).

The lack of browning and crisping limits the preparation of certain foods in a microwave oven. Other factors serve in such a decision as well. There is a definite relationship between a food's chemical composition and compatibility with microwave heating. Microwaves are attracted to foods of high moisture, sugar, sodium, and/or fat contents. Thus, these foods heat quickly, but localized overheating may be an extension of rapid warming (Food Engineering, 1983). Ohlsson (1983) found that high-moisture foods absorb less microwave energy as temperature is increased, while high-sodium foods absorb more. However, Stein (1972) disagreed, stating that high-moisture and high-fat foods were the most attractive to microwaves, regardless of temperature.

Water readily absorbs microwaves, but ice absorbs them at a much slower rate, causing uneven heating of frozen foods (Food Engineering, 1983). Five to ten percent of the water in a frozen food is in liquid form in a "concentrated solution of solutes" such as salt and sugar. This solution favors microwave absorption and heats quickly, sometimes resulting in localized overheating (Ohlsson, 1983).

Food density affects microwave energy absorption. When foods are dense, microwaves are absorbed primarily by the outer portion of the food. Heat is then transferred by conduction to the food center, but the outer surface of the food may overcook while the center is underdone (Consumer Reports,1981). A more homogenous food (ground lamb rather than a leg of lamb, for example) will cook more quickly in a microwave oven, due to a more even absorption and distribution of microwaves. The presence of bone in a meat will speed microwave cooking; the bone's minerals reflect microwaves, causing greater heating at the bone surface which is conducted to other areas of the muscle (Harrison, 1980).

Fenton (1957) noted that microwave cooking time "is a function of mass of food". Six beef patties required almost five times as long to cook as one patty; four potatoes needed twice the cooking time of one. Most sources suggest that foods such as meats and dense vegetables be cut or formed into uniform pieces to speed cooking. However, Ohlsson (1983) noted that microwaves concentrate toward the center of a sphere, so that meatballs or potatoes might be hot in the center and yet cold on the surface. For this reason, stirring, turning, or otherwise adjusting food placement is usually advised when cooking or heating in a microwave oven.

One additional phenomenon of microwave heating is "post heating temperature rise", where the temperature of the food continues to increase after the heating period. Temperature increase may be significant, especially with a greater food mass or if the cover of the cooking dish is left on (IMPI, 1987). To compensate for post heating temperature rise, foods are often removed from a microwave oven before they are fully cooked.

In 1983, Ohlsson stated that, in microwave heating, "hot and cold spots can be found in unexpected parts of the food". Microwave ovens have long been known to have uneven heating capabilities. Using a theoretical model of grapes in a viscous medium, where the grapes represent molecules of a food, Turpin (1989) noted that uneven heating is intrinsic to the operation principles of microwaves. In a conventional oven, Turpin stated, heat is applied to the outer food surface. Heat is then transferred inward by conduction, in a pattern both orderly and predictable. In a microwave oven, however, the intensity of the microwave field at a given location is dependent upon a multitude of factors. Additionally, both Turpin and Harrison (1980) affirmed that heat is generated within foods in a microwave oven. As a result, there is no orderly pattern to food heating in a microwave oven. O'Meara (1989) agreed, declaring that the localized heating in a microwave oven may be the equivalent of parts of the same food heated at 100% power, and parts at only 20% power. Turntables are included in some microwave ovens as a means of automatically adjusting food placement, to offset the "cold spots" and "hot spots".

Variable power is now available in most microwave ovens. Power can be reduced in gradients that are expressed in words (Medium High or Low, for example) or in units as small as single percentage levels. O'Meara (1989) wrote that desired effects of variable power included rapid heat conduction of transfer in the "off" time (see Technology Differences in Microwave Ovens", perhaps equalizing temperatures in food as hot regions gave up some of their heat to colder spots. The object then was a "more uniformly heated product than if it were heated continuously". O'Meara stated, however, that he had come across no published data to support this objective. Turpin (1989) disagreed; his theoretical model showed that reduced power resulted in a more uniform heating with fewer "hot spots" (although some still existed). Turpin reasoned that fewer "hot spots" would be present because food molecules receiving large amounts of energy could pass more of that energy on to colder areas before obtaining more energy from microwaves. In other words, magnetron "off" time provided a greater opportunity for heat conduction, as the "hot spots" in a food could transfer heat to the "cold spots" without being continuously charged by electromagnetic radiation energy.

Microwave Oven Technology

The magnetron tube in a microwave oven is the source of all microwave energy. When the magnetron is turned on, it produces continuous microwave energy (Pickett, Arnold, and Ketterer, 1985). In a standard microwave oven, this energy production is either at full (magnetron on) or nothing (magnetron off). Variable power in such ovens is provided by a relay contact, which allows the magnetron to be turned on for a percentage of its duty cycle, and then switches the magnetron off for the remainder of the duty cycle (Petruska, 1990). For example, at 70% power, the magnetron would be on for 70% of its duty cycle, producing continuous microwave energy. For the remaining 30% of the duty cycle, the magnetron would be switched off, allowing for no production of microwave energy. Duty cycles for magnetrons of the microwave ovens used in this study were 32 seconds (Petruska, 1990). The control standard microwave oven used in this study is called a "transformer" microwave oven, from a magnetic component called a power transformer (Petruska, 1990).

Another technology to control the emission of microwave energy from the magnetron uses an inverter power supply circuit. This circuit can control power available to the magnetron to a great degree. The magnetron in this type of microwave oven is on continuously at selected power levels from 100% down to 50%; however, with a reduction in selected power level, there is a reduction in output wattage. For example, at 70% power, the magnetron of the inverter microwave is on continuously at 70% of maximum microwave output wattage. Because the inverter circuit is capable of great control of the magnetron, power increments available on this oven are quite exact (1%). For power levels of 49% down to 1%, the inverter microwave "reverts" to transformer technology, cycling the magnetron on and off for percentages of its duty cycle (Petruska, (1990).

Custard

Custard is composed primarily of eggs and milk, and is thus a high moisture, high protein dairy product. Custard is also a delicate product, relying upon the gelation of egg proteins for the formation of a cohesive total mass (McGee, 1984).

Without the stabilizing influence of a thickener, custard may be quite susceptible to the vagaries in heating patterns within a microwave oven cavity. If overheated, the egg proteins and salts from the milk bond increasingly tightly, eventually resulting in curdling and syneresis (McGee, 1984).

Malloy (1988) cautioned against the use of lower-wattage microwave ovens in the preparation of custard because of poor and inconsistent results.

No research was found comparing custards cooked at varying power levels in a microwave oven.

Cake

High fat, high sugar, and high moisture cake batters fare best in microwave ovens. Surface browning will not occur, and the top surface may be uneven, or "cratered" (Atlanta- Southeastern Electrical Women's Round Table, 1975).

Street and Surratt (1961) investigated appearance and sensory appeal of yellow cakes prepared in a microwave oven. A cake mix was used requiring the addition of whole eggs and water, with the latter ingredient as the independent variable. As the amount of water in the batter increased, cake volume decreased, becoming similar to that of a cake baked conventionally. Surface contours of microwaved cakes were more irregular, but the cakes were more moist. Microwaved cakes were judged more tender by a sensory panel, with no significant differences in cell size, moisture level, or crumb character. Microwaved cakes lost a greater amount of weight during cooking and were less moist (as measured instrumentally) unless additional liquid was added to the batter.

These results are not in complete agreement with those published by Neuzil and Baldwin (1962). These investigators prepared yellow, white, and devil's food cake from basic recipes in conventional and microwave ovens. Cake volumes were higher in microwaved samples, but the differences were significant only for white cakes. All conventionally baked cakes were rated more tender (as measured by gelometer) than their microwaved counterparts. Microwaved cakes were again less moist than those baked conventionally, with greater percent weight loss during cooking.

Variable water amounts in microwaved cakes were not a critical factor in final surface contour, according to Martin and Tsen (1981). Water levels used ranged from 115-160% of flour weight. Minimal levels resulted in surface collapse of conventionally baked cakes, but not those cooked in a microwave oven. However, center cells in microwaved cakes were more irregular and thicker-walled than those in the centers of cakes baked conventionally.

Hill and Reagan (1982) found no significant differences in volume or moisture loss between cakes prepared in microwave and conventional ovens. Cakes were baked in an electric oven and cooked in microwave ovens both with and without turntables. A sensory panel evaluated cakes for appearance, texture, tenderness, mouthfeel, and flavor. Conventionally-baked cakes scored highest in appearance, even with browned crust removed; cakes prepared in a microwave oven without a turntable scored significantly lower in this attribute than those cooked in turntable-equipped microwave ovens. Texture and mouthfeel were both judged significantly better in cakes baked in the electric oven, but the presence or absence of microwave turntable did not alter results in these categories. Microwaved cakes had uneven surfaces and tunneling. Cakes cooked in a microwave oven without a turntable scored lowest in flavor, while those baked in a conventional oven were judged best in this characteristic. The researchers determined that shear scores were good predictors of acceptability. As shear scores increased, indicating a less tender cake, sensory scores decreased.

No research was found comparing cakes that had been prepared at different power levels in a microwave oven.

Ground Beef

Gast, Seperich, and Lytle (1980) reported that 65% of respondents in a poll stated that they prepared ground beef in the microwave oven. Taki (1985) claimed that, of respondents in a survey who owned microwave ovens, 98% cooked meat dishes in them, although the microwave oven was not the primary meat cooking source. Ground beef patties were one type of meat most often cooked in the microwave, although consumers were aware of the limitations of meat cooking in the appliance (Taki, 1985).

Beef patties used in all studies discussed were formulated solely of ground beef. Janicki and Appledorf (1974) measured effects of cooking method on moisture and lipid content of ground beef patties. Six-inch diameter, one-quarter inch thick patties were grill fried, broiled, or cooked in the microwave. Results showed that microwaved patties had the lowest cooked weights and percent yields when compared to grill fried or broiled patties. Beef cooked in the microwave oven also showed the greatest fat loss.

Drew and Rhee (1979) compared patties cooked in a microwave oven to those cooked in similar ovens with a browning grill, a browning element, an initial microwave cooking with a finish under a broiler, and a conventional electric oven. Greatest total cooking losses were obtained from patties cooked in both the microwave oven and the microwave with a browning element. Patties prepared in the microwave oven experienced the greatest drip loss. Patties cooked in the conventional oven scored highest for appearance, while those cooked in combination microwave ovens still scored significantly higher than patties heated in the regular microwave oven.

Starrak (1982) examined techniques for microwave cooking of beef patties. Quarter-pound and one-third pound patties were cooked at High power. Patties were doughnut-shaped, with a three-quarter inch diameter center hole to allow for fat drainage. Starrak noted that patties cooked singly needed to be inverted about midway through the cooking process, and reinverted just prior to removal from the microwave. Patties cooked two or four at a time did not require inversion, but they were turned 180o during cooking. Starrak maintained that standing time, with the patties wax-paper covered, prevented overcooking but allowed achievement of desired degree of doneness.

Starrak's cooking methods were in agreement with recommendations issued by IMPI (1987), which suggested doughnut-shaped patties and inversion halfway through the cooking period. Rotating the patties 90o or 180o during cooking was also recommended, as was cooking in a colander over a glass container to collect drippings.

An extensive study in 1988 (Malloy) tested low-wattage microwave ovens to determine whether special directions were necessary to counteract lower output wattage. Malloy found that a total of less than one pound of ground beef did not require special instructions for cooking in lower-wattage microwave ovens. Amounts in excess of one pound, however, needed separate information.

Potatoes

Kafka (1987) noted that potatoes cooked in a microwave oven do not have a traditional mealy texture or crisp skin. These observations confirmed the findings of a 1981 Consumer Reports article which stated that potatoes cooked in a microwave oven emerged similar to those foil-wrapped and baked in a conventional oven. Essentially, such potatoes are steamed, not baked.

A 1977 report (Maga and Twomey) published comparative sensory evaluations of potatoes baked conventionally and cooked in a microwave oven. Potatoes were evaluated upon appearance (both internal and external), aroma, and flavor. Microwave cooking of four tuber varieties resulted in significantly lower scores in all categories, compared to potatoes baked in conventional ovens.

Brittin and Trevino (1980) also compared potato cooking methods. Percent cook loss was much greater for microwaved potatoes than for those baked. In results similar to those of the Maga and Twomey panel, sensory panelists judged conventionally baked potatoes superior in color, flavor, and texture. However, when one hundred twenty consumers were questioned about the two cooking methods, there was no significant difference in method preference.

Broccoli

Gordon and Noble (1959) cooked fresh broccoli in boiling water, a pressure cooker, and the microwave oven; cooking times were calculated to yield similar tenderness, independent of method. Microwave broccoli was less green than the raw vegetable or that cooked by other methods. However, microwaved broccoli was judged to have a milder flavor than that which had been pressure cooked.

The results in the Gordon and Noble study do not agree completely with those obtained by Chapman et al (1960). In this research, microwaved fresh broccoli had a better color than that cooked in boiling water. However, frozen broccoli color results agreed with those of Gordon and Noble. In the Chapman study, broccoli samples were cooked for varying times. When cooked to estimated optimum stem texture, no flavor superiority was found by cooking method. Separate color, flavor, and texture evaluations were made for broccoli florets and stems.

According to a 1961 study (Kylen et al.) cooking method was related to palatability. The researchers reported significantly lower fresh-broccoli palatability when the vegetable was cooked in a microwave oven rather than in boiling water. Broccoli frozen for four months, however, was judged significantly more palatable when cooked by microwave.

Schrumpf and Charley (1975) concentrated on vegetable texture. Broccoli was cooked in boiling water and in a microwave oven; one lengthwise half of each piece was cooked by each method. The researchers reported shape distortion over the entire piece length of microwaved broccoli described as a "collapsed and shrunken appearance". Microwaved broccoli had a tougher outer surface but softer interior than that cooked in boiling water, while water-cooked weight loss was less than half that of the microwaved vegetable. Microwaved broccoli also had pronounced folding of cell walls. Schrumpf and Charley (1975) declared that buildup of pressure by rapid and continuous inversion of internal water to steam by microwave energy would not only force steam out of the cells but prevent re-entry of water.

Bowman et al. (1971) reported contradictory results to those of the 1975 Schrumpf and Charley study. Microwaved and boiling-water-cooked broccoli spears did not differ significantly in color, flavor, tenderness, or texture.

However, results may have been affected by the altitude at which this research was conducted (5,000 feet above sea level). In addition, the microwave oven used had a maximum output of 800 watts, higher than those employed in most other studies.

Frozen Food

Ohlsson (1983) stated that microwave heating of foods is based on the transfer of energy to the water in foods. In frozen foods, most water is in the form of ice. The microwave absorption of rate for ice is much less than that for water (Harrison, 1980). Consequently, the absorption rate for frozen foods is comparatively slow. However, the microwave absorption rate of a food is type-dependent relative to many factors, including density, homogeneity, chemical composition, and placement in serving dish. A 1981 Consumer Reports article stated that exteriors of frozen casseroles may be bubbling hot while the insides remain frozen solid. Certain foods in frozen dinners or dishes capable of absorbing microwaves at faster rates may overheat or dry out while ice is still present on other foods (Ohlsson, 1983).

O'Meara and Reilly (1986) declared that localized overheating in microwaved frozen multi-component meals was a widespread phenomenon. They formulated dinners consisting of a formed beef patty, mashed potatoes, and sliced carrots on microwaveable plastic plates. To discourage localized overheating, butter, sauces, gravy, and condiments were omitted. The dinners were frozen and then heated without turning until the meat temperature was 60o C (140o F). Due to "hot spot" patterns and food-related factors, in one instance, temperature difference greater than 150o F were recorded only one inch apart in the mashed potatoes. O'Meara and Reilly concluded that required heating time was not related directly to measured power output.

Summary

In general, microwave cooking and heating requires less time than conventional methods of boiling, steaming, baking, or broiling. The quality of the resulting food may be equal to that cooked by conventional methods in some cases. In the literature as a whole, however, most microwaved foods were rated lower by sensory panels in some attributes than conventionally-cooked counterparts. Instrumental differences were seen as well; for example, microwaved foods tended to lose more moisture during the cooking process, and localized over- or under-heating is a problem not normally encountered in conventional cooking.

Certainly, some foods are more compatible with microwave cooking than others. In the literature reviewed, cakes preformed fairly well when cooked in the microwave oven; most cake batters have certain characteristics (such as high sugar and moisture levels) which would attract microwaves. Whole potatoes were also successfully microwave-cooked, as was broccoli, rather surprisingly, as it is a variable-density vegetable. One might have expected such a vegetable to be overcooked in lower-density areas (and vice versa). Frozen foods were microwaved with mixed results, probably due to both the ice present and the small percent of highly concentrated solutes in solution still liquid within the food (Ohlsson, 1983). Ground beef and custard were cooked in the microwave oven with lesser degrees of success, however. The beef suffered from high evaporative and drip loss and lack of browning and crisping in sensory judging. Custard, a delicate dairy product, seemed to give inconsistent results, and researchers evidently found it difficult to determine doneness.

CHAPTER III

METHODOLOGY

Experimental Design

The two microwave ovens employed in this study were the Sharp R3A81 Carousel II Auto-Touch and the Sharp R300A Carousel II Auto-Touch (both from Sharp Electronics Corporation, Mahwah, NJ). Ovens were countertop models identical in interior and exterior size and shape. Each oven had 0.7 cubic feet cavity capacity and an interior glass turntable. The R3A81 operated on standard transformer technology (variable power cycling on-and-off of the magnetron); the R300A had the inverter technology for variable power. The maximum output wattage for the R3A81 was 600 watts, while that for the R300A was 620 watts; both wattages were obtained as a result of experimental testing by the Sharp Corporation.

Each food was prepared twice at either 100%, 70%, or 50% power in each microwave oven. The power levels of 100%, 70%, and 50% in the oven with the inverter corresponded to the High, Medium High, and Medium power settings, espectively, in the transformer microwave oven. The power levels were chosen as downstep gradients to provide a power-of-heating change thought sufficient to affect food quality. Power levels under 50% were not used; at these levels, the microwave oven with inverter technology "reverts" to transformer technology power cycling of the magnetron (on and off).

Preliminary Testing

Some preliminary testing was performed with water and batches of custard to enable the researcher to become familiar with the heating capabilities of each oven. Preliminary testing disclosed uneven heating patterns within each oven. In particular, both microwave ovens had "hot spots" at their turntable centers.

FOOD SELECTION

The foods selected for use in this research were chosen as representatives of a wide range of food systems. These systems included an egg gel/dairy product (custard), a system where food structure was based on starch gelatinization (cake), a muscle food with fat and moisture (ground beef patties), plant cell systems of both variable and uniform densities (broccoli and potatoes, respectively), and a frozen multi-food system (chicken pot pie).

Custard

Custard was selected as a high moisture, egg and milk protein food forming a delicate gel; the available energy must be sufficient to coagulate protein fibers so that the resulting product will achieve a good set. If excessive or uneven heating occurs, curdling and/or syneresis may result.

Chocolate Cake

Cake was selected as an example of a food whose structure is set by protein denaturation and gelatinization of starch. Cake is a flour based batter with high fat and sugar ratios (when compared to amount of flour). Fat, sugar, and moisture absorb microwave energy at a rapid rate; thus, batter content affects cooking time. Cakes can be cooked successfully in microwave ovens. A dark-colored cake was chosen to mask the lack of browning and crisping, an intrinsic part of microwave cooking. The dark color disguised an unbrowned cake crust which might have negatively influenced sensory panel members.

Ground Beef

Ground beef was chosen as a high moisture, high fat, muscle food. The fat content and geometric shape were controlled. As discussed in the review of literature, the ground beef patties were not expected to brown or crisp in the microwave ovens because of the negative temperature gradient, lack of surface dehydration, and brief cooking times.

Potatoes

Potatoes were selected as a plant cell system of uniform density. Because these tubers are about 70% water (Whitney and Hamilton, 1987), they were expected to be attractive to and therefore rapidly heated by microwaves. Cooking whole potatoes in a microwave oven, however, is complicated by lack of uniform shape and general unevenness of heating within the ovens as revealed in preliminary testing.

Frozen Broccoli

Broccoli was selected as a vegetable of variable density. Broccoli stalks are dense and sometimes woody with fibers while the florets are far less dense. Hence, the food is a plant cell system whose parts can be expected to respond differently to microwaves. Frozen broccoli was chosen for convenience, as it was storable throughout the duration of the study.

Frozen Pot Pie

A frozen chicken pot pie marketed by a nationally-known manufacturer was chosen as an example of a multi-food system of pastry, vegetables, meat, and sauce or gravy. This high fat, high sodium product is also typical of a convenience food that a consumer would prepare in a microwave oven. The microwave absorption rate for frozen foods is slower than for non-frozen foods because of the greater amount of energy required to melt ice (the frozen form of most of the moisture in a product) before the food can be heated. The different components of this multi-food system were expected to absorb microwave energy at varying rates; the corresponding measurement of this was the "evenness of temperature in sample" attribute rated by the sensory panel.

Pilot Study

Cooking times were established during a pilot study. Times were set for 100% (High) power initially; cooking times for other power levels were set tentatively by ratio of power percentage. For 70% (Medium High) power, cooking time for the particular food was multiplied by 1.43, as 100 is approximately equal to 1.43 x 70. Similarly, for 50% (Medium) power, cooking time for the food would be doubled for that at 100% (High) power, as 100 is equal to 2 x 50. Pilot work showed some need for modification in these timings, which were adjusted as necessary.

In the case of frozen foods, cooking times at 100% (High) power were within the range of times given on the box directions. Times for other power levels were set according to the formulae in the preceding paragraph.

Food Purchase, Preparation, and Storage

All foods selected were meant, according to cookbook or package directions, to be cooked/heated at 100% (High) power. Thus, as the R3A81 (transformer) microwave was the control oven in the study, foods cooked at High in that oven served as the standards for the study.

Pot pies and frozen broccoli were purchased prior to the beginning of the study and were kept frozen at -10o C until needed. Ground beef was purchased in 454 g. (1 lb.) packages from Radford Brothers Supermarket (Blacksburg, VA) and frozen at -10o C; beef was removed from the freezer 48-52 h. before use and thawed under refrigeration. All other foods and ingredients were purchased as necessary from Radford Brothers Supermarket (Blacksburg, VA). No ingredient was used beyond its date of expiration.

To ensure standardized placement of cooking plates and pans in ovens, templates were made for the plates and pans used. Each template was the diameter of the glass turntable, with an area cut out corresponding to the cooking vessel used.

All weighing was done on a Mettler PM 2000 top-loading balance (Mettler Instrument Corporation, Hightstown, NJ). Mixing times were clocked by a GraLab Universal timer (Model 171, Dimco GraLab Co., Dayton, OH) attached to a Farberware hand-held electric mixer (Model D2770, Farberware, New York,NY) which automatically shut off the mixer at the end of mixing time.

Instrumentation

Foods were measured instrumentally using a fluoroptic thermometer, a texture analyzer, and a top-loading balance. The Luxtron Fluoroptic Thermometer Model 755 (Luxtron Corporation, Mountain View, CA) measured post heating temperature rise via probes at the ends of two fiber optic cables. The thermometer was calibrated prior to use, and set to record temperatures in degrees centigrade.

The Steven-LFRA Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY) was used to assess tenderness. This instrument measures gram force required to depress or shrear an object.

Cooking/evaporative loss was determined by weight. The Mettler PM 2000 top-loading balance (Mettler Instrument Corporation, Hightstown, NJ) was used for this measurement.

Instrumental Measures and Sensory Attributes

Instrumental measures for this research were performed as requested for The International Microwave Power Institute (Clifton, VA) and Sharp Electronics Corporation (Mahwah, NJ). Sensory attributes for each food were chosen to complement the instrumental measures and, in some instances, from the researchers curiosity.

INSTRUMENTAL TESTING

To equalize temperature and humidity conditions within oven cavities, 720 ml. of cold tap water in a 1 liter glass measuring cup were heated for 3 min. at 100% (High) power in each oven at the beginning of every day of instrumental or sensory testing. In instrumental testing, microwave ovens were allowed to rest with door open for at least 15 min. between each use, and ovens were never operated simultaneously for the convenience of the researcher.

Custard

One recipe of custard was mixed according to the formulation in Appendix A. After standing for 90 sec. to allow for foam reduction, 85 g. of custard mixture was poured into each of five pre-weighed, 175 ml. clear glass custard cups. Custard weighing out and pouring were accomplished as rapidly as possible. Filled cups were then placed immediately on the microwave turntable in the pattern seen in Figure 1.

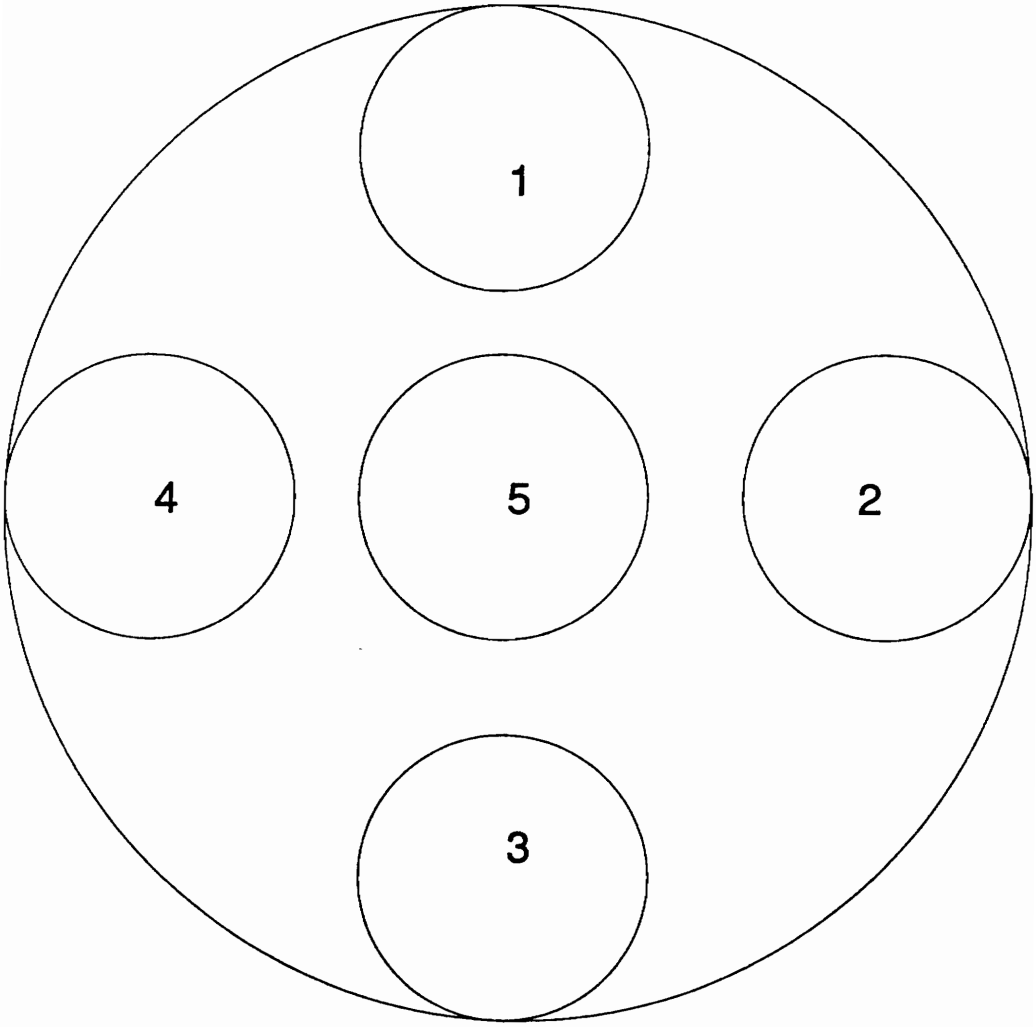

Figure 1: Cooking Pattern for
Microwaved Custards

Custard cups one through four touched the outer rim of the turntable; no two cups touched one another. Custards were cooked according to the times listed in Appendix A.

Cooking times were determined in pilot work, the objective being to achieve a well-set but not curdled product. An internal temperature of approximately 70° C (158° F) in cup custard 2 of the control (transformer) microwave oven when the temperature was taken immediately upon the end of the heating period was determined ideal; the cooking for this ideal result was at 100% (High) power.

When the cooking period ended, custards were removed immediately from the oven. Post heating temperature rise was measured using a Luxtron Fluoroptic Thermometer Model 755 (Luxtron Corporation, Mountain View, CA). Temperature probes were place in the centers of cup custards 2 and 5; temperatures were taken at 15 sec. intervals for a period of 3 min. Fluoroptic thermometer probes were hand held in place during this time.

Custards cooled at room temperature for approximately 30 min. before being placed under refrigeration. After another 30 min. (1 h. total cooling time), custards were tightly, individually covered with plastic wrap and replaced in refrigerator. All handling was done as gently as possible to cause minimum disturbance to custard set.

Custards were refrigerated for at least 24 h. but no longer than 30 h. All custards were then weighed to determine weight/evaporative loss during cooking. All custards were examined visually to check for any syneresis. Cup custards 1, 3, and 4 were then evaluated for tenderness using the Stevens-LFRA Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY), probe TA-10, to a penetration depth of 2 mm. at a speed of 2 mm./sec.

Chocolate Cake

Waxed paper was cut to fit the bottom of an octagonally round, 20 cm. (8") diameter, 48 oz. casserole dish (Anchor Hocking Plastics, Inc., USA). Casserole (hence forward referred to as "pan") with waxed paper liner was then weighed and weight recorded.

One recipe of chocolate cake batter was prepared according to the formulation in Appendix B. Immediately after final mixing, 600 g. of batter was poured into pan. Filled pan was then immediately placed in center of microwave turntable via template; pan was always placed so that handles were closest to shortest sides of microwave oven. Each cake was cooked according to the times listed in

Appendix B.

Batter amount and cooking times were established during pilot work. A cake was considered "done" when a toothpick inserted in the center down to the pan bottom emerged clean.

Immediately upon the end of the cooking period, the cake was removed from the oven. Temperature probes from the Luxtron Fluoroptic Thermometer Model 755 (Luxtron Corporation, Mountain View, CA) were inserted in the cake center and into the center of the cake approximately 2.5 cm. from one pan edge which had been the handle to the researcher's right upon placement in the oven. Post heating temperature rise was determined by taking temperature readings at 15 sec. intervals for 10 min.

Cakes were cooled to room temperature in the pan for approximately 2 h. Each was then weighed to determine weight/evaporative loss during cooking and cooling. Cooled cakes were double-wrapped with plastic wrap and left at room temperature for at least 24 h. but no longer than 30 h.

Cakes were evaluated for tenderness after the 24-30 h. standing time, as pilot work indicated that cakes were more tender after this time had elapsed. One 2.5 cm. square was cut from the cake center, one 2.5 cm. square was cut at the middle of the left pan handle, and one 2.5 cm square was cut halfway between the cake center and the right pan handle. All "squares" were the full height of the cake. All were evaluated turned onto their side so crusts would not influence tenderness reading. Readings were taken with the Stevens-LFRA Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY), using the "knife" blade. Penetration depth was 10 mm. at a speed of 2 mm./sec.

Ground Beef

Forty-eight to 52 h. prior to testing, ground round beef (maximum 15% fat) was removed from the storage freezer and thawed under refrigeration.

On testing day, a circle of waxed paper was cut to fit over the top of the cooking plate, the Bake N' Bacon Sheet (Nordic Ware). This was a circle of approximately 27 cm. (10.5") diameter of blue microwaveable plastic with ridges designed to suspend the food above the plate bottom.

An empty tim of canned salmon was cleaned and the top was removed. The tin, approximately 8 cm. (3") diameter and 4 cm. (1.5") in height, was used as a mold. It was sprayed lightly with vegetable oil cooking spray once prior to use.

For each patty, 113 g. of thawed ground beef was weighed out and placed in the mold. It was then compacted

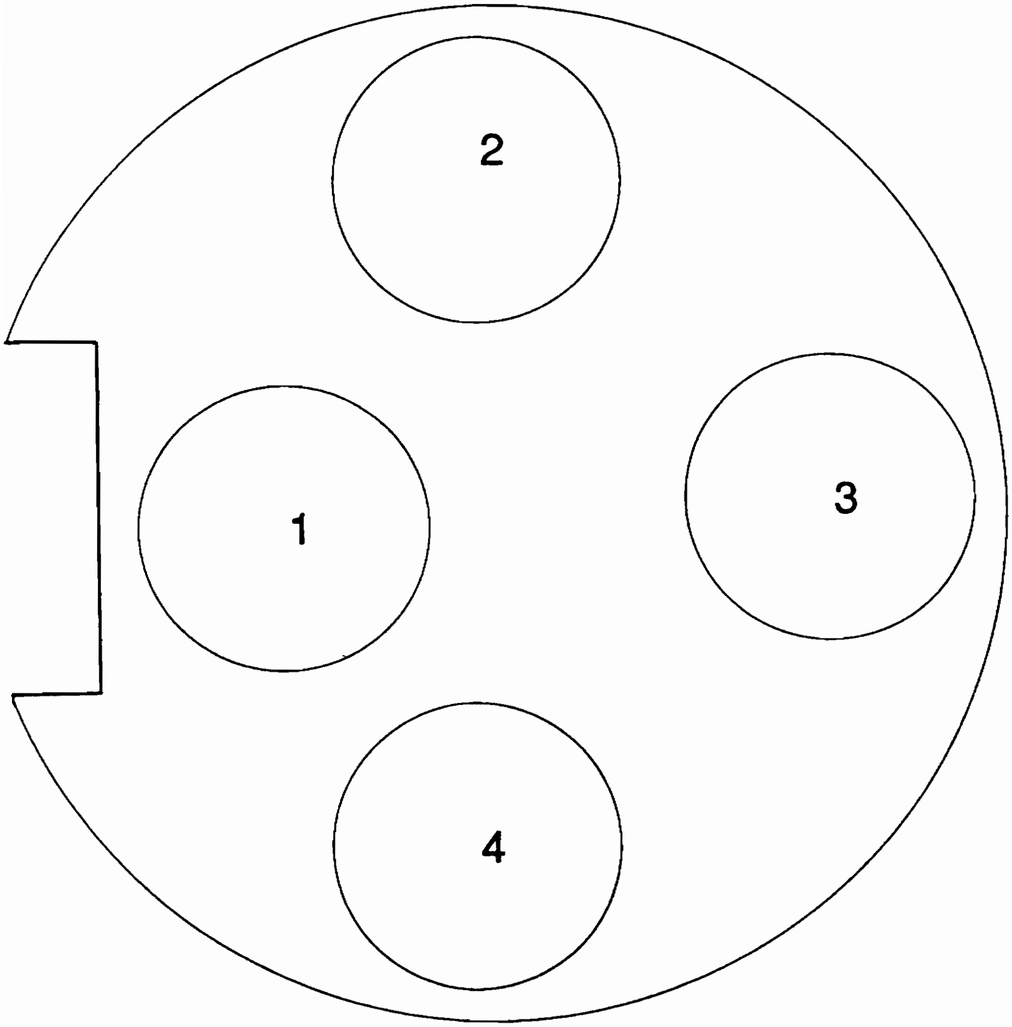

Figure 2: Ground Beef Patty Placement on Cooking Plate

with fingertips until it was well pressed down, with an even top surface. The mold was turned upside down and tapped gently on a hard, flat surface until the patty emerged; patties thus measured approximately 8 cm. diameter and 1.75 cm. in height. Patties were placed approximately 1 cm. from the edge of the cooking plate (see Figure 2). No patty touched any other, and Patty 1 was always placed nearest the notch in the cooking plate rim. After placement of the cut-to-fit waxed paper circle on tope of the patties, the plate was double-wrapped with plastic wrap and refrigerated until cooking, no more than 2 h. later.

At cooking time, plastic wrap was removed and the cooking plate placed immediately in the oven. Cooking plates were always placed on the turntable so that Patty 4 was closest to the door of the microwave oven. Cooking times for patties are listed in Appendix C.

Cooking times were established in pilot work. Cooking times produced a patty that was well-done (no pink throughout) and that reached a minimum interior temperature of 73.8° C (165° F). This temperature was measured immediately upon removal from the transformer oven after the patty had been cooked at 100% (High) power.

At conclusion of the cooking period, the cooking plate was removed immediately from the oven, and the waxed paper was taken off the top. Post heating temperature rise was determined by the Luxtron Fluoroptic Thermometer Model 755 (Luxtron Corporation, Mountain View, CA). Temperature probes were inserted into the center of Patty 1 and approximately 1 cm. from the outer edge (that closest to the cooking plate rim) of Patty 3. Temperatures were taken at 15 sec. intervals for 10 min. Visual appearance of patties was recorded (raw-looking patches or bloody-looking juices).

Beef patties were cooled approximately 20 min. after post heating temperature rise measurement was concluded. Patties were then weighed to determine cooking loss. Patties were evaluated for tenderness with the Stevens-LFRA Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY). Each patty was evaluated at top center and approximately 1 cm. from edge that had been closest to cooking plate rim. The TA-2 probe was used at 5 mm. penetration depth at a speed of 2 mm./sec.

Potatoes

White russet baking potatoes were used, averaging about 312 g. (11 oz.) in weight. Each potato was weighed, then washed and thoroughly dried. A sharp paring knife was used to make 6 slits, each approximately 2 cm. long, at random locations on the outer surface of the potato. Slits were made no more than 10 min. prior to cooking.

The potato was placed in the center of a white paper plate of 23 cm. (9") diameter. The plate was then centered on the oven turntable via template, and the oven was started. Cooking times are listed in Appendix D. Cooking times were adapted from those suggested in several microwave cookbooks.

At the end of the cooking period, the potato was removed immediately from the oven. Post heating temperature rise was measured with the Luxtron Fluoroptic Thermometer Model 755 (Luxtron Corporation, Mountain View, CA). Small knife slits were made into the potato center from the middle of the top surface and approximately 2.5 cm. from the end of the potato facing toward the investigator's right at the time of removal from the oven. One probe was placed into each slit. Temperature readings were taken at 15 sec. intervals for 10 min.

Probes were removed at the end of the 10 min. period. The potato was then cooled for an additional 30 min. at room temperature before weighing to determine weight/evaporative loss during cooking and cooling.

Tenderness was evaluated using the Stevens-LFRA Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY).

Each potato was halved horizontally, and the top half used for measurement. Tenderness was evaluated on cut side of potato half, along an imaginary line along the horizontal center of the potato. Points along this line were 2.5 cm. from each end of the potato (right and left) and in the center of the "line". Readings were taken using probe TA-52, to a penetration depth of 10 mm., at a speed of 2 mm./sec.

Broccoli

Broccoli used was Green Giant Brand Harvest Fresh Frozen Cut Broccoli (The Pillsbury Company, Minneapolis, MN) in the 255 g. (9 oz.) package. Broccoli was removed from freezer, then box; a slit approximately 2 cm. in length was cut in the top center of the larger, flat side of the plastic package, according to box directions. The broccoli package was then replaced in the freezer.

Just prior to cooking, broccoli package was again removed from freezer and placed in the center of a 23 cm. (9") diameter white microwaveable paper plate. The slit face of the plastic package faced upwards, and the short edge of the plastic package to the investigator's right upon removal from the freezer faced the back of the oven. The plate was then placed on the center of the microwave turntable, via template, with the broccoli package placed on the plate center. Cooking times are listed in Appendix E. Cooking times at 100% (High) power were listed within suggested cooking time range on box instruction. Immediately following the heating period, the broccoli was removed from the oven. Post heating temperature rise was measured with the Luxtron Fluoroptic Thermometer Model 755 (Luxtron Corporation, Mountain View, CA). One probe was inserted into the approximate center of a piece of broccoli stalk through the slit in the center of the plastic package.

The remaining probe was inserted through a slit into a piece of stalk approximately 1 cm. from that package (short) edge facing the investigator's right when the broccoli was removed from the oven. Temperatures were taken at 15 sec. intervals for 10 min.

Following removal of the probes, the broccoli cooled in its package at room temperature for 45 min. The package was weighed, then slit open and the broccoli removed to a plate. The packaged was then rinsed, dried, and weighed. These measurements allowed for calculation of weight loss during cooking.

Tenderness was assessed by means of the Stevens-LFRA Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY). Four pieces of broccoli stalk per package were selected randomly. Tenderness was evaluated using the "knife" blade to a 6 mm. penetration depth, at a speed of 2 mm./sec.

Frozen Pot Pie

A 397 g. (14 oz). Swanson Hungry Man Frozen Chicken Pot Pie (Campbell Soup Company, Camden, NJ) was removed from its box and weighed. Quickly, before thawing could occur, small holes were bored through the crust with the tip of a sharp paring knife both at the surface center of the crust and the vertical center of the crust approximately 2.5 cm. from the short edge of the pie facing the investigator's left upon removal from the box (see Figure 3, Points X and Y). The pie was then replaced in the freezer.

Just prior to cooking, the pie was again removed from the freezer and placed on the center of a 23 cm. (9") diameter white microwaveable paper plate. Pies were placed

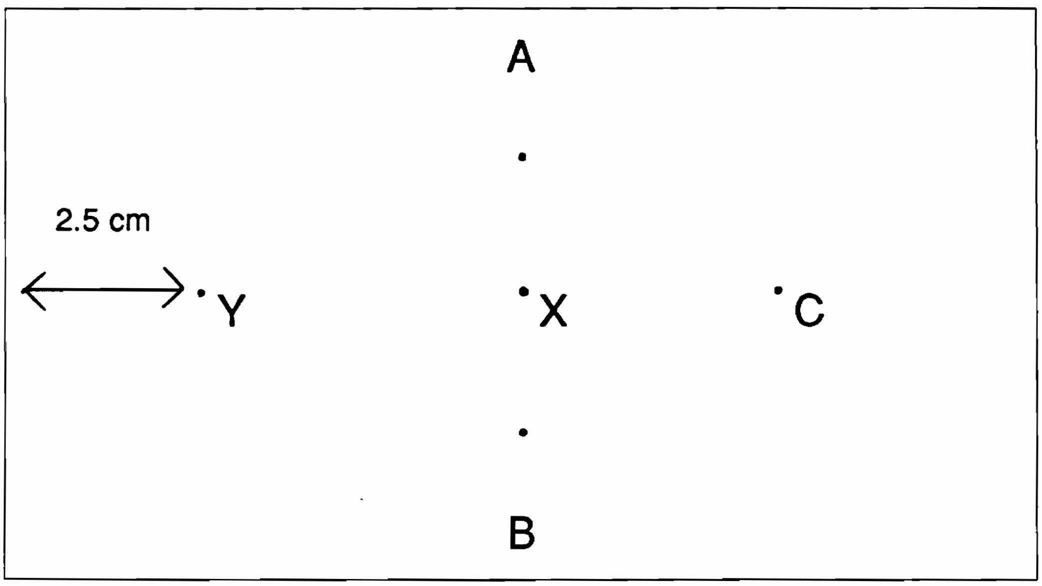

Figure 3: Instrumental Testing Points
for Pot Pies

on the plate so that the bored hole nearest the pie tin edge was closest to the back of the oven. The plate was then placed at the turntable center via template. Heating times for the product are listed in Appendix F. Heating times were within the suggested range on box directions for 100% (High) power.

Immediately upon the end of the heating period, the pie was removed from the oven. Post-heating temperature rise was determined with the Luxtron Fluoroptic Thermometer, Model 755 (Luxtron Corporation, Mountain View, CA). One probe was place into each of the two holes bored before cooking; probes were hand held in the approximate depth center of the pie. Temperature readings were taken at 30 sec. intervals for 20 min.

At the end of 20 min., the probes were removed. Tenderness of crust was then evaluated by the Stevens-LFRA Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY). Tenderness was assessed using the metal cracker ball to a penetration depth of 3 mm. at a speed of 2 mm./sec. Tenderness was measured in three places. Point A was halfway between the center bored hole and the long edge of the crust farthest from the investigator. Point B was halfway between the center bored hole and the long edge of the crust closest to the investigator. Point C was halfway between the center bored hole and the short edge of the crust to the investigator's right upon the pie's removal from the oven (See Figure 3).

After evaluation of tenderness, the pie was weighed to determine evaporative loss in cooking. The contents of the pie tin were then discarded. The tin itself was washed, thoroughly dried, and weighed, allowing for determination of weight loss during cooking.

SENSORY TESTING

General

Seven panelists were recruited from students at Virginia Polytechnic Institute and State University. Panelists were informed that they would be required to taste a variety of foods, including red meat and a dairy product. No panelists claimed allergic reaction to any food or stated that there was any food they wouldn't eat (except liver). Panelists were informed that they would be paid $25.00 at the conclusion of the study.

Panelists were trained in two sessions. In each session, panelists were presented with three foods similar to those they would test in the actual evaluation, and the actual corresponding questionnaires that would be used in evaluation. In training as in the evaluation session, panelists were required to sip water before and between testing each product, and each variation of each product.

Questionnaires involved attributes that were food-type dependent. Attributes were determined by the investigator. Characteristics were rated along a 10 cm. anchored, unstructured scale with the minimum or non-existent rating on the left anchor and the maximum or most total rating on the right anchor. Panelists were allowed to rate food attributes outside of the scale anchors if they felt it was merited.

Sensory evaluation took place in the sensory booths in Wallace Hall at VPI&SU. Each panelists was provided with a cup of cold tap water, a white paper napkin, a table fork, and a plastic spoon when custard was to be consumed. Questionnaires were placed on each desk according to the foods to be served that day. Extra cups and utensils and a pitcher of cold tap water were available.

Panels were scheduled for 3 p.m. on Mondays, Wednesdays, and Thursdays over a four-week period. Six foods (three different foods, each prepared at one power level in each of the two ovens) were evaluated each time. Panelists were identified on questionnaires from given panelist numbers, 1 through 7. All foods were coded with random, three letter codes. Panelists were requested to sip water before evaluating each sample. Samples were rated by placing a vertical line along the appropriate scale, then labelling the vertical line with the three letter code given the sample. All panelists finished evaluating both samples of one food before the next food was served. All hot samples to be evaluated on a particular day were served before non-heated or refrigerated foods (cake and/or custard) for the convenience of the researcher.

The foods served on a particular day were selected randomly in advance of any sensory testing, and laid out in a schedule. For each food, approximately half the panel tried a particular sample first, while half tried the other sample first. All samples, except for custards, were presented on 23 cm. (9") diameter white paper plates with a line drawn down the middle and one three letter code written on each half. Panelists were instructed to try the sample on their left first. In all cases, retasting was permitted as long as the panelists took a sip of water prior to retasting. Panelists were not required to eat all of a sample, but they were allowed to do so if they wished.

The seven panelists consisted of four women and three men, all between the ages of 20 and 30. Panelists were allowed one day's absence in the course of the twelve days of testing. However, Panelist 7, one of the women, incurred an excessive number of absences and was dropped from the panel by mutual agreement. None of Panelist 7's results have been included in this research.

Temperature and humidity conditions within oven cavities were equalized as described in Instrumental Testing. For cooked or heated foods, ovens were operated simultaneously so panelists could compare food samples directly.

Custard

Custard was prepared one recipe at a time; four full recipes were required for each sensory evaluation. Custard was made according to the formulation in Appendix A, and weighed, cooked, and cooled according to the instructions for instrumental testing. However, post test heating temperature rise was not measured in these custards, and the custard in cup 5 was not used for sensory panel work.

Custards were refrigerated for at least 24 h. but no longer than 30 h. and were kept under refrigeration until serving time. Custards were then removed from refrigerator and labelled on the side of the glass cup with a random three-letter code. Two custards, one bearing each code, were place on a tray so that one cup would clearly be on a panelist's left and one cup would clearly be on the panelist's right. The tray was then presented to the panelist.

Custards were evaluated for creaminess (defined as the degree of dairy sensation imparted by the product), sweetness, smoothness, and degree of set (See Appendix G). A blank space was left at the questionnaire bottom for any comments the panelist wished to make.

Chocolate Cake

Cake was prepared one recipe at a time; two full recipes were required for each sensory evaluation. Cake was made according to the formulation in Appendix B, then weighed, cooked, cooled, wrapped, and left to stand as described in the instrumental testing section. However, post heating temperature rise was not measured for sensory panel cakes.

After standing at least 24 h. but no longer than 30 h., cakes were unwrapped on testing day no longer than 3 h. before tasting would occur. Each cake was cut into eight wedges of approximately equal size. Wedges were removed from pan, wrapped tightly in plastic wrap, and placed on precoded paper plates. Plates were presented to panelists on trays so that one cake sample would clearly be to the panelist's left.

Cakes were evaluated for moistness, tenderness (defined as tenderness while chewing, not at first bite), degree of chocolate flavor, and cell size. A space was left at the bottom of the questionnaire for any additional comments the panelist had (See Appendix H).

Ground Beef

Each sensory evaluation required 908 g. (2 lb.) of ground beef. Patties were thawed, molded, placed on cooking plate, wrapped, refrigerated, and cooked as described in instrumental testing section.

At the end of the cooking period, the cooking plate was removed immediately from the oven and the waxed paper was taken off the top. All patties were cut in half, and halves were transferred to precoded paper plates, which were served on trays to panelists immediately. Patties were not drained of grease or juices to ensure that panelists received them still hot. Trays were presented so that one half patty was clearly to the panelist's left. Panelists were instructed to eat from the center of the cut edge of their sample half patty.

Ground beef was evaluated for tenderness (defined as tenderness while chewing, not at first bite), beefiness of flavor, and juiciness. A space was left at the questionnaire bottom to provide room for any comments a panelist wished to make (See Appendix I).

Potato

Potatoes were weighed, washed, dried, and slit according to descriptions in the instrumental testing section. One whole potato was used for each microwave oven for each panel testing (two total per evaluation). Potatoes were cooked as described in the instrumental testing section. For times listed see Appendix D.

Potatoes were allowed to rest in the microwave oven (with door closed) for 2 min. after the end of the cooking period. Potatoes were then removed from ovens. Approximately 2.5 cm. of each end was cut off and discarded; the remaining potato was halved horizontally. Each half was then sliced into three chunks as equal as possible, yielding six portions per potato. Chunks were placed on precoded paper plates and served to panelists as quickly as possible. No condiments were provided.

Potatoes were evaluated on whiteness of flesh, tenderness (defined as tenderness while chewing, not at first bite), and moistness. A space was provided at the questionnaire bottom for any comments a panelist wished to make (see Appendix J).

Broccoli

One package of broccoli was used per oven type per power level (two packages per sensory evaluation). Broccoli was prepared and cooked according to instructions listed in instrumental testing section.

Immediately following the heating period, the broccoli was removed from the oven. The plastic package was cut open. Several chunks of broccoli, including both florets and stalk, were judged by the investigator to be a "sample". Each sample was placed on a precoded paper plate, which was then served to a panelist on a tray so that one sample was clearly on the panelist's left. Apportioning and serving were conducted as rapidly as possible so that panelists could sample broccoli while it was still hot.

Broccoli was evaluated on color (greenness), freshness of flavor, and texture (degree of woodiness). A space was left blank at questionnaire bottom for any comments a panelist had (see Appendix K).

Frozen Pot Pie

A 397 g. (14 oz.) Swanson Hungry Man Frozen Chicken Pot Pie (Campbell Soup Company, Camden, NJ) was removed from its box. Quickly, before thawing could occur, the crust was scored deeply with a small, sharp paring knife. One scoring cut divided the crust in two along the length; two scoring cuts divided the crust into thirds across the width. Six approximately equal portion were thus created into each of two pies for each evaluation. Pies were scored one at a time to minimize thawing potential, then returned to the freezer for no more than 1 h.

Pie placement in the oven and heating times are in accordance with those listed in the instrumental testing section.

Pies were removed from the oven at the end of the heating period. Immediately, a large spoon was used to cut through the crust scorings so that a pie sample could be scooped out and placed on a precoded paper plate. Separate spoons were used for each pie. Plates were presented to panelists on trays so that one sample would clearly be on the panelist's left. Serving was accomplished as quickly as possible so that panelists could sample the pie while it was still hot.

Pot pies were evaluated for consistency of temperature in sample and for crust texture. A space was provide at the questionnaire bottom for any comments a panelist had (see Appendix L).

CHAPTER IV

RESULTS AND DISCUSSION

CUSTARD

Sensory

Custard was notable for the great amount of variation that occurred during cooking, even within batches. One panelist sampling a custard might comment upon its hard set; another, sampling custard from the same oven-load, would complain of runniness. The most common criticism was that the custard had a set top layer but was "soupy" or "watery" underneath. Syneresis was either minimal or absent in all custards. Probable cause for uneven cooking might be either exposure to uneven heating or insufficient cooking time. Repeated trials in pilot work established cooking times prior to the actual study; it is unlikely that cooking time necessary to establish a good set would change drastically without apparent cause. Uneven heating is very common in microwave ovens, even those equipped with turntables. The greatest amount of energy was probably concentrated at the custard surface and those custard portions nearest the container. Actual results and the above theory do not agree with the "negative temperature gradient" idea (where the temperature of the product surface is less than the temperature 2-3 cm. subsurface) expressed by IMPI (1987). This idea might result in a product more set inside than on top, the reverse of what was seen.

Sensory panel results for custard are shown in Tables 1 -3. Custards cooked at 100% power in the inverter oven were judged both creamiest (greatest degree of dairy sensation imparted) and sweetest (Table 3). Custards cooked at 50% power in this oven were judged least creamy and least sweet, but difference were not significant.

Custards cooked at 50% power in the inverter oven were also scored least smooth, significantly less so than those cooked at 70% or 100% power. Those cooked at 70% power were rated smoothest. These results do not agree with those obtained in the transformer oven (Table 2), where custards cooked at Medium (50%) power were significantly smoother than those cooked at other power levels. Greater smoothness at lowest used power level had been the expected result; it was thought that heating at higher power, even for a shorter time, would result in possible overheating of the delicate egg protein-milk salts gel (McGee, 1984).

Custard cooked at 100% (High) power in both ovens were less set than those cooked at other power levels, but the difference was significant only in the inverter oven (Table

TABLE 1

MEAN SENSORY SCORES FOR CUSTARD COOKED IN INVERTER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	**50% (Medium)**	**70% (Medium High)**	**100%(High)**
CREAMINESS	4.07_a (1.94)	5.46_a (1.35)	5.51_a(1.23)
SWEETNESS	5.00_a (0.93)	5.46_a (0.99)	5.59_a(0.62)
SMOOTHNESS	4.07_a (1.96)	6.88_b (1.30)	6.04_b(1.24)
DEGREE OF SET	7.97_a (0.73)	6.84_a (0.88)	3.34_b(2.15)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α =.05.

Creaminess: 1 = not at all creamy, 9 = very creamy
Sweetness: 1 = not nearly sweet enough, 9 = much too sweet
Smoothness: 1 = not at all smooth, 9 = very smooth
Degree of Set: 1 = not at all set, 9 = very set

TABLE 2

MEAN SENSORY SCORES FOR CUSTARD COOKED IN TRANSFORMER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	50% (Medium)	70% (Medium High)	100%(High)
CREAMINESS	5.52_a (2.25)	6.27_a (1.43)	6.64_a(1 35)
SWEETNESS	4.89_a (1.41)	5.05_a (1.14)	5.38_a(1.84)
SMOOTHNESS	5.98_a (1.60)	4.57_b (2.17)	4.65_b(2.17)
DEGREE OF SET	6.28_a (1.42)	5.28_a (2.12)	3.76_a(2.54)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α =.05.

Creaminess: 1 = not at all creamy, 9 = very creamy
Sweetness: 1 = not nearly sweet enough, 9 = much too sweet
Smoothness: 1 = not at all smooth, 9 = very smooth
Degree of Set: 1 = not at all set, 9 = very set

TABLE 3

MEAN SENSORY SCORES OF CUSTARD COOKED IN INVERTER AND TRANSFORMER OVENS

POWER LEVEL

	Medium		Medium High		High	
	50% I	50% T	70% I	70% T	100% I	100%T
Characteristic						
CREAMINESS	4.07	5.52	5.46	6.27	5.51	* 6.64
SWEETNESS	5.00	4.89	5.46	5.05	5.59	5.38
SMOOTHNESS	4.07	5.98	6.88	4.57	6.04	4.65
DEGREE OF SET	7.97	* 6.28	6.84	5.28	3.34	3.76

All scores are means based on 2 replication judgings by each of 6 judges.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

Creaminess: 1 = not at all creamy, 9 = very creamy
Sweetness: 1 = not nearly sweet enough, 9 = much too sweet
Smoothness: 1 = not at all smooth, 9 = very smooth
Degree of Set: 1 = not at all set, 9 = very set

1). Cooking at 50% (Medium) power produced custards with the greatest degree of set (again, in both ovens), but differences between those cooked at 50% (Medium) power and those cooked at 70% (Medium High) power were not significant in either oven (Tables 1-2).

Mean sensory scores in Table 2 show that custards cooked at High (100%) in the transformer oven were judged creamiest. This is in agreement with the custards cooked in the inverter oven. Results for sweetness also agreed with the inverter-oven-cooked custards, as those cooked at High (100%) power were rated sweetest by the panel. Neither creaminess nor sweetness scores were significantly different.

Mean sensory score comparisons between inverter and transformer ovens are displayed in Table 3. Only two categories were significantly different, and in each case the difference appeared at only one power level. Custards cooked at 50% power in the inverter oven were significantly more set than their counterparts cooked in the transformer microwave. This may be due to the longer cooking time found necessary during pilot work to achieve a good set in custards cooked in the inverter oven. In addition, custards cooked at High (100%) power in the transformer oven were rated creamier than those cooked at the same power level in the inverter oven.

Instrumental

The results of instrumental testing are shown in Tables 4-5 and Figures 4-6. No significant differences were found among power levels (within oven types) for percent weight loss or tenderness. Percent weight loss occurred in a fairly narrow range (7.77% up to 9.54%). Mean tenderness scores occurred in a narrow range (9.00 up to 10.33) in the transformer oven; this was not found in the inverter oven, where mean tenderness scores ranged from 4.33 at 50% figure power to 10.33 at 70% power (Table 4).

Mean tenderness scores were lowest at 50% (Medium) power in both ovens, indicating a less firm product. The results in this category are the opposite of those in the sensory evaluation, where cooking at 50% (Medium) power produced custards judged to have the greatest degree of set. In the transformer oven, mean percent weight loss was also greatest at Medium power. The instrumental results are in disagreement with Penfield and Campbell (1990) who declared that slower cooking of custard results in a lower coagulation temperature. Custards cooked at lesser power levels for longer times would therefore be firmer and more

TABLE 4

MEAN INSTRUMENTAL SCORES FOR CUSTARD

PREPARED IN INVERTER AND TRANSFORMER OVENS

INVERTER

Power Level	**50%**	**70%**	**100%**
Characteristic			
% WEIGHT LOSS	7.96_a	8.26_a	7.80_a
TENDERNESS	4.33_a	10.33_a	7.33_a

TRANSFORMER

Power Level	**Medium**	**Medium High**	**High**
Characteristic			
% WEIGHT LOSS	9.54_a	8.38_a	7.77_a
TENDERNESS	9.00_a	10.33_a	9.33_a

% Weight loss means are based on 2 replications of 5 cups of custard.

Tenderness means are based on 2 replications of 3 cups of custard, measured by grams/force (G/F).

Within rows, different letters indicate scores significantly different at $\alpha = .05$.

TABLE 5

MEAN INSTRUMENTAL SCORE COMPARISON BETWEEN CUSTARD PREPARED IN INVERTER AND TRANSFORMER OVENS

	POWER LEVEL						
	Medium		Medium High		High		
Characteristic	50% I		50% T	70% I	70% T	100% I	100%T
% WEIGHT LOSS	7.96		9.54	8.26	8.38	7.80	7.77
TENDERNESS	4.33	*	9.00	10.33	10.33	7.33	9.33

% Weight loss means are based on 2 replications of 5 cups of custard.

Tenderness means (G/F) are based on 2 replications of 3 cups of custard.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

Higher tenderness scores indicate a less tender product.

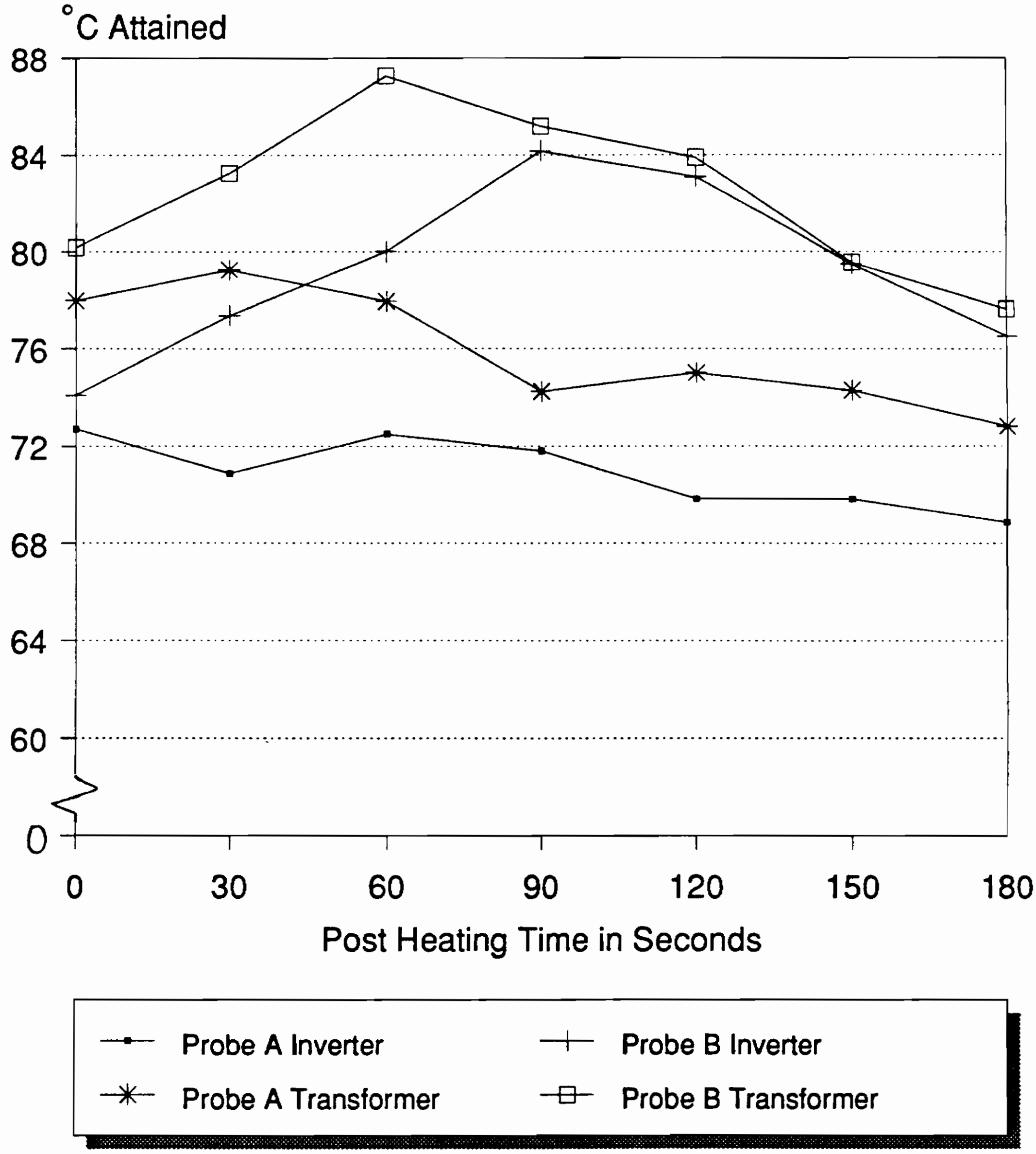

Figure 4: Post Heating Temperature Rise In Custards Cooked at 50% (Medium) Power

"A" indicates thermometer probe placement in center of cup 2
"B" indicates thermometer probe placement in center of cup 5
See Instrumental Testing Section

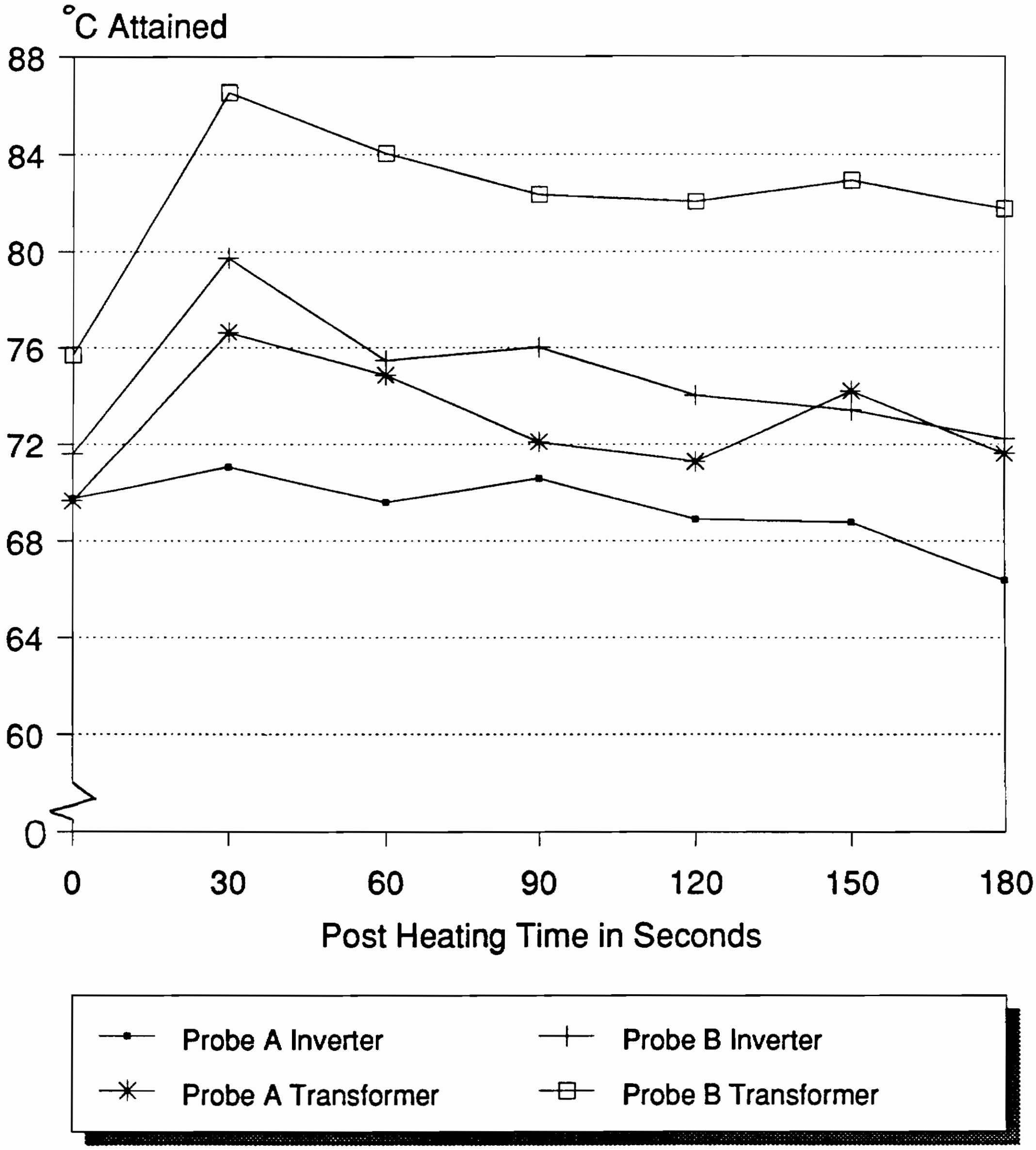

Figure 5: Post Heating Temperature Rise
In Custards Cooked at 70% (Medium High) Power

"A" indicates thermometer probe placement in center of cup 2
"B" indicates thermometer probe placement in center of cup 5
See Instrumental Testing Section

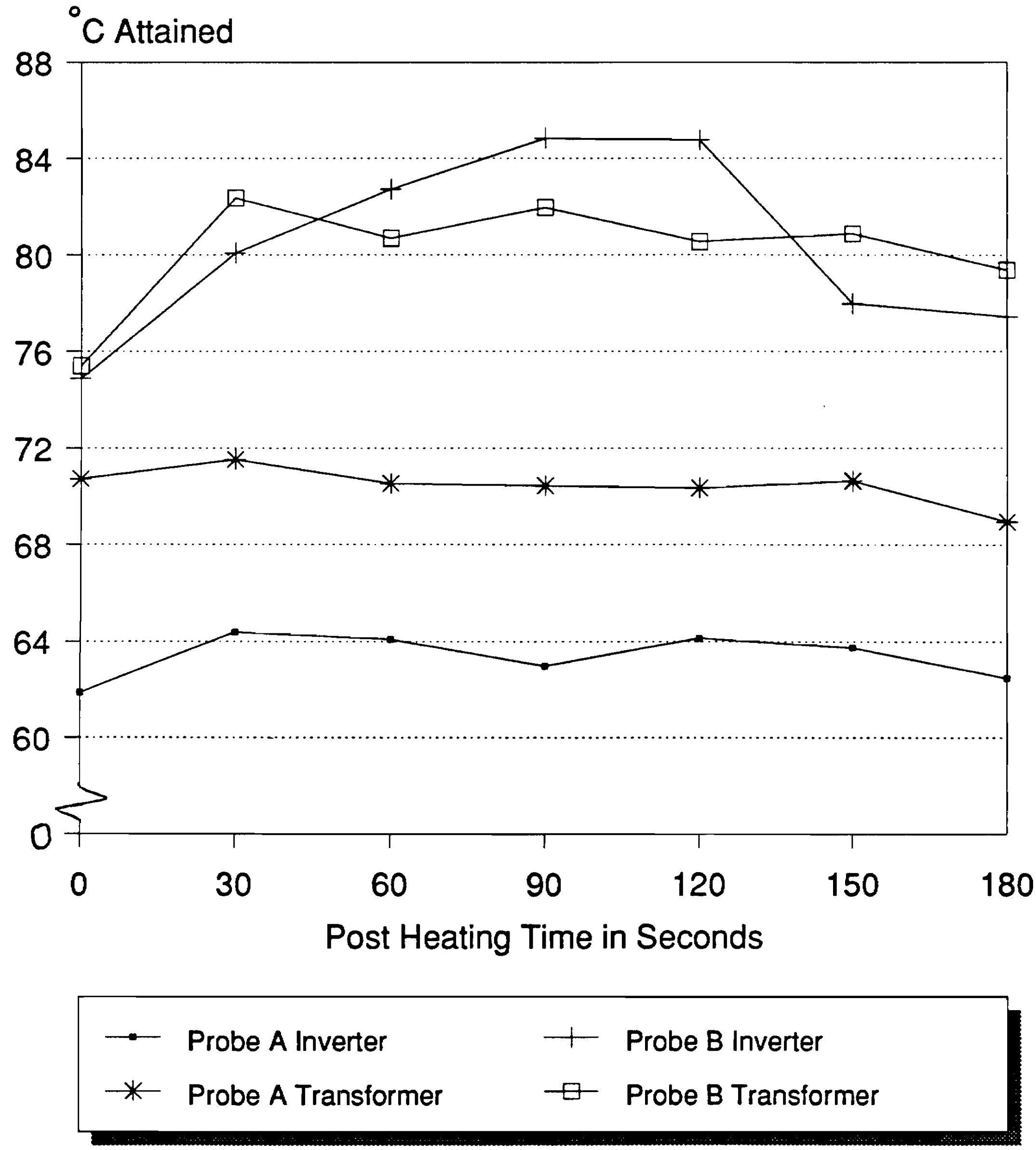

Figure 6: Post Heating Temperature Rise In Custards Cooked at 100% (High) Power

"A" indicates thermometer probe placement in center of cup 2
"B" indicates thermometer probe placement in center of cup 5
See Instrumental Testing Section

set with less risk of overheating.

The custard cooked at Medium (50%) power in the transformer oven had the greatest mean weight loss,compared to the greatest mean weight loss in the inverter oven in custard cooked at 70% power (Table 4). In both ovens, custard cooked at 100% (High) power had lowest percent weight loss, again perhaps due to the shorter cooking period, even at a higher power level.

Figures 4, 5, and 6 represent post heating temperature rise phenomenon in the custards. From these graphs it is possible to see two immediate trends. The custard cooked at a higher power level will not necessarily attain the highest temperatures in post heating temperature rise. The highest mean temperature during the post heating period was recorded in custard cooked in the transformer oven at Medium power (87.25° C, 60 seconds post heating). The second noticeable trend is that custards cooked in the centers of both ovens (cup 5) all had higher mean center temperatures than those cooked closer to the turntable edge (cup 2). This trend started with the initial temperature measurement and continued throughout the remainder of the 3 minute charted period. This would indicate that "hot spots" for the microwaves oven used in the study were located at the turntable centers. As further evidence of central "hot spots", custards prepared for sensory panel testing at position 5 (turntable center) in either oven were not used; without exception, they curdled during the cooking period, regardless of power level.

The majority of the custards measured for post heating temperature rise experienced "double peaking" during the 3 minute charted period. That is, the interior temperature of the custard would rise, then fall, then rise again. This occurred at all power levels. With one exception, temperatures fell after the second peaking (in the transformer oven, cup custard 5 at high power experienced a triple peaking - see Figure 6). Within power levels, peaking occurred at different times within the charted 3 minute period. This "double peaking" is partially in agreement with research by Penfield and Campbell (1990). These investigators note that temperatures rise rapidly early on in baked custards. The heating curve levels as gelation begins, then the temperature rises again at the completion of coagulation. The custards in this study were not baked, but heating patterns may be similar to those of baked custards. It is not known, however, why temperatures within the custards fell, rather than levelling off, prior to the second rise in temperature.

CAKE

Sensory

The sensory panel's most frequent comments about cake samples centered upon lack of chocolate flavor and toughness. Some explanation of both might be found within the cake formula itself (see Appendix B). The cake contained no eggs. Egg yolks are nearly 33% fat by weight (Whitney and Hamilton, 1987), and fat is both a significant carrier of flavor and a tenderizer (McGee, 1984). The fat level in this cake without egg yolks may have been too low to allow for much chocolate flavor development. Similarly, an eggless cake might be less tender than one containing eggs, even if both are formulated with the same amount of fat.

In preliminary work, the cakes were shown to be more tender by compression tests the day after baking, when the panelists sampled them. This, in itself, is contrary to most findings in literature. Possibly water vapor had some role in this seeming paradox. Because the cakes were not removed from the pans after cooking, the steam that formed on the inner pan sides and bottom while the cake cooled may have become incorporated into the cake; the majority of this process may have taken place after the cakes had cooled.

Small amounts of recondensed steam may have been absorbed only after a certain amount of retrogradation or staling had occurred. This moisture may have replaced what had been lost, or it may have been in excess of that amount. Certainly, there were no panelist complaints of cakes lacking moistness, and preliminary work showed percent weight loss from cooking to be changed minimally by a 24 hour standing period. Differences in percent weight loss between cakes just cooled and those that had stood 24 hours were less than 0.33%. This may account for the cakes' "improved" tenderness after standing. Another possible explanation for this occurence is free water movement. Free water within the cakes may have migrated from crumb to crust, resulting in a more even moisture distribution throughout the product after standing.

The mean sensory scores for cake are displayed in Tables 6-8. Although the panelists did not comment about lack of moistness, cakes were judged less moist than tender, overall, although no differences were significant in either category. No cakes were judged to be "very moist", and none came near that mark (Tables 6-7). There results are somewhat in agreement with Street and Surratt (1961) and Neuzil and Baldwin (1962). These investigators claimed that microwaved cakes were less moist than conventionally baked

TABLE 6

MEAN SENSORY SCORES FOR CAKES COOKED IN INVERTER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	50% (Medium)	70% (Medium High)	100%(High)
MOISTNESS	3.65_a (0.73)	4.10_a (1.95)	3.40_a(1.40)
TENDERNESS	4.67_a (0.98)	4.74_a (2.08)	4.30_a(0.97)
CHOCOLATE FLAVOR	4.66_a (1.68)	4.63_a (2.19)	4.40_a(1.21)
CELL SIZE	4.55_a (1.16)	4.44_a (1.38)	4.94_a(1.41)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α=.05.

Moistness:	1 = very dry, 9 = very moist
Tenderness:	1 = very tough, 9 = very tender
Chocolate Flavor:	1 = very weak, 9 = very strong
Cell Size:	1 = very small, 9 = very large

TABLE 7

MEAN SENSORY SCORES FOR CAKES COOKED IN TRANSFORMER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	**50% (Medium)**	**70% (Medium High)**	**100%(High)**
MOISTNESS	3.90_a (1.53)	4.21_a (1.35)	4.06_a(1.32)
TENDERNESS	4.48_a (0.95)	5.00_a (1.80)	4.75_a(1.50)
CHOCOLATE FLAVOR	4.68_a (0.92)	4.52_a (1.59)	5.17_a(0.98)
CELL SIZE	3.58_a (1.09)	4.73_a (1.75)	4.38_a(0.96)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α =.05.

Moistness: 1 = very dry, 9 = very moist
Tenderness: 1 = very tough, 9 = very tender
Chocolate Flavor: 1 = very weak, 9 = very strong
Cell Size: 1 = very small, 9 = very large

TABLE 8

MEAN SENSORY SCORES OF CAKES COOKED

IN INVERTER AND TRANSFORMER OVENS

POWER LEVEL

	Medium		Medium High		High	
	50% I	**50% T**	**70% I**	**70% T**	**100% I**	**100%T**
Characteristic						
MOISTNESS	3.65	3.90	4.10	4.21	3.40	4.06
TENDERNESS	4.67	4.48	4.74	5.00	4.30	4.75
CHOCOLATE FLAVOR	4.66	4.68	4.63	4.52	4.40	* 5.17
CELL SIZE	4.55	3.58	4.44	4.73	4.94	4.38

All scores are means based on 2 replication judgings by each of 6 judges.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

Moistness: 1 = very dry, 9 = very moist
Tenderness: 1 = very tough, 9 = very tender
Chocolate Flavor: 1 = very weak, 9 = very strong
Cell Size: 1 = very small, 9 = very large

counterparts. Direct comparison between microwaved and conventionally baked cakes is not possible here, but enough moisture may have been lost during microwave cooking to influence the panelists' assessments of both moistness and tenderness. Possibly, moistness ratings were also affected by the level of fat in the cake formula; McGee (1984) noted that fat made cakes "moister and smoother in the mouth". These cakes without eggs may therefore have seemed less moist and less tender to panelists.

The cake rated least moist was in the oven for the shortest amount of time. A cake cooked at 100% in the inverter oven (Table 8) was judged less moist than cakes cooked at 50% (Medium) power in either oven. It had been expected that cakes cooked for the longest time, even at lower power level, would be least moist.

No cake came near having a chocolate flavor characterized as "very strong" (Tables 6-7). However, the only significant difference in cake sensory panel scores occurred in this category. Cakes cooked at High power in the transformer oven had significantly stronger chocolate flavor than those cooked at 100% in the inverter oven (Table 8).

As with all cake sensory categories, the mean scores for cell size fell within a rather narrow range (3.58 up to

4.94), indicating a cell size smaller rather than larger. No significant difference were found in cell size within oven type or between ovens. The investigator observed some tunnelling, in accordance with the findings of Hill and Reagan (1982). Top surfaces of cakes were uneven, in agreement with the same researchers. The investigator found, however, that power level at which a cake was cooked was directly proportional to unevenness of top surface and cell size on the cake's top crust.

There were also "crowns" on all microwaved cakes. These "crowns" were small circles (about 5 cm. diameter) in the top center crust of the cake. These circles would be risen above definite but very narrow trenches in the surrounding crust. The "crown" was often slightly higher than the remaining cake surface, but not always, and not consistently at power level or oven type. McGee (1984) describes a "ring-like layering" in a cake, caused by uneven heating, where liquid batter heated quickly rises along the outer edges, spreads across the cake top, and plunges downward into the center. Certainly, the microwaves used in this study have "hot spots" in their centers, and both probably heat unevenly enough for such a phenomenon to occur.

Instrumental

Instrumental testing results for cakes are displayed in Tables 9-10 and Figures 7, 8, and 9. In both ovens, percent weight loss was greatest at 100% (High) power and least at 50%(Medium) power, although differences were not significant. Higher power level may have resulted in greatest percent weight loss, despite a shorter cooking time (see Table 10).

The greatest percent weight loss accompanied the instrumentally most tender cakes, in agreement with sensory panel results (Table 8). While differences were not significant, cakes cooked at 100% (High) power were most tender instrumentally, followed by those cooked at 70% (Medium High) power (see Table 9). Cakes with the least percent weight loss (those cooked at 50% or Medium power) were least tender in compression testing. Cakes cooked for a longer time, even at a lower power level, might have undergone excessive denaturation of gluten, resulting in a tougher product. Post heating temperatures were fairly consistent in cakes, but only by oven type and thermometer probe placement. In all cakes cooked in the inverter oven (Figures 7-9), the probe placed in the cake center recorded a slight temperature rise, followed by a gradual downturn.

TABLE 9

MEAN INSTRUMENTAL SCORES FOR CAKES

PREPARED IN INVERTER AND TRANSFORMER OVENS

INVERTER

Power Level	50%	70%	100%
Characteristic			
% WEIGHT LOSS	4.72_a	5.32_a	5.64_a
TENDERNESS	251.50_a	160.50_a	154.00_a

TRANSFORMER

Power Level	Medium	Medium High	High
Characteristic			
% WEIGHT LOSS	5.84_a	5.92_a	6.42_a
TENDERNESS	207.50_a	185.50_a	160.00_a

% Weight loss means are based on 2 replications of each cake.

Tenderness means (G/F) are based on 2 replications of each cake; only mean scores for center cake squares are listed.

Within rows, different letters indicate scores significantly different at $\alpha = .05$.

Higher tenderness scores indicate a less tender product.

TABLE 10

MEAN INSTRUMENTAL SCORE COMPARISON BETWEEN CAKES

PREPARED IN INVERTER AND TRANSFORMER OVENS

POWER LEVEL

	Medium		Medium High		High	
	50% I	50% T	70% I	70% T	100% I	100%T
Characteristic						
% WEIGHT LOSS	4.72	5.84	5.32	5.92	5.64	6.42
TENDERNESS	251.50	207.50	160.50	185.50	154.00	160.00

% Weight loss means and tenderness means (G/F) are based on 2 replications.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

Higher tenderness scores indicate a less tender product.

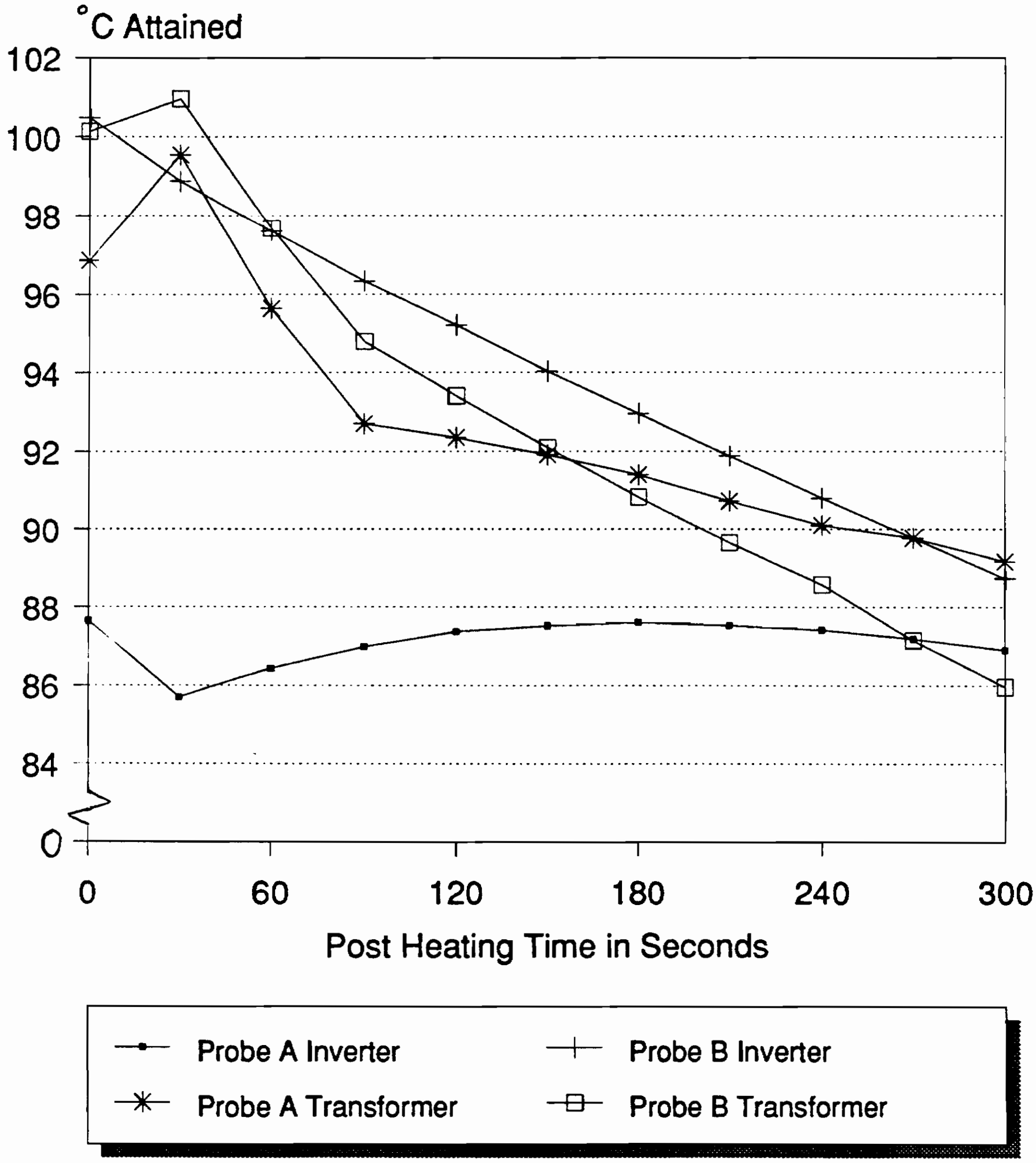

Figure 7: Post Heating Temperature Rise In Cakes Cooked at 50% (Medium) Power

"A" indicates thermometer probe placement in cake center
"B" indicates thermometer probe placement near cake edge
See Instrumental Testing Section

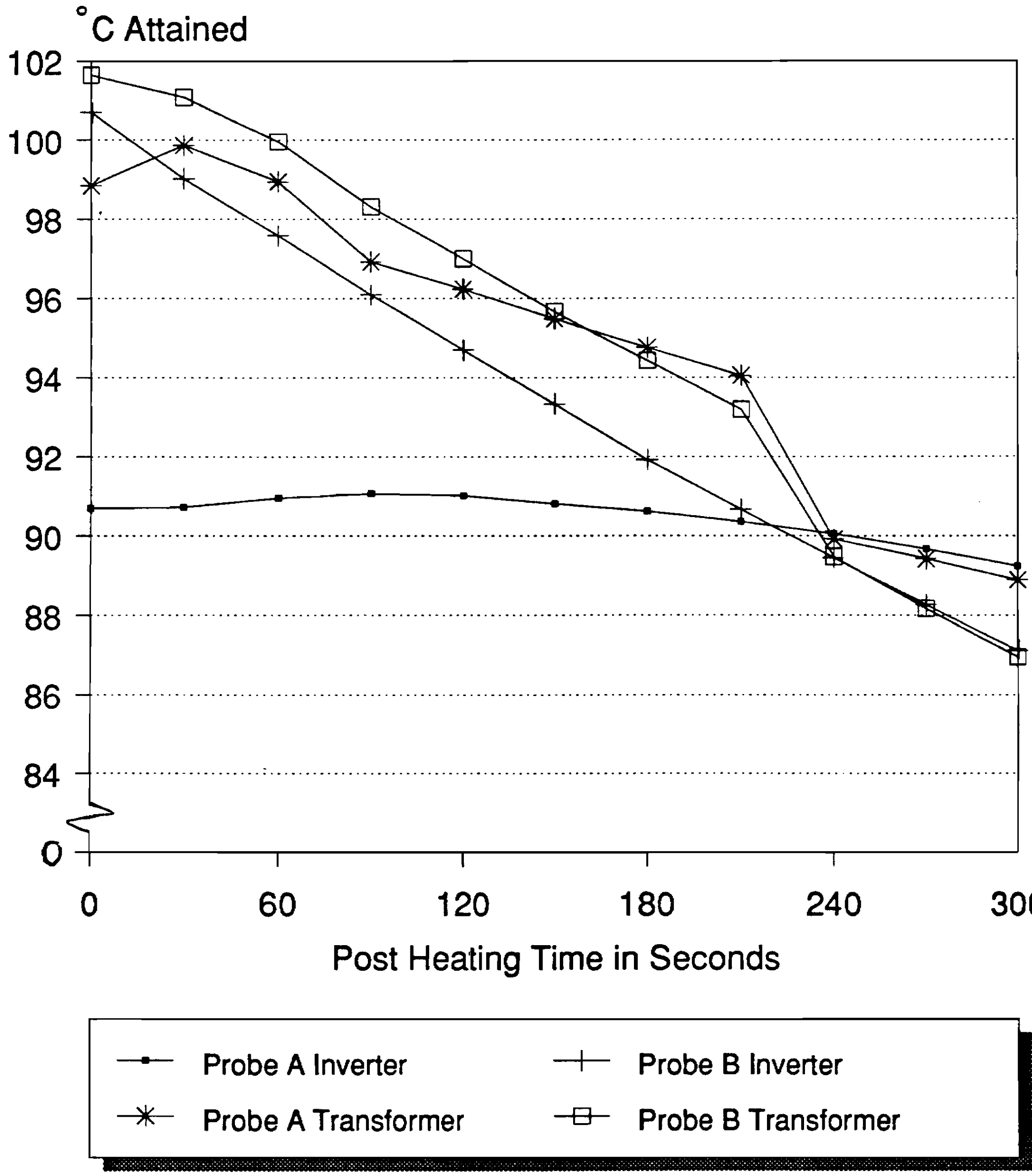

Figure 8: Post Heating Temperature Rise
In Cakes Cooked at 70% (Medium High) Power

"A" indicates thermometer probe placement in cake center
"B" indicates thermometer probe placement near cake edge
See Instrumental Testing Section

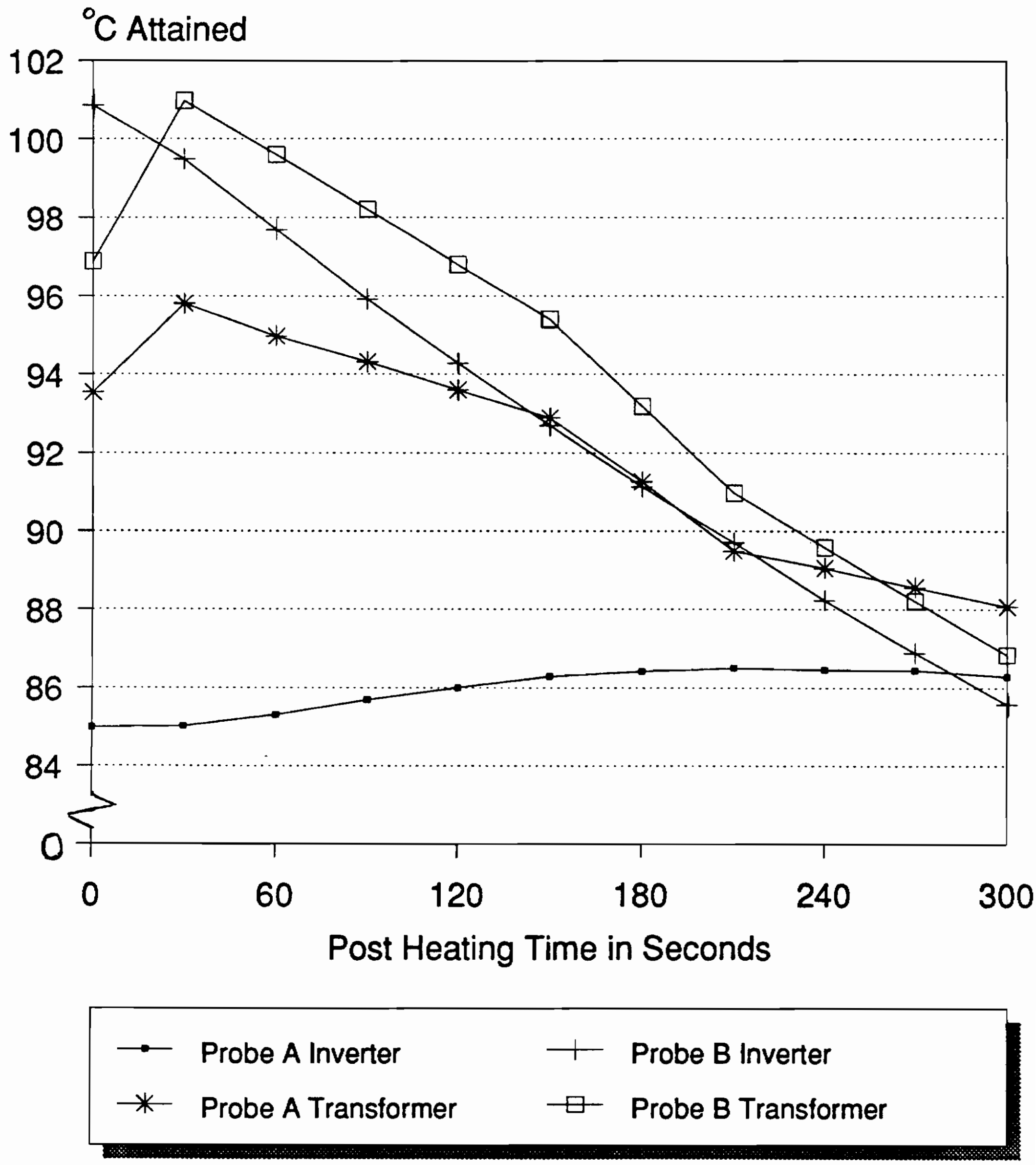

Figure 9: Post Heating Temperature Rise In Cakes Cooked at 100% (High) Power

"A" indicates thermometer probe placement in cake center
"B" indicates thermometer probe placement near cake edge
See Instrumental Testing Section

Probes placed nearer the cake edge in the inverter oven recorded no rise and a substantial fall in temperature during the 5 minute charted period.

In both ovens, the temperatures nearer the cake edges were higher than those in the center at the time of removal from the oven and lower than the center temperatures at the end of the recording period. In the inverter oven, these temperature differentials were 10-15o C at the beginning of the measured period. Differences between center and edge temperatures were less than 5o C for the cakes cooked in the transformer oven at the outset of the charted period.

GROUND BEEF PATTIES

Sensory

Panelists commented most frequently on the lack of beef flavor in the ground beef patties. One panelist stated that the patties resembled "beef flavored water" in taste. Probably, the lack of flavor was at least partially due to the lack of Maillard browning. Browning contributes color as well as taste and texture; in accordance with this, other panelist criticisms included lack of browning. Panelists also complained of patty toughness, perhaps resulting from length of cooking (patties were cooked to the well-done stage) or from the large percent weight loss of moisture and/or fat during cooking. Possibly, cooking losses may have drained enough fat from the patties so that the beef flavor came through only partially or minimally.

Mean sensory scores for beef patties are listed in Tables 11-13. The patties judged most tender were cooked at High power in the transformer oven; those judged most chewy were cooked at Medium power in the same oven. However, there were no significant differences in tenderness among patties cooked in either type of oven or at any power level. It had been expected that those patties cooked longest (at 50% or Medium power) would be least tender because of prolonged exposure to energy. Possibly, beef is less sensitive to energy level, especially as it is a fairly uniform food with fat and water added. Fluid loss of moisture, fat, and juices may be at a rate independent of microwave power level.

Those patties judged least beefy in flavor were also cooked at High power in the transformer oven (Tables 12 and 13). Here again, there were no significant differences in beefiness of patty flavor by power level or oven type, although patties cooked at all power levels in the inverter oven were rated beefier in flavor than those cooked in the transformer oven. No patty cooked at any power level in

TABLE 11

MEAN SENSORY SCORES FOR GROUND BEEF PATTIES COOKED IN INVERTER OVEN AT 3 POWER LEVELS*

Characteristic	POWER LEVELS 50% (Medium)	70% (Medium High)	100% (High)
TENDERNESS	5.21_a (1.58)	5.38_a (1.21)	5.88_a (1.89)
FLAVOR	5.77_a (1.81)	5.36_a (0.98)	5.09_a (1.83)
JUICINESS	5.86_a (1.35)	5.98_a (1.65)	4.93_a (2.10)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α=.05.

Tenderness: 1 = not at all chewy, 9 = very chewy
Flavor: 1 = not at all beefy, 9 = very beefy
Juiciness: 1 = not at all juicy, 9 = very juicy

TABLE 12

MEAN SENSORY SCORES FOR GROUND BEEF PATTIES

COOKED IN TRANSFORMER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	50% (Medium)	70% (Medium High)	100%(High)
TENDERNESS	6.16_a (1.47)	5.61_a (1.29)	4.38_a(1.32)
FLAVOR	5.05_a (1.83)	4.95_a (1.21)	4.36_a(1.46)
JUICINESS	3.78_a (1.27)	5.75_a (1.68)	6.57_b(1.81)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α=.05.

Tenderness: 1 = not at all chewy, 9 = very chewy
Flavor: 1 = not at all beefy, 9 = very beefy
Juiciness: 1 = not at all juicy, 9 = very juicy

TABLE 13

MEAN SENSORY SCORES OF GROUND BEEF PATTIES COOKED IN INVERTER AND TRANSFORMER OVENS

POWER LEVEL

	Medium		Medium High		High	
	50% I	50% T	70% I	70% T	100% I	100%T
Characteristic						
TENDERNESS	5.21	6.16	5.38	5.61	5.88	4.38
FLAVOR	5.77	5.05	5.36	4.95	5.09	4.36
JUICINESS	5.86 *	3.78	5.98	5.75	4.93	6.57

All scores are means based on 2 replication judgings by each of 6 judges.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

Tenderness: 1 = not at all chewy, 9 = very chewy
Flavor: 1 = not at all beefy, 9 = very beefy
Juiciness: 1 = not at all juicy, 9 = very juicy

either oven came anywhere near a flavor rating of "very beefy" (see Table 13).

The significant differences among beef patty sensory scores occurred in the juiciness category. Patties cooked at High (100%) in the transformer oven were rated most juicy of all patties (Table 12), and were significantly juicier than patties cooked at other power levels in that oven. This was not true in the inverter oven (Table 11) where the patties cooked at 70% power were judged juiciest. In the inverter oven, however, there were no significant differences among juiciness ratings by power level. Possibly, in the transformer oven, patties cooked for the shortest time, even at the highest power level, had less of a chance to lose moisture, fat and juices.

In power level comparisons between oven types, again the only significant difference occurred in the juiciness category. Patties cooked at 50% (Medium) power in the inverter oven were significantly more juicy than their counterparts cooked in the transformer oven (Table 13).

Instrumental

Instrumental testing results for ground beef patties are displayed in Tables 14-15 and Figures 10-12. Greatest percent weight loss occurred in the inverter oven in patties cooked at 50% power. Least percent weight loss was found in patties cooked at High (100%) power in the transformer oven (Table 14). There were no significant differences among power levels or between oven types. However, these patties followed the trend expected of those cooked for sensory evaluation. That is, those patties cooked for the longest time (at 50% or Medium power) experienced overall greatest percent weight loss (Table 15).

Patty tenderness (measured instrumentally) yielded inconsistent results (Table 14). Patties cooked at Medium power in the transformer oven and measured near the edge were least tender. Tenderness scores fluctuated widely. In the transformer oven, patties cooked at Medium High power and measured at center were significantly more tender than those cooked at other power levels in the same oven and measured in the same area. This is in conflict with patty sensory evaluation, where no differences were significant in tenderness (Tables 11-13). This difference in tenderness also did not extend to the inverter oven. However, those patties cooked at 50% power in the inverter oven and measured near the edge were significantly more tender than their transformer-cooked counterparts (Table 15).

Post heating temperature rise is shown in Figures 10-12. Figure 10 is a chart of the "rise" in patties cooked at 50% (Medium) power, notable chiefly for the lack of temperature rise after heating. In both ovens, the interior center patty temperature both started and ended the charted period at higher level than the patty temperatures taken nearer the edge. While both microwaves used in this study had "hot spots" at their turntable centers (the location of the patties discussed here), positioning of the patties was such that the two locations at which "center" and "edge" temperatures were taken were not that physically distant.

Some post heating temperature rise did occur in patties cooked at 70% (Medium High) power (see Figure 11). At this power level in both ovens, temperatures taken in patty centers rose, although the rise was slight. In the inverter oven, the temperature fell, then rose, peaking at 90 seconds and then falling for the remainder of the charted period. In the transformer over, the patty center temperature rose gradually, peaking at about 180 seconds post heating before falling slightly. When temperatures were taken near patty edges, however, results differed to a greater extent. Patties cooked in the inverter oven experienced no post heating temperature rise. Those cooked in the transformer oven peaked quickly, at about 30 seconds post heating, then

TABLE 14

MEAN INSTRUMENTAL SCORES FOR GROUND BEEF PATTIES

PREPARED IN INVERTER AND TRANSFORMER OVENS

	INVERTER		
Power Level	50%	70%	100%
Characteristic			
% WEIGHT LOSS	34.09_a	33.67_a	32.11_a
TENDERNESS (center)	159.50_a	146.37_a	171.63_a
(edge)	148.75_a	141.25_a	148.87_a

	TRANSFORMER		
Power Level	Medium	Medium High	High
Characteristic			
% WEIGHT LOSS	33.67_a	33.48_a	31.72_a
TENDERNESS (center)	160.00_a	137.63_b	178.62_a
(edge)	189.75_a	162.37_a	171.25_a

% Weight loss and tenderness means (G/F) are based on 2 replications for each of 4 patties.

Within rows, different letters indicate scores significantly different at $\alpha = .05$.
Higher tenderness scores indicate a less tender product.

TABLE 15

MEAN INSTRUMENTAL SCORE COMPARISON BETWEEN GROUND BEEF PATTIES PREPARED IN INVERTER AND TRANSFORMER OVENS

	POWER LEVEL					
	Medium		Medium High		High	
Characteristic	50% I	50% T	70% I	70% T	100% I	100%T
% WEIGHT LOSS	34.09	33.67	33.67	33.48	32.11	31.72
TENDERNESS (center)	159.50	160.00	146.37	137.63	171.63	178.62
(edge)	148.75	* 189.75	141.25	162.37	148.87	171.25

% Weight loss means and tenderness means (G/F) are based on 2 replications for each of 4 patties.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

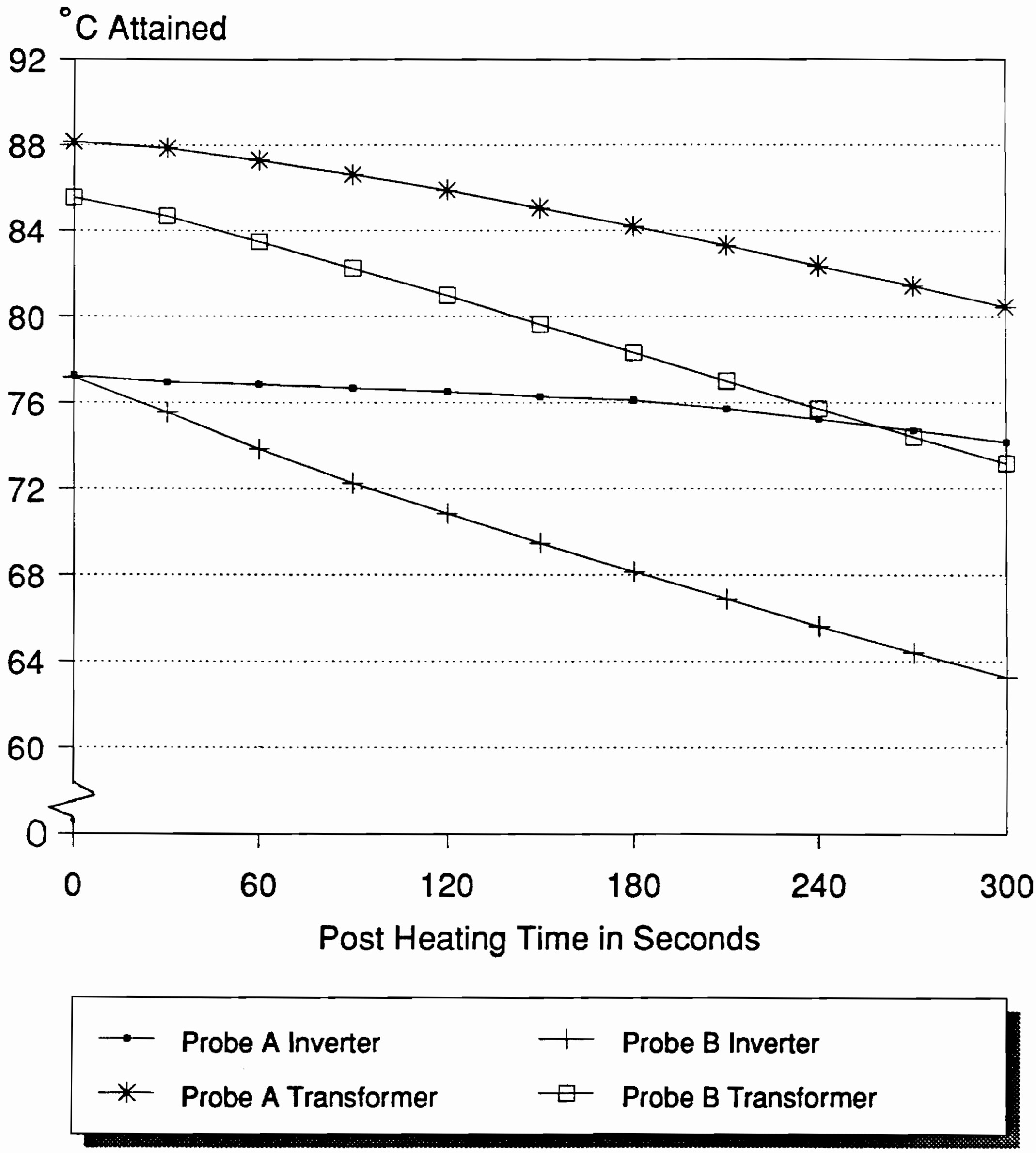

Figure 10: Post Heating Temperature Rise
In Ground Beef Patties Cooked at 50% (Medium) Power

"A" indicates thermometer probe placement in patty center
"B" indicates thermometer probe placement near patty edge
See Instrumental Testing Section

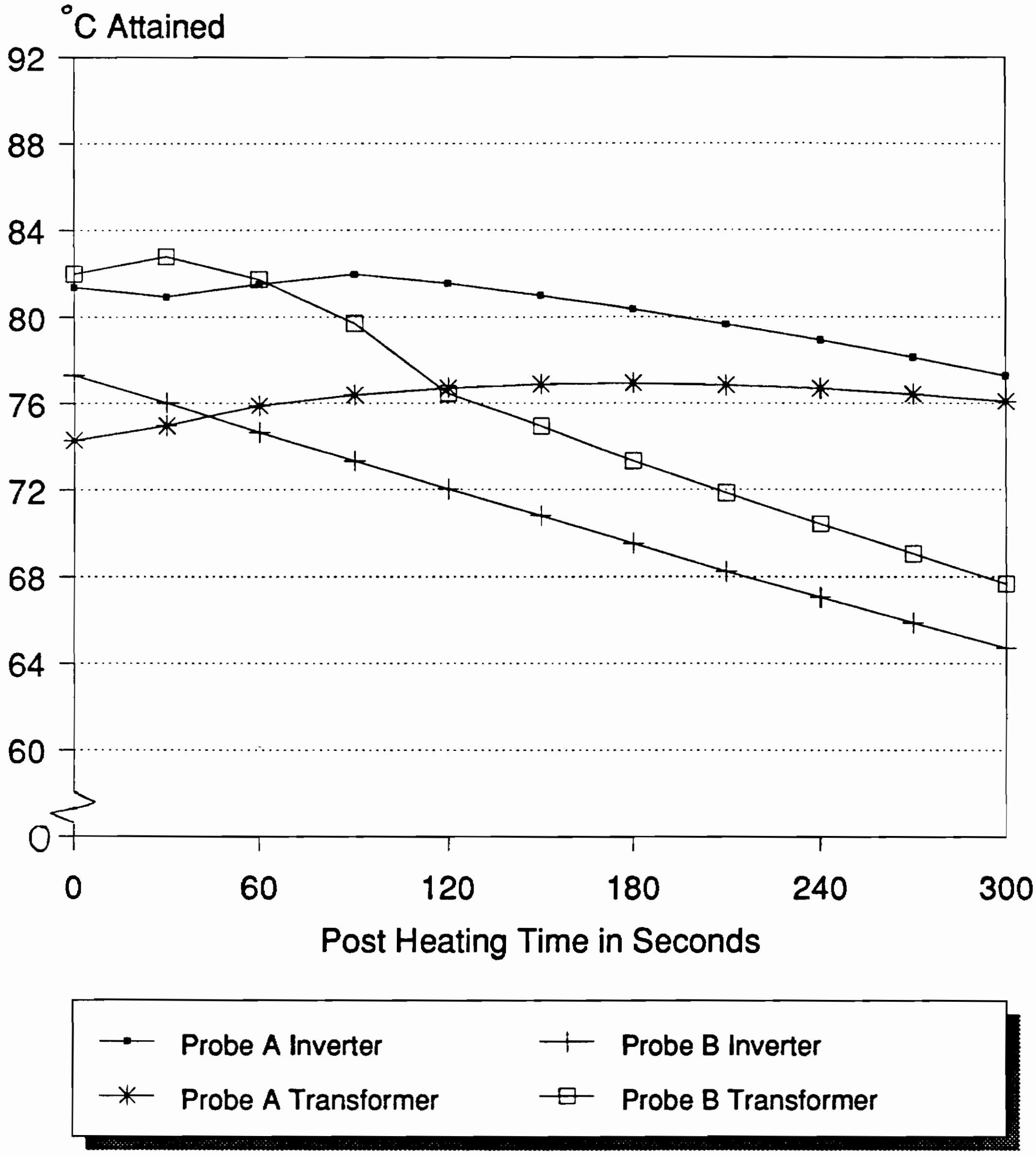

Figure 11: Post Heating Temperature Rise
In Ground Beef Patties Cooked at 70% (Medium High) Power

"A" indicates thermometer probe placement in patty center
"B" indicates thermometer probe placement near patty edge
See Instrumental Testing Section

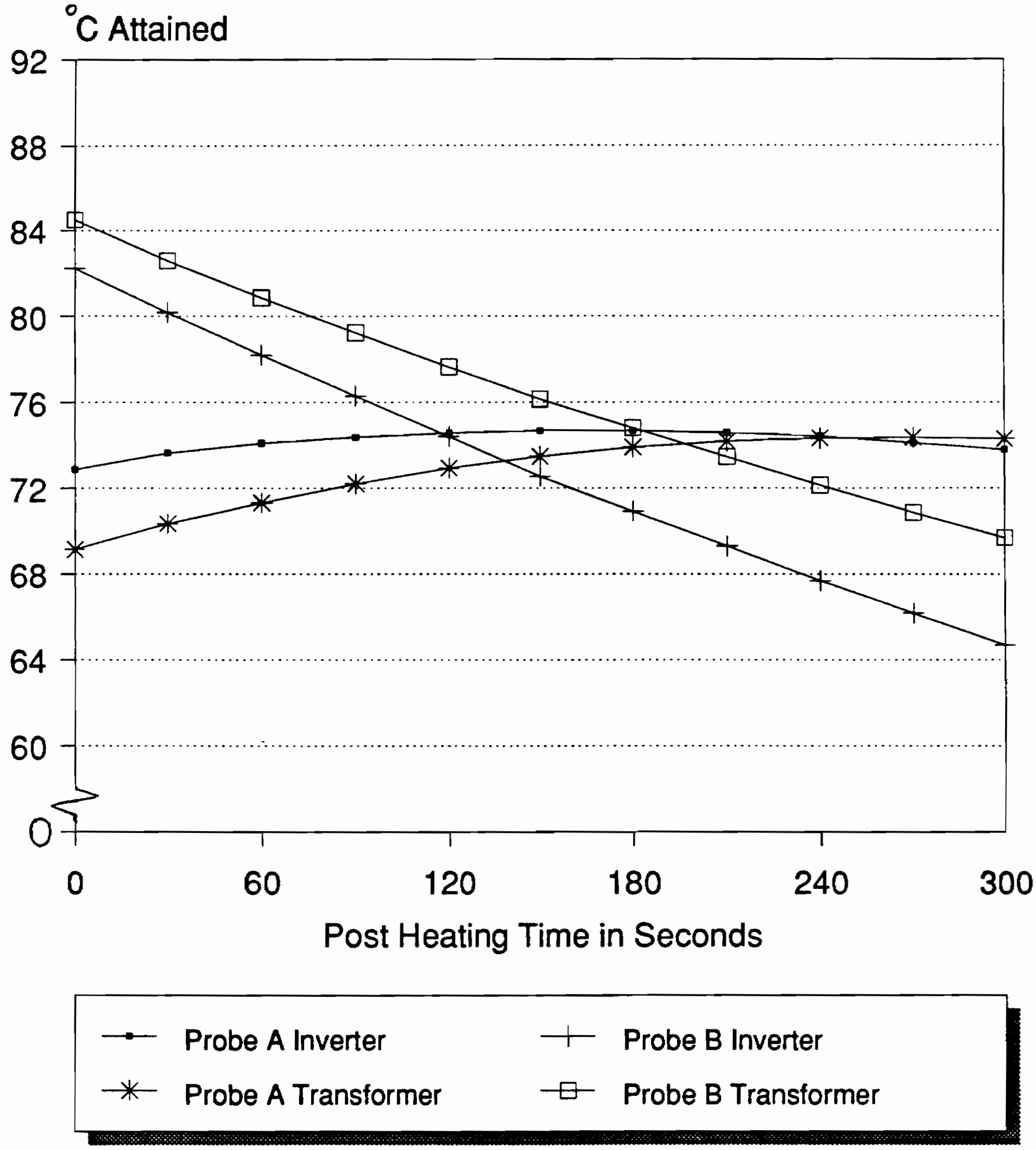

Figure 12: Post Heating Temperature Rise
In Ground Beef Patties Cooked at 100% (High) Power

"A" indicates thermometer probe placement in patty center
"B" indicates thermometer probe placement near patty edge
See Instrumental Testing Section

fell for the remainder of the charted period. In both ovens, temperatures taken at patty centers were lower at the beginning of the measured period than those taken near edges, but higher at the period's end.

These results are similar to those obtained for patties cooked at 100% (High) power (Figure 12). Here, however, there were no post heating temperature rises near patty edges in either oven. Again, at this power level, center patty temperatures started lower but ended higher at the termination of the charted period. Here, in both ovens, center patty temperatures increased gradually before falling slightly.

POTATO

Sensory

Potatoes were selected for this study as a plant cell system of uniform density. According to the sensory panel, however, the microwaved potatoes were anything but uniform. The most frequent comment about this food was that it was unevenly cooked. Parts were said to be hard or crunchy; other parts within the same sample would be done or even overdone and mushy. Panelists noted unevenness of cooking despite the presence of a microwave turntable to rotate the food and despite the fact that potatoes were cooked singly. Certainly, at least part of the uneven cooking must be attributed to potato shape. While the vegetable's density may have been uniform, potatoes do not grown into evenly-shaped tubers. Because of this, and because the potatoes were not cut into uniform pieces to allow easier and faster microwave penetration, the potatoes emerged from the microwaves unevenly cooked.

Mean sensory scores for potatoes are show in Tables 16-18. There were no unanimous trends within cooked potatoes; no one power level seemed to provide tubers of greatest or least color, tenderness, or moistness. In the transformer oven, the potato judged whitest in color was cooked at High (100%) power; that judged least white was cooked at Medium High (70%) power, but differences were not significant (see Table 17). These results were reversed in the inverter oven, with the potato rated whitest having been cooked at 70% (Medium High) power (Table 16). The least white potato was cooked at 100% (High) power; this potato was significantly less white than those cooked at other power levels, but only for the inverter oven. Note in Table 18 that the potato cooked at 70% power in the inverter oven was rated significantly whiter than that cooked at the same power level in the transformer oven. Results in this category

TABLE 16

MEAN SENSORY SCORES FOR POTATOES COOKED IN INVERTER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	50% (Medium)	70% (Medium High)	100%(High)
COLOR	5.14_a (0.99)	5.68_a (0.82)	4.57_b(0.98)
TENDERNESS	5.18_a (1.22)	5.00_a (1.41)	4.94_a(1.15)
MOISTNESS	4.10_a (1.02)	4.73_b (0.90)	3.84_a(0.75)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α =.05.

Color: 1 = less white, 9 = more white
Tenderness: 1 = very hard, 9 = very soft
Moistness: 1 = very dry, 9 = very moist

TABLE 17

MEAN SENSORY SCORES FOR POTATOES COOKED IN TRANSFORMER OVEN AT 3 POWER LEVELS*

Characteristic	POWER LEVELS 50% (Medium)	70% (Medium High)	100% (High)
COLOR	4.46_a (2.39)	3.99_a (1.17)	5.39_a(1.15)
TENDERNESS	6.23_a (0.42)	4.39_b (1.32)	5.32_a(1.81)
MOISTNESS	5.13_a (1.51)	4.35_a (1.01)	4.57_a(1.41)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α=.05.

Color: 1 = less white, 9 = more white
Tenderness: 1 = very hard, 9 = very soft
Moistness: 1 = very dry, 9 = very moist

TABLE 18

MEAN SENSORY SCORES OF POTATOES COOKED IN INVERTER AND TRANSFORMER OVENS

	POWER LEVEL					
	Medium		Medium High		High	
Characteristic	50% I	50% T	70% I	70% T	100% I	100%T
COLOR	5.14	4.46	5.68	* 3.99	4.57	5.39
TENDERNESS	5.18	* 6.23	5.00	4.39	4.94	5.32
MOISTNESS	4.10	5.13	4.73	4.35	3.84	4.57

All scores are means based on 2 replication judgings by each of 6 judges.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at $\alpha = .05$.

Color: 1 = less white, 9 = more white
Tenderness: 1 = very hard, 9 = very soft
Moistness: 1 = very dry, 9 = very moist

were, overall, inconclusive.

The same cannot be said in the tenderness category. For both ovens, potatoes cooked at 50% (Medium) power were rated softer than those cooked at other power levels (seen Tables 16 and 17). In the inverter oven, potatoes cooked at 100% power were rated hardest, but no differences were significant. In the transformer oven, however, potatoes cooked at Medium High (70%) power were significantly harder than those cooked at other power levels. It had been expected that potatoes exposed to energy for the longest time (those cooked at 50% or Medium power) would be softest; it is not known why differences were significant for only one oven type. Differences in tenderness between oven types were significant only at the 50% (Medium) level, where the transformer oven potato was significantly softer than the tuber cooked in the inverter oven (Table 18).

For the inverter oven, mean sensory scores for moistness were lower indicating some degree of dryness in the cooked product. The potato cooked at 70% power was significantly more moist than those cooked at other power levels. This was not the case in the transformer oven, where scores were, overall, slightly higher. In this oven, the potato cooked at Medium (50%) power was judged most moist, but no differences were significant. It had been expected that potatoes cooked for the shortest length of time, even at High (100%) power, would have had the least loss of moisture, but that is not what the sensory panel found. There were no significant differences within similar power levels between oven types (Table 18).

Instrumental

Instrumental testing results are displayed in Tables 19- 20. Instrumental results were also inconsistent in both categories. It had been expected that the potatoes subjected to energy for the longest time (those cooked at 50% or Medium power), would have had the greatest moisture evaporation and thus highest percent weight loss. This was true in the inverter oven, but not in the transformer microwave. By extension of the theory, the potato cooked for the shortest length of time (at 100% or High power) should have experienced lowest percent weight loss. This did not occur in the inverter oven, but did hold true in the transformer oven (Table 19). Additionally, no differences were significant, either between power levels or oven type (Table 20).

Mean tenderness scores were highest at 100% power in the inverter oven, and at Medium (50%) power in the

TABLE 19

MEAN INSTRUMENTAL SCORES FOR POTATOES

PREPARED IN INVERTER AND TRANSFORMER OVENS

INVERTER

Power Level	50%	70%	100%
Characteristic			
% WEIGHT LOSS	10.31_a	10.03_a	10.11_a
MEAN TENDERNESS*	44.00_a	50.33_a	54.00_a

TRANSFORMER

Power Level	Medium	Medium High	High
Characteristic			
% WEIGHT LOSS	11.94_a	13.27_a	11.44_a
MEAN TENDERNESS*	52.00_a	48.17_a	50.00_a

*"Mean tenderness" is an average score computed from the three points of tenderness measurement per potato - See Instrumental Testing Section.

% Weight loss and tenderness means are based on 2 replications per power level and oven type.

Within rows, different letters indicate scores significantly different at α =.05.

TABLE 20

MEAN INSTRUMENTAL SCORE COMPARISON BETWEEN POTATOES PREPARED IN INVERTER AND TRANSFORMER OVENS

	POWER LEVEL					
	Medium		Medium High		High	
Characteristic	50% I	50% T	70% I	70% T	100% I	100%T
% WEIGHT LOSS	10.31	11.94	10.03	13.27	10.11	11.44
MEAN TENDERNESS*	44.00	52.00	50.33	48.17	54.00	50.00

*"Mean tenderness" is an average score computed from the three points of tenderness measurement per potato - See Instrumental Testing Section.

% Weight loss and tenderness means are based on 2 replications per power level and oven type.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

Higher tenderness scores indicate a less tender product.

transformer oven (higher scores indicate a less tender product). The most tender potatoes were those cooked at Medium High (70%) power in the transformer oven, and 50% (Medium) power in the inverter oven. Again, differences were not significant between power levels or oven type.

Because potatoes are an agricultural, grown, largely unprocessed product, there are bound to be great variations between individual tubers. There may be variation to a lesser extent within the individual specimens. It is believed that this variability is at least partially accountable for the inconsistencies found among potatoes in this study.

Post heating temperature rise is recorded in Figures 13- 15. It had been expected that this rise would be pronounced in potatoes because of their overall mass and volume, but such was not the case. There were few examples of post heating temperature rise; the only sharp temperature rise occurred at 50% (Medium) power in the inverter oven (see Figure 13). The probe placed in the potato center recorded a temperature rise of just over 1.6° C in 30 seconds. After that, however, the temperature fell steadily. At this power level, as well as all others, the temperature near the potato edge was often higher than that in the center at the beginning of the charted period. The

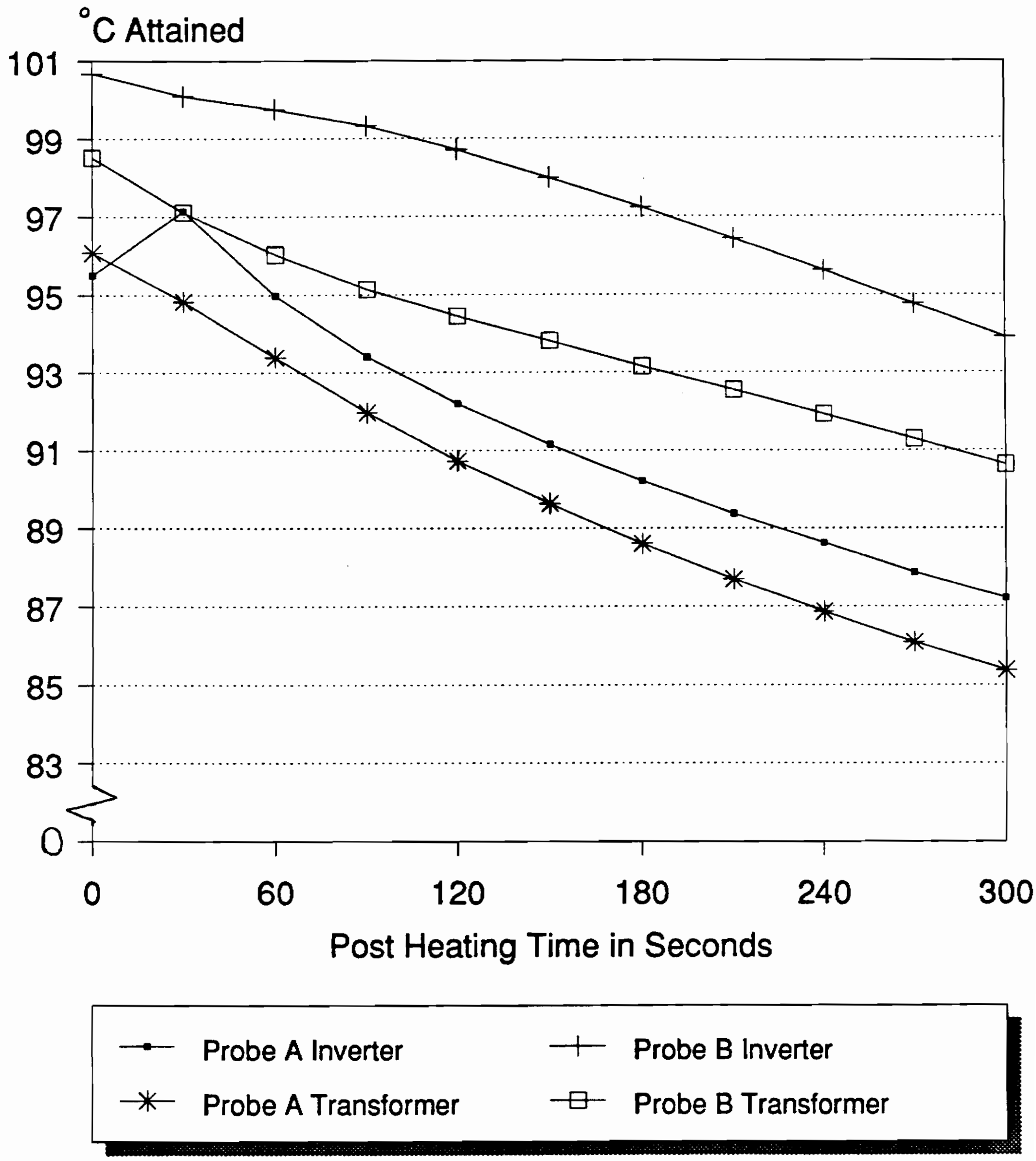

Figure 13: Post Heating Temperature Rise In Potatoes Cooked at 50% (Medium) Power

"A" indicates thermometer probe placement in potato center
"B" indicates thermometer probe placement near potato edge
See Instrumental Testing Section

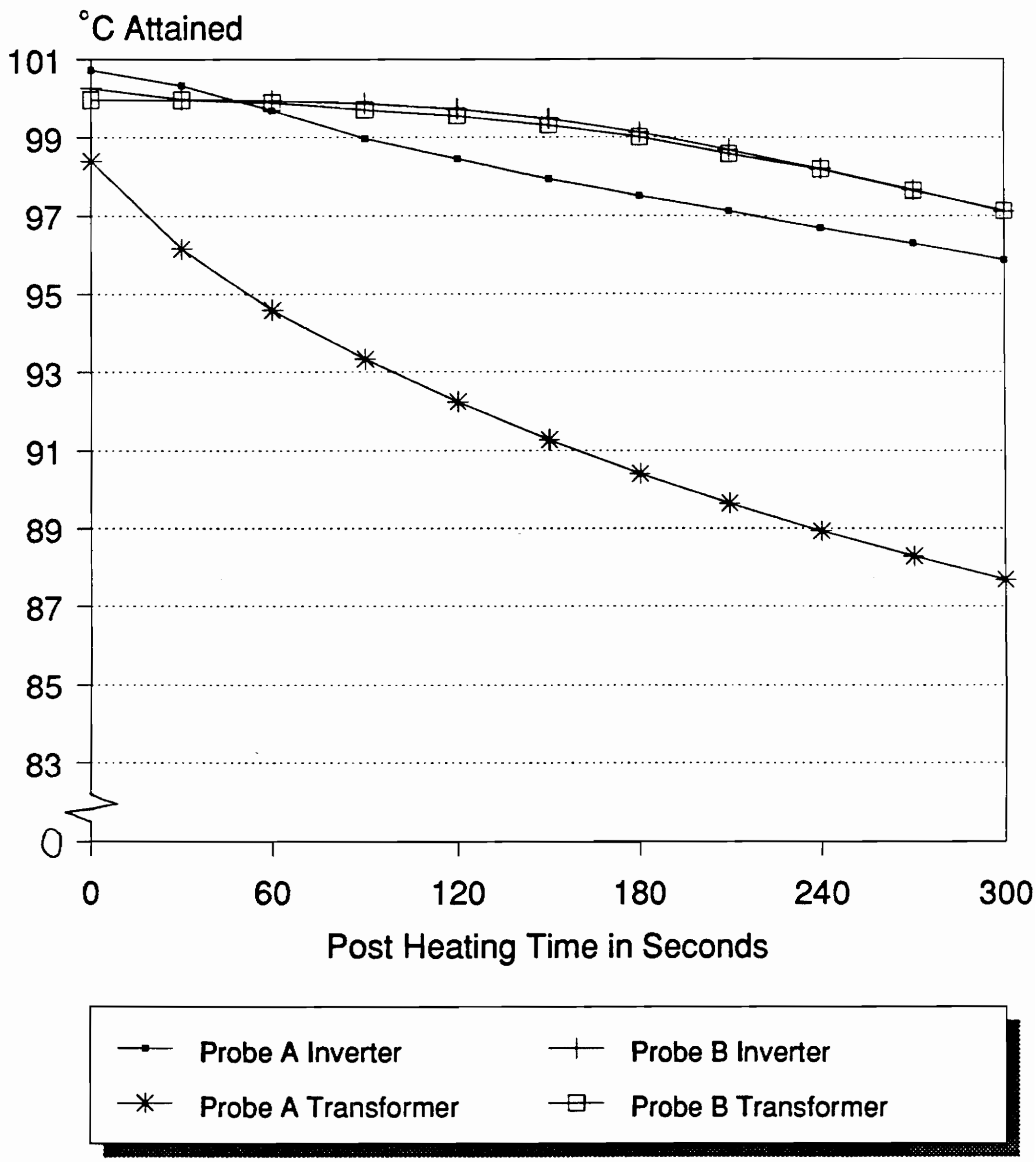

Figure 14: Post Heating Temperature Rise
In Potatoes Cooked at 70% (Medium High) Power

"A" indicates thermometer probe placement in potato center
"B" indicates thermometer probe placement near potato edge
See Instrumental Testing Section

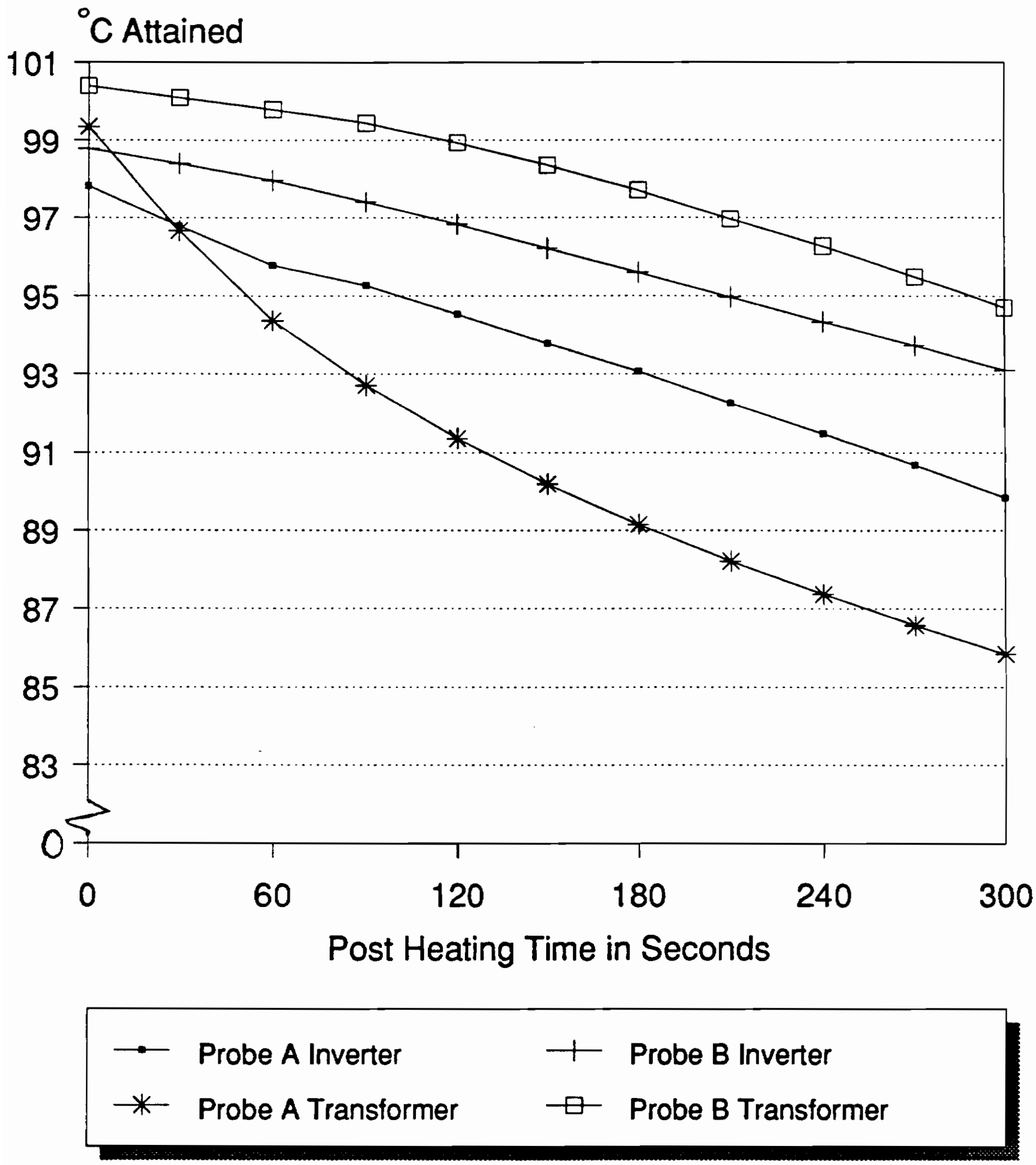

Figure 15: Post Heating Temperature Rise In Potatoes Cooked at 100% (High) Power

"A" indicates thermometer probe placement in potato center
"B" indicates thermometer probe placement near potato edge
See Instrumental Testing Section

near-edge temperature was always higher at the end of this period, in both ovens and at all power levels. Probable cause for this is potato shape. Most often, potatoes tend to be slightly thinner toward their edges, in a tapering of volume from the potato middle. More energy can therefore be absorbed more quickly in this less bulky region, leading to higher temperature there.

Post heating temperature rise at 70% (Medium High) power is shown in Figure 14. At this power level, there was a very slight post heating temperature rise for about 30 seconds near the edge of the potato cooked in the transformer oven. There has also a slight rise in the near-edge temperature of the inverter-microwave potato, but this rise came after a slight initial drop.

No post heating temperature rise was recorded at 100% (High) power (Figure 15). As the potatoes were cooked for the shortest time period at this power level, it is possible that the time period was too short to allow a significantly greater amount of energy to accumulate near the potato edge. In this figure, as in Figure 14, it is interesting to note the temperature disparity between the two probe locations (within the same potato) for potatoes cooked in the transformer oven. These temperature gulfs are much wider in these two figures than for potatoes cooked in the inverter oven. Possibly, this suggests greater unevenness of heating in the transformer oven, but the phenomenon did not occur at 50% (Medium) power. More likely, these gulfs were due to natural variation among or within the potatoes themselves.

BROCCOLI

Sensory

Broccoli was selected for this study as a vegetable of variable density. Like potatoes, broccoli used in this research is an agricultural product, minimally processed before cooking. There was considerable variation in shape and weight among broccoli pieces, contributing to inconsistent results.

Because broccoli is so variable, it had been expected that panelists would find broccoli samples unevenly cooked at times. In fact, unevenness of the cooked product was the panel's most frequent comment. Panelists sometimes complained of mushy florets and hard, tough stalks, within one sample. Panelists also noted that most samples had a bright green color when first cooked. This is in agreement with Bowmen et al (1971) who reported that the color of microwaved broccoli did not differ from that cooked in boiling water. The investigators visual observations did

TABLE 21

MEAN SENSORY SCORES FOR BROCCOLI COOKED

IN INVERTER OVEN AT 3 POWER LEVELS*

Characteristic	50% (Medium)	70% (Medium High)	100%(High)
COLOR	4.94_a (1.38)	5.92_a (1.13)	5.06_a(1.18)
FLAVOR	6.16_a (1.16)	5.29_a (0.71)	5.65_a(0.97)
TEXTURE	3.85_a (1.77)	5.56_a (1.35)	4.43_a(1.63)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α =.05.

Color: 1 = very pale green, 9 = very dark green
Flavor: 1 = not at all fresh, 9 = very fresh
Texture: 1 = not at all woody, 9 = very woody

TABLE 22

MEAN SENSORY SCORES FOR BROCCOLI COOKED IN TRANSFORMER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	50% (Medium)	70% (Medium High)	100%(High)
COLOR	5.41_a (0.53)	4.73_a (1.18)	4.67_a(1.25)
FLAVOR	5.02_a (0.96)	4.80_a (2.01)	5.00_a(0.99)
TEXTURE	2.78_a (1.20)	4.24_b (1.54)	4.30_b(1.50)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α=.05.

Color: 1 = very pale green, 9 = very dark green
Flavor: 1 = not at all fresh, 9 = very fresh
Texture: 1 = not at all woody, 9 = very woody

TABLE 23

MEAN SENSORY SCORES OF BROCCOLI COOKED

IN INVERTER AND TRANSFORMER OVENS

POWER LEVEL

	Medium			Medium High		High		
	50% I		50% T	70% I	70% T	100% I		100%T
Characteristic								
COLOR	4.94		5.41	5.92	4.73	5.06		4.67
FLAVOR	6.16	*	5.02	5.29	4.80	5.65	*	5.00
TEXTURE	3.85		2.78	5.56	4.24	4.43		4.30

All scores are means based on 2 replication judgings by each of 6 judges.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α=.05.

Color: 1 = very pale green, 9 = very dark green
Flavor: 1 = not at all fresh, 9 = very fresh
Texture: 1 = not at all woody, 9 = very woody

not agree with those of Schrumpf and Charley (1975). These researchers described a "collapsed and shrunken appearance" in microwaved broccoli which was not seen in this study. However, the broccoli in this study was in chunks, sealed in a plastic pouch with a small amount of liquid, and frozen, while the 1975 Schrumpf and Charley study used fresh produce.

Mean sensory scores for broccoli are displayed in Tables 21-23. The mean color scores for broccoli did not differ significantly between power level or oven type. The darkest green color was observed by panelists at 70% power in the inverter oven (Table 21) and at Medium (50%) power in the transformer oven (Table 22), but no differences were significant.

Broccoli cooked at 50% (Medium) power in the inverter oven was judged to have the freshest flavor, while that cooked at 70% power had the least fresh flavor (Table 21). In the transformer oven, sensory scores for broccoli flavor were almost equal at Medium and High power. There were few significant differences, except in a power level comparison between ovens (Table 23). At both 50% (Medium) and 100% (High) power, the inverter-microwaved broccoli flavor was rated significantly fresher than its counterpart cooked in the transformer microwave.

Broccoli tenderness was the only category with significant differences between power levels, and then only in one oven. In the inverter oven, the least woody broccoli according to panelist ratings was that cooked at 50% power, while that cooked at 70% power had the woodiest texture (Table 21). In the transformer oven, however, broccoli cooked at Medium (50%) power was significantly less woody in texture than that cooked at other power levels (Table 22). The investigator believed that cooking for a longer period of time, even at a lower power level, might allow for some breakdown of fibers within the vegetable.

Instrumental

Mean instrumental scores for broccoli are displayed in Tables 24-25 and Figures 16-18. Due to reasons discussed at the beginning of the sensory section, significant differences for the tenderness category were not reported since the scores among samples varied to extremes. When calculated, standard deviations in some instances, were larger than the differences between the means; therefore, these scores were also not reported.

A minimal degree of percent weight loss occurred during

TABLE 24

MEAN INSTRUMENTAL SCORES FOR BROCCOLI

PREPARED IN INVERTER AND TRANSFORMER OVENS

INVERTER

Power Level	50%	70%	100%
Characteristic			
% WEIGHT LOSS	0.25_a	0.39_a	0.30_a
TENDERNESS*	886.33	286.67	223.67

TRANSFORMER

Power Level	Medium	Medium High	High
Characteristic			
% WEIGHT LOSS	0.86_a	0.42_a	0.53_a
TENDERNESS*	522.67	499.33	827.00

*Significant differences for Tenderness were not calculated due to fluctuations. See Broccoli Results and Discussion.

% Weight loss and tenderness means (G/F) are based on 2 replications per power level and oven type.

Within rows, different letters indicate scores significantly different at α=.05.

Higher tenderness scores indicate a less tender product.

TABLE 25

MEAN INSTRUMENTAL SCORE COMPARISON BETWEEN BROCCOLI PREPARED IN INVERTER AND TRANSFORMER OVENS

	POWER LEVEL					
	Medium		**Medium High**		**High**	
Characteristic	**50% I**	**50% T**	**70% I**	**70% T**	**100% I**	**100%T**
% WEIGHT LOSS	0.25	0.86	0.39	0.42	0.30	0.53
TENDERNESS*	886.33	522.67	286.67	499.33	223.67	827.00

*Significant differences for Tenderness were not calculated due to fluctuations. See Broccoli Results and Discussion.

% Weight loss and tenderness means (G/F) are based on 2 replications per power level and oven type.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

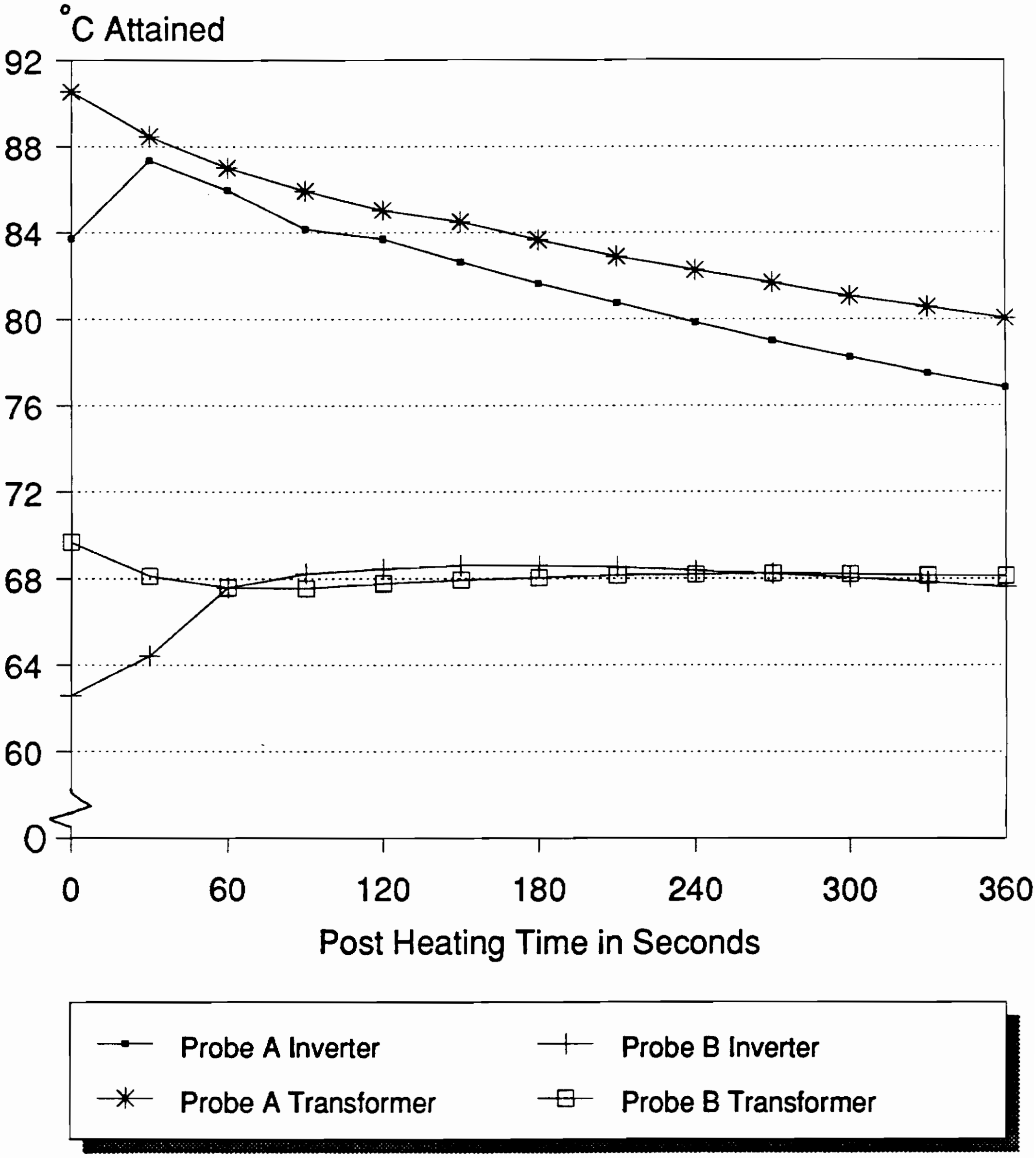

Figure 16: Post Heating Temperature Rise
In Broccoli Cooked at 50% (Medium) Power

"A" indicates thermometer probe placement in package center
"B" indicates thermometer probe placement near package edge
See Instrumental Testing Section

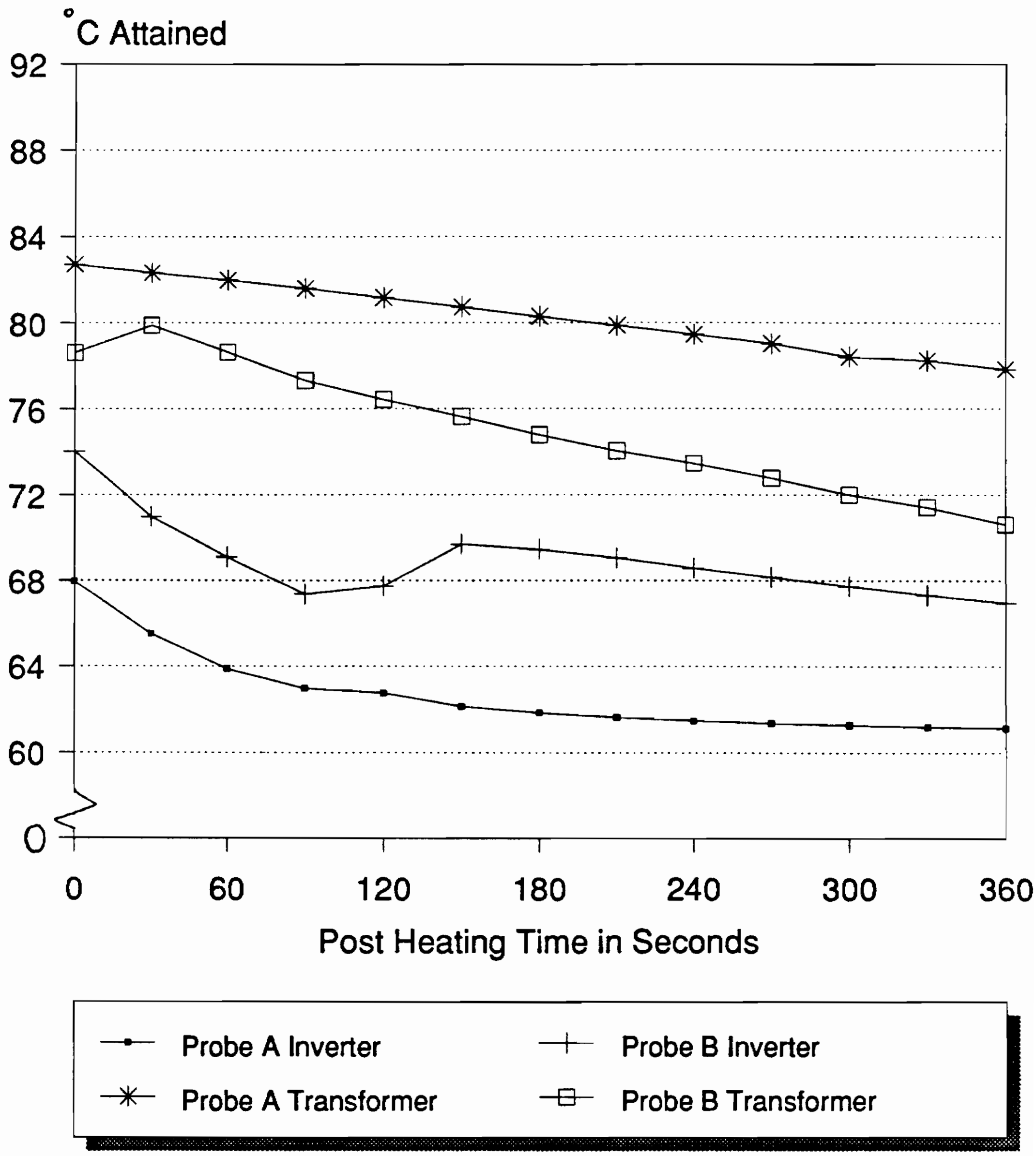

Figure 17: Post Heating Temperature Rise
In Broccoli Cooked at 70% (Medium High) Power

"A" indicates thermometer probe placement in package center
"B" indicates thermometer probe placement near package edge
See Instrumental Testing Section

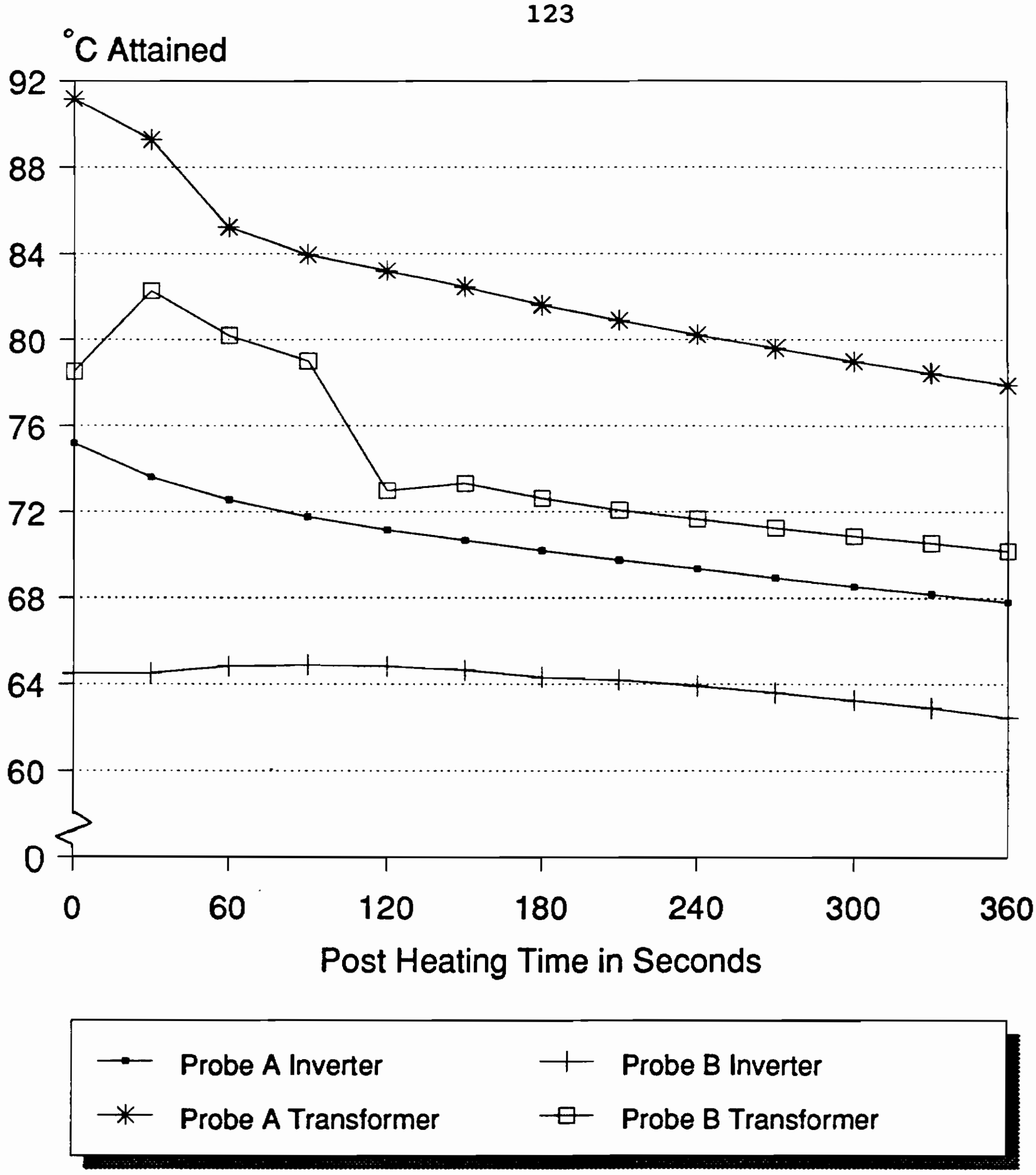

Figure 18: Post Heating Temperature Rise In Broccoli Cooked at 100% (High) Power

"A" indicates thermometer probe placement in package center
"B" indicates thermometer probe placement near package edge
See Instrumental Testing Section

cooking (Table 24). It is true that the broccoli was in sealed plastic pouches, but the small knife slit made in each pouch according to box directions was expected to have allowed for greater moisture/evaporative loss. In the inverter microwave, the greatest percent weight loss occurred at 70% power, while the least was at 50% power. No differences were significant. While there were no significant differences in the transformer microwave either, the loss pattern was slightly different. The broccoli cooked at Medium (50%) power in the transformer microwave had greatest percent weight loss, but a direct relationship between cooking power level and percent weight loss cannot be established as a result of these data.

Post heating temperature rise in broccoli is charted in Figures 16-18. The results are quite inconsistent here, too. In Figure 16, for broccoli cooked at 50% (Medium) power, both probe locations of inverter-cooked broccoli experienced a post heating temperature rise, although the rise was sharp and quick at the center and more gradual near the pouch edge. In the transformer oven, temperatures at the pouch center experienced no post heating rise; temperatures near the pouch edge fell, then rose gradually to nearly the end of the charted period.

At 70% (Medium High) power, results were dissimilar.

There was no post heating temperature rise at the pouch center in either microwave oven. In the inverter microwave, temperatures near the pouch edge fell for 90 seconds, rose for 60 seconds, then fell for the remainder of the charted period. Temperatures near the pouch edge of the transformer-cooked broccoli behaved more typically, rising immediately after heating for 30 seconds, then declining (see Figure 17).

At both 70% (Medium High) and 100% (High) power, both "sets" of temperatures (pouch center and pouch edge) of broccoli cooked in the inverter oven remained lower than the sets of broccoli cooked in the transformer microwave. At 100% (High) power (Figure 18), as at 70% (Medium High) power, there was no post heating temperature rise at the pouch center in either microwave. Near pouch edges, post heating temperature rise was gradual in the inverter oven, peaking at about 90 seconds post heating. In the transformer microwave, temperatures "double peaked" near the pouch edge, falling after 30 seconds post heating and rising to a second, lower peak at 150 seconds post heating.

Post heating temperature rise had not been expected at any power level within either oven. Broccoli pieces, even within a pouch, had not been thought of sufficient mass to retain enough energy for this phenomenon. In addition, the broccoli used was frozen. Harrison (1980) noted that the microwave absorption rate for ice is much less than that for water. It had been expected that energy absorbed by the frozen broccoli and liquid might have been enough to thaw and heat both, but probably insufficient to allow for a rise in temperature after heating.

FROZEN POT PIE

Sensory

Excluding custard, the pot pie drew the most complaints and the most negative comments from panel members. Most mentioned that meat within a sample was hot, while vegetables might be cool and crunchy in texture. Occasionally, a panelist would complain of a sample being half warm and half cold. Crust texture also varied greatly within a pie, from hard to soggy. The investigator's visual observations found that an area variable in size near and around the crust center was usually puffed-up and quite hard, while the crust nearer the pie edges was most often very soft and soggy. Additionally, a small patch, about the size of a quarter, under the center top crust was invariably overdone and quite brown. Sometimes, this area was overdone to a scorched and black (burnt) look. Probably, due to "hot

TABLE 26

MEAN SENSORY SCORES FOR POT PIES HEATED

IN INVERTER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
	50% (Medium)	70% (Medium High)	100%(High)
Characteristic			
CONSISTENCY OF TEMPERATURE	5.03_a (0.56)	5.58_a (1.85)	4.38_a(1.39)
CRUST TEXTURE	5.68_a (1.13)	5.02_a (0.88)	4.34_a(1.78)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α =.05.

Consistency of temperature: 1 = not at all consistent
2 = very consistent

Crust Texture: 1 = not at all hard
9 = very hard

TABLE 27

MEAN SENSORY SCORES FOR POT PIES HEATED IN TRANSFORMER OVEN AT 3 POWER LEVELS*

	POWER LEVELS		
Characteristic	50% (Medium)	70% (Medium High)	100%(High)
CONSISTENCY OF TEMPERATURE	5.98_a (1.52)	5.65_a (1.49)	3.75_a(1.41)
CRUST TEXTURE	3.94_a (2.41)	5.10_a (1.44)	4.54_a(1.60)

*Means are based upon 2 replications by each of 6 judges.

Numbers appearing in parentheses after scores are standard deviations.

Within rows, different letters indicate scores significantly different at α=.05.

Consistency of temperature: 1 = not at all consistent
2 = very consistent

Crust Texture: 1 = not at all hard
9 = very hard

TABLE 28

MEAN SENSORY SCORES OF POT PIES HEATED

IN INVERTER AND TRANSFORMER OVENS

POWER LEVEL

	Medium		**Medium High**		**High**	
Characteristic	**50% I**	**50% T**	**70% I**	**70% T**	**100% I**	**100%T**
CONSISTENCY OF TEMPERATURE	5.03	5.98	5.58	5.65	4.38	3.75
CRUST TEXTURE	5.68	3.94	5.02	5.10	4.34	4.54

All scores are means based on 2 replication judgings by each of 6 judges.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

Consistency of temperature: 1 = not at all consistent; 9 = very consistent

Crust Texture: 1 = not at all hard; 9 = very hard spots" in the microwave centers, heat built up on the inside crust center, causing this browned or burnt patch; the heat or steam buildup must have been considerable to have caused such coloration within a microwave heated product. The other complaints of uneven heating within samples are also in agreement with Consumer Reports research (1981) and the 1986 O'Meara and Reilly study, both of which found localized overheating and inconsistency of temperature within heated/cooked foods that had been frozen.

Mean sensory scores are shown in Tables 26-28. In both ovens, consistency of temperature within the sample was lowest at 100% (High) power; in the transformer oven, consistency of temperature was significantly lower at High power than at other power levels. Probably, heating time at High (100%) power was insufficient to allow for complete thawing and heating of the product by conduction or radiation, regardless of power level. Consistency of temperature was greatest at 70% power in the inverter oven, but no differences were significant. There were also no significant differences between power levels and oven type (Table 28).

In keeping with the investigator's visual observations, mean sensory scores for crust texture were inconsistent. In the inverter oven, crust texture was softest at 100% power and hardest at 50% power (see Table 26); no differences were significant. Crust texture was softest at Medium power in the transformer microwave and hardest at Medium High power, but differences were again insignificant, as they were in Table 28. Based upon visual observations in pilot work, these inconsistencies had been expected; it was not believed that power level would greatly affect crust texture.

Instrumental

Mean instrumental scores for pot pie are shown in Tables 29-30 and Figures 19-21. The greatest percent weight loss was recorded for those pies heated at 100% (High) power in both ovens. It had been expected that those pies heated for the longest time (at 50% or Medium power) would have experienced greatest percent weight loss based on lengthiest exposure to energy source, regardless of intensity or power level. However, no differences were significant in this category, either within or between oven types or power levels. Lowest percent weight loss was recorded at Medium High power in the transformer oven and at 50% (Medium) power in the inverter microwave.

Post heating temperature rise phenomenon is recorded in Figures 19-21. Results in this area were also inconsistent

TABLE 29

MEAN INSTRUMENTAL SCORES FOR POT PIES

PREPARED IN INVERTER AND TRANSFORMER OVENS

INVERTER

Power Level	50%	70%	100%
Characteristic			
% WEIGHT LOSS	7.07_a	7.94_a	8.40_a
MEAN TENDERNESS*	182.83	152.17	323.83

TRANSFORMER

Power Level	Medium	Medium High	High
Characteristic			
% WEIGHT LOSS	7.13_a	6.92_a	7.23_a
MEAN TENDERNESS*	233.33	211.33	275.17

*Mean Tenderness (G/F) is an average of the three points of tenderness assessed per sample. See Instrumental Testing Section.

Significant differences for Tenderness were not calculated due to fluctuations. See Pot Pie Results and Discussion.

% Weight loss and tenderness means are based on 2 replications per power level and oven type.

Within rows, different letters indicate scores significantly different at $\alpha = .05$.

TABLE 30

MEAN INSTRUMENTAL SCORE COMPARISON BETWEEN POT PIES PREPARED IN INVERTER AND TRANSFORMER OVENS

POWER LEVEL

	Medium		Medium High		High	
	50% I	50% T	70% I	70% T	100% I	100%T
<u>Characteristic</u>						
% WEIGHT LOSS	7.07	7.13	7.94	6.92	8.40	7.23
MEAN TENDERNESS*	182.83	233.33	152.17	211.33	328.83	275.17

*Mean Tenderness (G/F) is an average of the three points of tenderness assessed per sample. See Instrumental Testing Section.

Significant differences for Tenderness were not calculated due to fluctuations. See Pot Pie Results and Discussion.

% Weight loss and tenderness means are based on 2 replications per power level and oven type.

Within each category, "I" indicates inverter oven and "T" indicates transformer oven.

Score pairs designated by "*" are significantly different at α =.05.

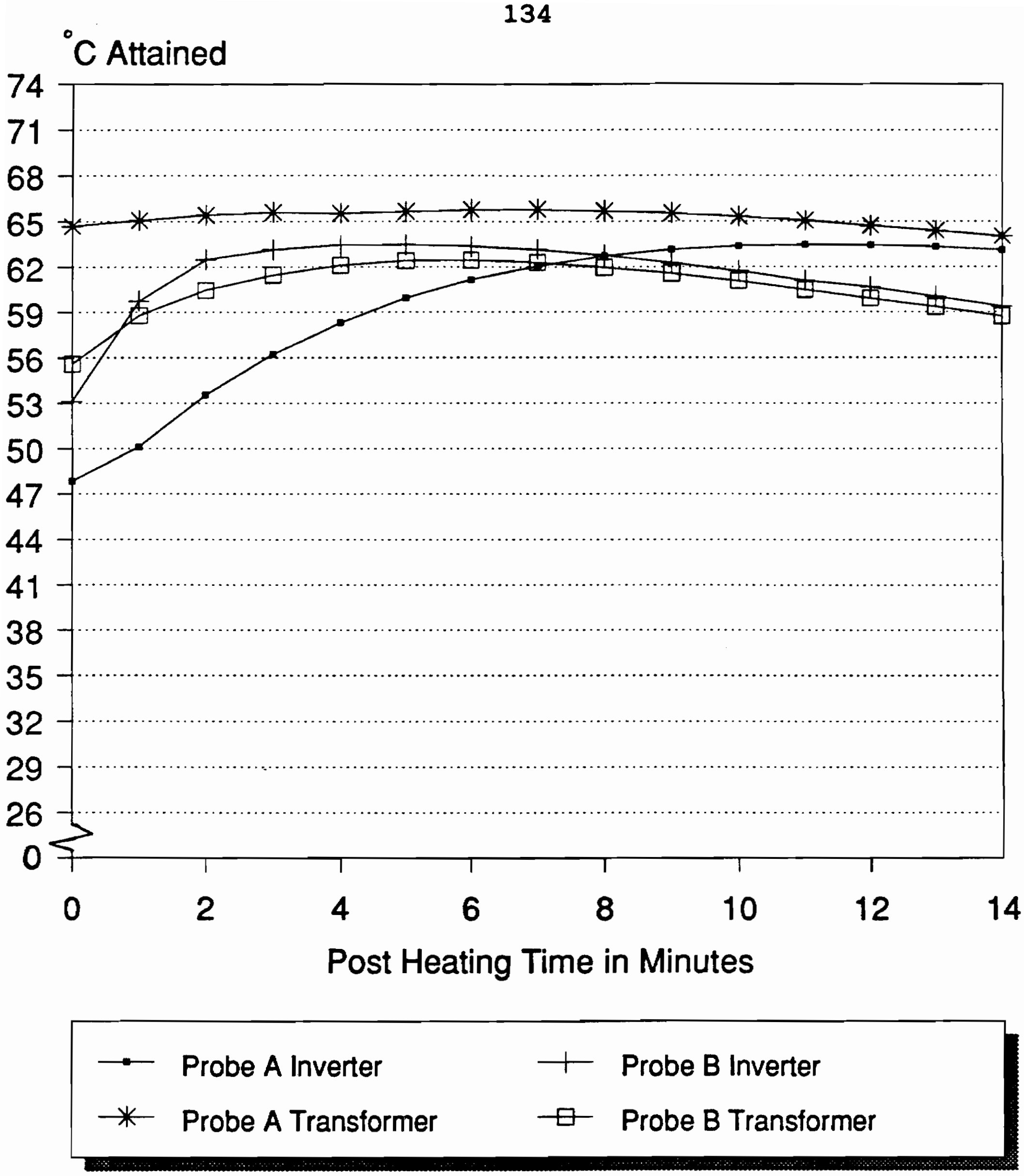

Figure 19: Post Heating Temperature Rise In Pot Pies Heated at 50% (Medium) Power

"A" indicates thermometer probe placement at pot pie center
"B" indicates thermometer probe placement near pot pie edge
See Instrumental Testing Section

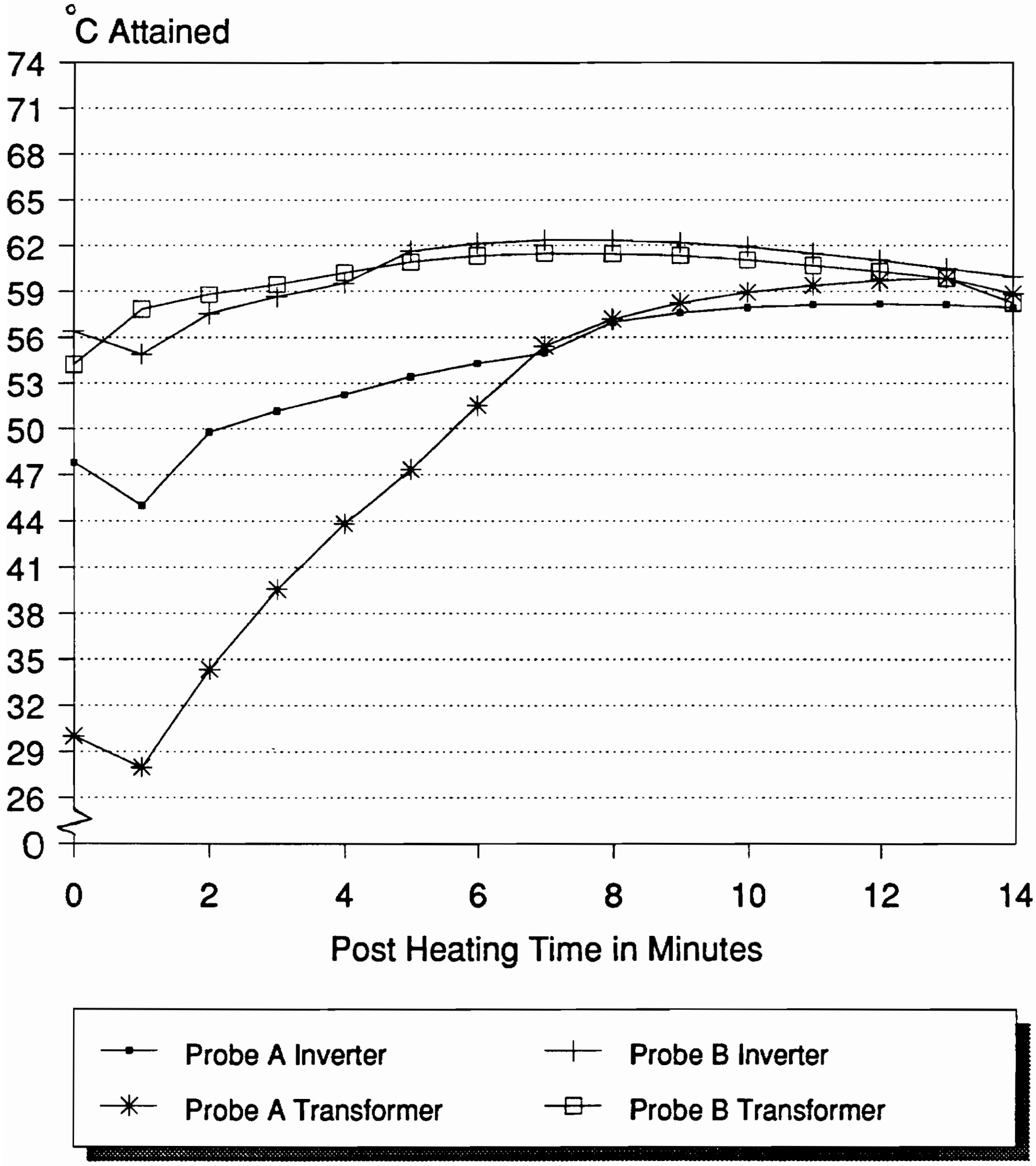

Figure 20: Post Heating Temperature Rise
In Pot Pies Heated at 70% (Medium High) Power

"A" indicates thermometer probe placement at pot pie center
"B" indicates thermometer probe placement near pot pie edge
See Instrumental Testing Section

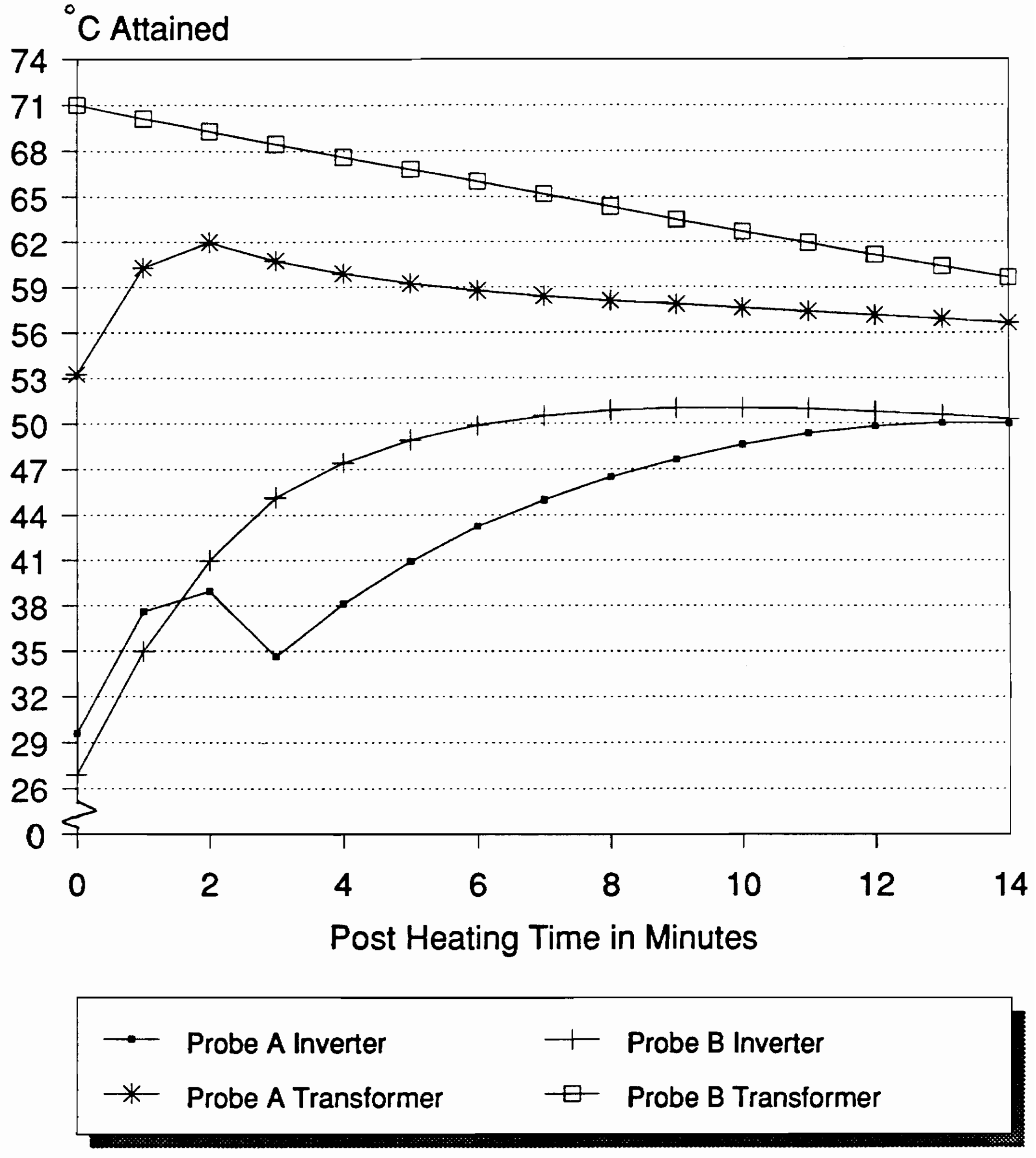

Figure 21: Post Heating Temperature Rise
Pot Pies Heated at 100% (High) Power

"A" indicates thermometer probe placement at pot pie center
"B" indicates thermometer probe placement near pot pie edge
See Instrumental Testing Section

between, and sometimes within, power levels. At 50% (Medium) power, both locations in both pot pies experienced a post heating temperature rise (Figure 19). It is interesting to note how close in temperature pot pies were (by probe location) at the end of the charted period.

The most spectacular post heating temperature rise occurred at 70% (Medium High) power (see Figure 20). This rise, in the center of the pot pie heated in the transformer oven, occurred from 1 minute to 13 minutes after heating. In three of four cases, post heating temperature rise at this power level took place after an initial temperature decrease for 1 minute. Again, at this power level, final temperature readings for both locations were quite close, despite a wide divergence initially.

At 100% (High) power, initial temperature divergence between different ovens was also quite wide (Figure 21). The pot pies heated in the inverter oven experienced more drastic temperature rises for a longer time period than their counterparts heated in the transformer microwave; near the edge of the pot pie heated in the transformer oven, in fact, there was no post heating temperature rise, although this location attained highest initial temperature (at 0 minutes post heating).

As a result of preliminary work and localized overheating observed, post heating temperature rise had been expected at pot pie centers, but not necessarily near the pie edges. Because ice absorbs microwave energy at a slower rate than water (Harrison, 1980) and because pot pies were frozen prior to heating, it had been thought temperature inconsistency and unevenness of heating might be more pronounced away from the center "hot spots" of the microwaves used in this research. It should also be noted that pot pies, as a multifood system of variable density, showed by far the longest period of post heating temperature rise (when it occured) as opposed to that of the other foods employed for this study. This may have been due to overall pie mass, the pie container (a coated aluminum, which might have retained heat better than other cooking vessels used and certainly enclosed all but the top surface of the pie during the post heating period), and/or other unknown factors.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

Microwave ovens are used to heat or cook a variety of foods. Microwave heating involves the transfer of electromagnetic radiation (microwaves) to a dipolar molecule within the food. A microwave field oscillates about five billion times per second; the vibration rate of the dipoles (usually water molecules) affected will thus be quite rapid, causing a very quick increase in temperature of the water molecules, and therefore, the food.

Microwave heating ability of a food is affected by many factors. These include the food's chemical composition, mass, shape, density, and initial temperature. The nature of microwave heating does not allow for the browning or crisping of foods. Because microwave ovens are known to frequently have "hot spots" or "cold spots" within their cavities, turning or stirring food heated in a microwave oven is usually advised.

The magnetron tube in a microwave oven is the source of microwave energy. In a transformer microwave oven, the most common type, the magnetron is either on or off. When turned on, the magnetron produces energy at full power. Variable power in this type of microwave oven is provided by a relay contact which allows the magnetron to be turned on for a percent of its normal working cycle (duty cycle).

A newer technology in variable power includes the addition of an inverter power supply circuit. This circuit controls power available to the magnetron to an exact degree. The magnetron in the inverter microwave oven has power output controlled at levels from 100% down to 50%; the magnetron still operates continuously, but output wattage is powered down to the percent level selected. For power levels below 50%, the magnetron in the inverter microwave oven acts similarly to the normal transformer microwave mode of operation.

The purpose of this research was to determine the effect on food quality of varying power levels in microwave cooking. A second purpose was to determine whether microwave oven technology (continuous or cycled power) affected food quality.

The two microwave ovens employed in this research were identical in interior and exterior size and shape. Each had a cavity of 0.7 cubic feet and an interior glass turntable. The transformer microwave oven had maximum output wattage of 600 watts and was the control oven in the study. The microwave with inverter technology had maximum output wattage of 620 watts.

The six foods selected for use in this research were designed to represent a broad spectrum. Those used were custard (a high protein dairy product and egg gel), cake (structure dependent upon protein denaturation and starch gelatinization), ground beef (high moisture, high fat muscle food), potatoes (a plant cell system of uniform density), frozen broccoli (a variable-density vegetable), and a frozen pot pie (a multi-food system with high fat and sodium content). Each food was prepared twice at each power level in each microwave oven; power levels used were 100% (High), 70% (Medium High), and 50% (Medium). All foods selected, if cookbook or package directions were followed, were meant to be cooked or heated at 100% (High) power; foods cooked at that power level served as the study controls. Cooking times at all power levels were established in pilot work.

Sensory evaluation was conducted by trained panel of six individuals, all between the ages of 20 and 30. Panelists were recruited from students at Virginia Polytechnic Institute and State University. Questionnaires involved attributes that were food-type dependent. Characteristics were rated along a 10 cm. anchored, unstructured scale. Foods served on a particular day were selected randomly in advance of testing.

Instrumental testing for foods consisted of measuring post heating temperature rise, percent weight loss during cooking, and tenderness where applicable. Foods used for instrumental testing were prepared identically to those used for sensory work, but all instrumental testing was completed prior to the beginning of sensory work.

Statistical means and standard deviations were calculated at the end of the study. Where appropriate, significant differences were calculated using an ANOVA at a value of $\alpha = .05$.

Significant differences were discovered among power levels. Cooking at 50% (Medium) power produced custards less smooth, while broccoli texture was woodier than at other power levels. Medium High (70%) power resulted in more moist potatoes which were harder in texture, and beef patties more tender at center. Custards cooked at 100% (High) power were less set than those cooked at other power levels, while potatoes were whiter in color. Cakes were more tender at this power level, while beef patties were juicier and pot pie was less consistent in temperature.

Within particular foods, there were also significant differences between oven types. At Medium (50%) power, the inverter microwave provided custards more set and less tender than the transformer oven. The inverter oven also produced broccoli with a fresher flavor, potatoes with a softer texture, and beef patties more tender near edges than those cooked in a transformer microwave. At 70% (Medium High) power, transformer microwave cooking resulted in a potato less white than that cooked in the inverter oven. High (100%) power inverter-microwaved custard was less creamy than its transformer-cooked counterpart, while broccoli and cake cooked in the inverter microwave at this power level had a fresher flavor and a weaker chocolate flavor, respectively.

Above all, the individual food system must be considered when evaluating the effects of power level and oven type. Within the confines of this research, neither null hypothesis was disproved. Based on calculated significant differences, it cannot be stated that there are overall differences in quality between foods cooked at the different power levels or in the two oven types used here. However, it can be said that, for certain foods, there are advantages in preparing them at a particular power level and/or in one type of microwave oven.

Custards formed a better set in the inverter oven at lower power levels, probably because they were heated more gently and so stood less chance of curdling. A power setting of about 70% would likely provide a good balance of set, smoothness, and tenderness. The inverter microwave also produced a more tender cake, but only at 100% power. Broccoli was also rated as having a fresher flavor in the inverter microwave. There seemed to be few significant advantages to cooking a food in the transformer microwave, except for speed. In all cases where time had to be adjusted to ensure sufficient cooking/heating of a food, the foods prepared in the inverter microwave invariably needed more time, but at the most this was a minute or two of difference, and usually it was much less than that.

On the assumption that consumers will continue to purchase and utilize microwave ovens, the inverter microwave oven would seem to have a promising future. The precise nature of control exerted over the output wattage emitted from the magnetron (at least for power levels of 50% and higher) might provide a genuine advantage for the consumer. This advantage is analogous to that of the gas burner's over the electric coil in a conventional range top. Like the gas burner, the inverter microwave provides infinite control over heating power. The electric coil provides absolute (lesser) control over heating power, as does the transformer microwave oven. The consumer using the inverter microwave oven would be able to make an exact choice of power level, and not merely a choice of power level range. The continuous, lower output wattage at reduced power levels provided by the inverter microwave oven may also result in a more gentle heating than the short, maximum output wattage bursts of the transformer oven. This may be important in the heating or cooking of delicate foods, such as the custard used in this study.

Some cookbook or label instructions for microwaveable foods might need to be rewritten. While all of the foods used in this research were meant to be cooked/heated at 100% (High) power, some foods might do better at a lower power setting for a longer time. Pot pie, for example, was more consistent in temperature when heated at lower power levels. Custards had a better set. When the differences in time between heating at higher and lower power are measured in seconds, perhaps the consumer would benefit from higher food quality with a waiting period only minimally longer.

It is the investigator's hope that this research might be a first step toward generic microwave cookbooks. Presently, most microwave ovens come packaged with cookbooks pertaining specifically to them. Most directions on microwaveable foods are for heating at a particular power level within a time range, but there is always a note that the product was tested in an oven with specific output wattage. If the output wattage in the consumer's oven differs from that on the package, optimum heating times may change considerably.

A possible solution to the above dilemma would be the establishment of cooking charts. For example, a food might be cooked in a microwave oven of 600-650 W. maximum output wattage for 10 minutes at 75% power. The cookbook or package directions would then list alternate heating instructions for microwave ovens with maximum output ratings of 400-500 W, 500-600 W, and those of 650 W and higher. A timing range listed for a variety of maximum output wattages in cookbooks or on packaging would aid the consumer in obtaining an acceptable cooked or heated product, instead of one potentially over- or under-cooked.

The divergent qualities that caused the foods selected for this study to be chosen ar the most likely contributors to the lack of consistent results. However, more research is necessary to lend validity to such a statement.

Recommendations

Further study is recommended. Future researchers in this area should either broaden food selection to obtain more generalized results or restrict food selection to a narrow category for more specific information. More than one microwave oven of each technology type should be used, and more than two replications of each food should be performed. Investigators might also employ conventional methods of cooking to enable more in-depth comparison of results. In addition, a thoroughly trained sensory panel of decent size (at least ten individuals) would lend greater validity to sensory scores received.

The inverter microwave oven used in this research had a maximum output wattage of 620 W. Future ovens of this type might do well to have a maximum output of around 700 W, with a larger cavity capacity than the 0.7 cubic feet found in this inverter microwave. A larger cavity capacity with higher maximum output wattage would allow for the more speedy preparation of foods, and of larger quantities of food when necessary. The manufacturer might also consider a smaller version of the inverter oven for smaller or single-person households, with maximum output wattage slightly below the present level.

It is also suggested that future inverter ovens possess convection capability. A large capacity microwave oven with infinite power control <u>and</u> the ability to brown and crisp foods would certainly encourage consumers to cook more foods, and more types of foods, within it. The combination of microwave cooking speed and thermal oven browning capability is one that should appeal to many potential microwave oven buyers.

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APPENDIX A

CUSTARD FORMULATION

AND MICROWAVE COOKING TIMES

CUSTARD FORMULATION

Adapted from The Microwave Guide and Cookbook (General Electric Company) 1982.

150 g. whole egg, lightly beaten, at refrigerator temperature

390 ml. whole milk, at refrigerator temperature

52 g. granulated sugar

1.3 g. salt

2 ml. pure vanilla extract

Place egg and milk in 1 l. bowl. Sprinkle in sugar; add salt and vanilla. Beat 30 sec. at speed 1 with a hand-held Farberware electric mixer Model D2770 (Farberware, New York, NY). Allow to rest 90 sec. for foam reduction.

COOKING TIMES FOR MICROWAVED CUSTARDS

Microwave Oven

Power Level	Transformer	Inverter
50% (Medium)	8 min. 30 sec.	11 min.
70% (Medium High)	6 min.	6 min. 30 sec.
100% (High)	4 min. 15 sec.	4 min. 30 sec.

APPENDIX B

CHOCOLATE CAKE FORMULATION AND MICROWAVE COOKING TIMES

CHOCOLATE CAKE FORMULATION

Adapted from An Exciting New World of Microwave Cooking (Litton, Pillsbury Publications, 1971).

241 g. dark brown sugar

193 g. all-purpose, bleached flour

22 g. unsweetened cocoa powder

5.3 g. baking soda

3.0 g. salt

220 ml. cold tap water, divided

60 ml. vegetable oil

15 ml. distilled vinegar

5 ml. pure vanilla extract

Measure dark brown sugar, flour, cocoa, baking soda and salt into 1.5 l. mixing bowl. Add 150 ml. water. Beat with hand-held Farberware electric mixer Model D2770 (Farberware, New York, NY) for 10 sec. at speed 1. Increase to speed 2; beat 20 sec. more.

Add remaining 70 ml. water, oil, vinegar, and vanilla. Beat 30 sec. at speed 1. Scrape bowl thoroughly for 7 strokes with rubber spatula. Beat batter 30 sec. at speed 2.

COOKING TIMES FOR MICROWAVED CHOCOLATE CAKES

Microwave Oven

Power Level	Transformer	Inverter
50% (Medium)	11 min.	12 min.
70% (Medium High)	8 min.	8 min. 35 sec.
100% (High)	6 min.	6 min.

APPENDIX C

COOKING TIMES FOR MICROWAVED GROUND BEEF PATTIES

COOKING TIMES FOR MICROWAVED GROUND BEEF PATTIES

Microwave Oven

Power Level	Transformer	Inverter
50% (Medium)	10 min.	10 min.
70% (Medium High)	7 min. 9 sec.	7 min. 9 sec.
100% (High)	5 min.	5 min.

APPENDIX D

COOKING TIMES FOR MICROWAVED POTATOES

COOKING TIMES FOR MICROWAVED POTATOES

Microwave Oven

Power Level	Transformer	Inverter
50% (Medium)	10 min.	10 min.
70% (Medium High)	7 min. 9 sec.	7 min. 9 sec.
100% (High)	5 min.	5 min.

APPENDIX E

COOKING TIMES FOR MICROWAVED BROCCOLI

COOKING TIMES FOR MICROWAVED BROCCOLI

Microwave Oven

Power Level	Transformer	Inverter
50% (Medium)	10 min.	10 min.
70% (Medium High)	7 min. 9 sec.	7 min. 9 sec.
100% (High)	5 min.	5 min.

APPENDIX F

COOKING TIMES FOR MICROWAVED POT PIES

COOKING TIMES FOR MICROWAVED POT PIES

Microwave Oven

Power Level	Transformer	Inverter
50% (Medium)	20 min.	20 min.
70% (Medium High)	14 min. 18 sec.	14 min. 18 sec.
100% (High)	10 min.	10 min.

APPENDIX G

CUSTARD QUESTIONNAIRE

CUSTARD

Date:____________ Panelist Number:__________

CREAMINESS:
not at all creamy — very creamy

SWEETNESS:
not nearly sweet enough — much too sweet

SMOOTHNESS:
not at all smooth — very smooth

DEGREE OF SET:
not at all set — very set

COMMENTS:

APPENDIX H

CAKE QUESTIONNAIRE

CAKE

Date:____________ Panelist Number:__________

MOISTNESS: very dry ——— very moist

TENDERNESS: very tough ——— very tender

CHOCOLATE FLAVOR: very weak ——— very strong

CELL SIZE: very small ——— very large

COMMENTS:

APPENDIX I

GROUND BEEF QUESTIONNAIRE

GROUND BEEF

Date:______________ Panelist Number:____________

TENDERNESS:

not at all chewy	very chewy

FLAVOR:

not at all beefy	very beefy

JUICINESS:

not at all juicy	very juicy

COMMENTS:

APPENDIX J

POTATO QUESTIONNAIRE

POTATO

Date:____________ Panelist Number:__________

COLOR:

less white	more white

TENDERNESS:

very hard	very soft

MOISTNESS:

very dry	very moist

COMMENTS:

APPENDIX K

BROCCOLI QUESTIONNAIRE

BROCCOLI

Date:______________ Panelist Number:____________

COLOR: very pale green — very dark green

FLAVOR: not at all fresh — very fresh

TEXTURE: not at all woody — very woody

COMMENTS:

APPENDIX L

POT PIE QUESTIONNAIRE

POT PIE

Date:_____________ Panelist Number:___________

CONSISTENCY OF TEMPERATURE IN SAMPLE:

not at all consistent ———————————————— very consistent

CRUST TEXTURE:

not at all hard ———————————————— very hard

COMMENTS:

VITA

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The author then worked in marketing research, printing, and advertising. In the fall of 1986, the author began attending classes at Montclair State College in Upper Montclair, New Jersey. Except for brief summer stints in two test kitchens in the western United States, the author has resided in Blacksburg, Virginia since late 1987, where she has been working toward her Master of Science degree in Human Nutrition and Foods.

Stephanie D. Zonis