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Energy Utilization Characteristics of Selected Electrical Commercial Food Service Equipment

Frank Romanelli
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Frank Romanelli entitled "Energy Utilization Characteristics of Selected Electrical Commercial Food Service Equipment." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Human Ecology.

Mary Jo Hitchcock, Major Professor

We have read this dissertation and recommend its acceptance:

Grayce E. Goertz, Betty L. Beach, John H. Gibbons

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a dissertation written by Frank Romanelli entitled "Energy Utilization Characteristics of Selected Electrical Commercial Food Service Equipment." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Home Economics.

Mary Jo Hitchcock, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

ENERGY UTILIZATION CHARACTERISTICS OF SELECTED ELECTRICAL COMMERCIAL FOOD SERVICE EQUIPMENT

A Dissertation

Presented for the

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Degree

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Frank Romanelli

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This dissertation is dedicated to the
memory of my parents:
Giacomo and Constanza Romanelli

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ABSTRACT

Energy utilization characteristics for commercial food service equipment were determined to provide data to establish the cost of energy in the preparation of food products. Twenty pounds of frozen pre-cooked breaded chicken quarters were cooked to an end point temperature of 180° F. using a deep fryer, a braiser, a two-pan bake oven, and a convection oven.

Kilowatt-hour readings were made to measure energy consumption of each piece of equipment. An alternate technique was developed to estimate energy consumption of each piece of equipment by using energy ratings in combination with measuring the on-time of the thermostat signal light. The energy consumption data from the meters were compared to the energy consumption data as estimated by the thermostat timing technique.

A seven-member taste panel evaluated quality characteristics of color, tenderness, juiciness, flavor, and overall acceptability of the chicken quarters cooked in the four pieces of equipment. For the quality characteristic of color, the chicken cooked in the bake oven was judged by the panel as lower in desirability than chicken cooked in the other equipment. Chicken cooked in the four types of equipment was similar for each of the other quality characteristics.

Pearson product-moment correlation coefficient data indicated that no significant relationship existed between cooking kilowatt-hour (kwh) consumption and sensory acceptance scores.

A linear relationship existed between cooking time and on-time of the thermostat signal light. The predictability percentage from

cooking time to on-time of the thermostat signal light was: deep fryer 38.7, braiser 98.8, bake oven 88.8, and convection oven 53.0. This indicated that cooking time can be used to predict the on-time of the thermostat signal light with some degree of accuracy for the braiser and bake oven.

The braiser was found to be most energy intensive for warm-up and least energy intensive for cooking the chicken. The deep fryer was least energy intensive for warm-up and most energy intensive for cooking. For total kwh consumption, the braiser was highest and the convection oven lowest.

The deep fryer required the least amount of time to warm-up, and the braiser the most time. The braiser cooked the chicken in the shortest amount of time, whereas the bake oven required the longest time. The deep fryer needed the least amount of total time while the bake oven required the most. This information could be important in scheduling of equipment use for food preparation to conserve energy and reduce operating costs.

The estimation of energy consumption from the on-time of the thermostat signal light as predicted from cooking time can be used by any operator of similar electrical commercial food service equipment. The kwh consumption can then be converted to BTU's and placed on the standardized recipe to provide energy utilization information for the planning of food preparation.

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CHAPTER I

INTRODUCTION

Energy prices in the United States have risen markedly in the last two to three years, and the future outlook is for a continual increase (Welch, 1974a). The major concerns reported by food service operators were cost and availability of energy (Sant, 1976a). At the 1975 meeting of the International Foodservice Manufacturers Association, Jim Hasslocker of Frontier Enterprises of Texas, noted that the utility bills for his restaurants had risen from $12,000 to $36,000 in less than two years. Staggering increases like these are seen all over the country.

The development of conservation techniques was considered the first step to assist in relieving the concerns for the cost and availability of energy. Bakos (1975) reported that fast food chains, such as McDonald's, Pizza Hut, and Sambo's, have had energy conservation programs for almost two years. Conservation is a means of utilizing energy more efficiently. The future energy supply prospects warrant something more. This research will assist food service operators to develop guidelines for management control of their energy resources. The knowledge of how and where energy is being utilized in a food service operation is a prerequisite for the establishment of controls.

The National Restaurant Association (NRA Washington Report, 1975) is concerned with the energy problem and has appointed an Energy Advisory Council. The Midwest Research Institute (MRI) was commissioned by the

Council to conduct two studies of energy utilization and conservation. A report prepared by Booz, Allen, and Hamilton Associates (1975) for the Federal Energy Administration indicated that the National Restaurant Association sponsored studies contain the only information currently available on energy consumption in the food service industry.

One of the studies of energy management in the food service industry conducted by the Midwest Research Institute indicated the following breakdown of energy consumption for a general menu restaurant: food preparation; heating, ventilation, and air conditioning; sanitation; lighting; and refrigeration (Welch, 1974a). Whether or not the breakdown was considered typical of all food service operations was not reported; however, control of all costs that affect the food preparation area is essential for the success of most food service operations. The project officer of the Food Service Division, Walter Reed Army Medical Center, stated at the 1975 annual meeting of the American Society for Hospital Food Service Administrators that energy may become so important that the food service system could one day be measuring energy per meal or the cost of energy per meal (Davis, 1975).

Standardized recipes are of paramount importance in the food preparation area in that they assist in establishing food quality, quantity, and cost controls. The knowledge of how much energy it takes to produce a standardized recipe would be most beneficial to food service operators. This information would help determine the cost to prepare a recipe and when energy is in short supply (brownouts, rationing) which recipe to prepare or which method of preparation would be least costly.

Food preparation was identified in the MRI study as the category in which the largest percentage of energy was consumed. This category generally is separated into four areas: prepreparation, preparation, holding, and service. Most cooking equipment found in the preparation area is powered by three types of fuel: gas, steam, and electricity. Figure 1 (Appendix B) illustrated the use of fuels in the food preparation area.

The four types of equipment chosen for this study were: deep fryer, braiser, bake oven, and convection oven. These four types of equipment are usually heated by natural gas or electricity. Electrical equipment was chosen for this study because natural gas may soon be restricted as to its use. The Federal Power Commission in a report dated June 19, 1976 indicated that natural gas contracts will be reduced by 25 percent this year. This comes after a 20 percent shortage in contract requirements during 1975 (Anon., 1976b). Another report stated that should we continue to use natural gas at 1972 consumption rates and if gas prices are held at current levels, the United States will be out of natural gas by 1986 (Hobson, 1976a).

The objectives of this study were:

1. To develop a methodology which food service operators could use to estimate energy consumption when cooking selected food products with an electric: deep fryer, braiser, bake oven, and convection oven.
2. To determine which of the four types of electrical commercial food service equipment when cooking 20 pounds of frozen pre-cooked breaded chicken quarters is least energy intensive and produces the most acceptable product with least energy consumption.

The null hypothesis was that there is no relationship between cooking time and the on-time of the thermostat signal light. Should a relationship exist, a formula could be designed to predict the on-time of the thermostat signal light from the cooking time. The predicted time then could be converted into estimated kilowatt-hour consumption per unit, portion, or pound of food product.

The methodology developed by this research may be used by food service operators to determine, without the use of meters, the energy utilization of similar electrical food service equipment. This information then could be indicated on the standardized recipes and used to more effectively control the use of energy in the food preparation area.

CHAPTER II

REVIEW OF LITERATURE

I. THE ENERGY PROBLEM

While the United States faces serious energy problems, the food and lodging industry is affected directly by any reduction in the supply of energy and by the dramatically increasing costs. During the past few years, energy prices have risen considerably; and the outlook for any decline is remote because of the following factors:

1. The fossil fuel supply of the United States is limited.
2. The technologies necessary to provide new sources of energy require years to develop.
3. Energy supplies will cost more to produce, thus prices will be higher.
4. The increased cost of foreign oil imports shows no sign of returning toward previous lower levels (Welch, 1974a).

The food industry in all its aspects consumes about 12 percent of the nation's energy, separated into the following categories: agriculture, 19 percent to 24 percent; food processing, 35 percent to 39 percent; wholesale and retail food sales, plus away from home and at home food preparation, 37 percent to 46 percent (Haaland, 1975). The food service industry is especially dependent on a continual supply of energy for operation of their businesses and for transportation for their patrons (Sant, 1976b).

The food and lodging industry is particularly concerned with the effects of shortages and ever-increasing costs of energy. In 1974, 900 hotels and motels reported that while payroll and related costs in the

heat, light, and power departments held to a normal pace, the utility costs and expenses increased by 31.9 percent (Anon., 1975b).

The American Hotel and Motel Association has named an Energy Task Force which is planning an ambitious three-to-five year industry-wide energy conservation program estimated to cost at least $175,000 in 1976 (Snyder, 1975). The director of energy control for the Howard Johnson Company reported on September 29, 1975 that their utility costs were approximately 4 percent of sales (Turner, 1975). The average cost for utilities in the hotel-motel industry is now approaching 6 percent of sales and is becoming an increasing concern to operators all over the United States.

The National Restaurant Association also is concerned with the energy problem and has appointed an Energy Advisory Council. This Council commissioned the Midwest Research Institute to conduct two studies on energy utilization and conservation (NRA Washington Report, 1975). The first study was in response to the National Restaurant Association's concern over fuel allocation plans under study by the Federal government. The research conducted was to compare the energy usage of preparing meals in the restaurant with energy usage of preparing meals in the home. The National Restaurant Association hoped that such a study would demonstrate whether the food service industry is an excessive user of energy, or if it could serve meals on a competitive basis and perhaps even save energy when compared with home meal preparation. Questionnaires sent out to operators representing all types of food service establishments were categorized into fast food, coffee shops, cafeterias, table service, and restaurants in hotel/motel operations.

An average family size of three persons eating one-third of their meals away from home was used for the evaluation of home meal preparation. Three of the restaurant categories, fast food, coffee shops, and cafeterias, reported using less energy per customer than home meal preparation. The hotel/motel category energy usage was approximately 19 percent less efficient than for home meal preparation, whereas table service restaurants were 36 percent less efficient. With reference to the entire food service industry, the study concluded that no significant difference in energy consumption occurred when a person ate a meal in a restaurant or prepared a meal at home (Welch, 1974b).

Kenneth Burley (1976), a food service consultant, suggested that in an advanced technological society it was almost indefensible for millions of families to cook at home. Families would be repeating essentially the same task at each meal over and over on a miniscule scale, squandering effort, time, and energy.

The food service industry has counted on inexpensive sources of energy to ease the load of high labor costs and expensive equipment. Utility costs may never cost as much as wages but any savings by conservation means more profit for the operator (Raskin, 1974). Many food service operators believe that since the rates are set, often by regulatory agencies, and since there is no competitive bidding, and usually only one supplier, little can be done about utility costs (Keiser and Kallio, 1974). However, accountability in industry has always been a big problem. As a result, some food service operations may follow the lead of Loma Linda University in California where all departments will be metered and accountable for the energy they consume (Davis, 1975).

II. ENERGY CONSERVATION PROGRAMS

Energy has recently been recognized as a vital resource necessary for the continual operation of any food service system. As a result, effective energy management programs take on special significance. To establish the program, all the energy that enters into the food service operations must be audited. From the audit, areas and processes which use large amounts of energy will be located and identified. Once the energy content of food products is determined, appropriate costs may be applied and menus priced profitably (Sant, 1976a). After the energy content of products and processes are determined as in British thermal units (BTU's), the products can be ranked by BTU's per unit, BTU's per dollar of sales, and BTU's per dollar profit. Then as energy availability becomes more limited, a change could be made to the least energy intensive or most profitable mode of operation. When energy is used more effectively, product costs could be reduced and profits improved (Gatts et al., 1974).

The major concerns of food service operators relating to energy are costs, quantity, and type available. The development of conservation techniques is the first step being taken to assist in relieving these concerns. Conservation is a means of utilizing energy more efficiently.

Current Research

A report prepared for the Federal Energy Administration indicated that the studies conducted by the Midwest Research Institute for the National Restaurant Association contain the only information currently available on energy consumption in the food service industry (Booz et al.,

1975). A Purdue University researcher reports that only 40 percent of the energy going into the average kitchen is used for cooking of food. The other 60 percent is absorbed by the equipment or is ventilated out the hood. The design and use of the cooking equipment are the sources of the greatest energy savings (Avery, 1974). An equipment census survey indicated that gas or electricity costs and restrictions only influenced food service operators' purchases 19 percent of the time (Anon., 1974).

Equipment Trends

Equipment manufacturers are developing new energy-saving equipment. The Peerless Stove Company has designed a pizza oven with a BTU rating of 40,000 per hour. This is a two-thirds reduction from the usual 120,000 BTU oven and has been accomplished with no change in capacity and required cooking time. A new bun grill reduces the traditional 18,000 BTU per hour loaded or not to 13,500 BTU loaded and 3,400 BTU on stand-by. A new broiler reduces the energy required to cook a pound of meat from 2,000 BTU's to 1,125 BTU's (Wallace, 1975).

International Dairy Queen has installed a new deep frying cooking computer which reportedly conserves energy by regulating shortening temperature. Kentucky Fried Chicken stores now use a new light weight filter paper for straining deep fryer shortening. Results indicate shorter filtering time and a decrease in electrical usage. Pamex Foods, a chain operating 31 restaurants in the Southwest, has implemented an energy conservation program. A schedule has been instigated for turning equipment on in sequence during opening hours to avoid high demand charges (Anon., 1976a).

III. ENERGY MANAGEMENT

The knowledge of how and where energy is being utilized in a food service operation is a prerequisite for the establishment of energy management controls. A study of energy management in the food service industry conducted by the Midwest Research Institute indicated the following energy-use breakdown for a general menu restaurant: food preparation 45.1 percent; heating, ventilation, and air conditioning 32.1 percent; sanitation 12.6 percent; lighting 8.2 percent; and refrigeration 2.0 percent (Welch, 1974a). The MRI study indicated that almost half of all the energy used in a typical general menu restaurant is consumed in food preparation. This compares favorably with the report given by J. B. Moore, vice-president of construction and equipment for Hardee's Food Systems, Inc., at the National Restaurant Association Hotel-Motel Show held in May 1976 in Chicago, Illinois. His report was entitled "Energy Management in the Fast-Food Industry." Hardee's energy usage breakdown was: cooking 60.6 percent; heating and air conditioning 20.9 percent; hot water 9.5 percent; and lighting 9.0 percent (Moore, 1976).

The MRI energy-use breakdown and the Hardee's study both indicate that the food preparation area is a large consumer of energy. In the food preparation area, standardized recipes are of importance in establishing food quality, quantity, and cost controls. Control of all costs that affect the food preparation area is essential for the success of most food service operations. The knowledge of how much energy it takes to produce a standardized recipe would be most beneficial to food service operators. This information would help determine the cost to

prepare a recipe and, when energy is in short supply such as with brownouts or rationing, which recipe to prepare.

In the past few years, the food and lodging industry has become increasingly conscious of the amount of energy and kinds of energy sources needed to maintain its business operations. With the oil embargo of 1974, a shortage of natural gas and propane in many parts of the country, rising fuel prices, and a new national effort to conserve natural resources, energy conservation has moved from a goal to an imperative, especially for the cost-conscious food service operator.

While there is little information available concerning the energy lost through food waste in the United States, it appears that energy can be conserved through improved production, handling, and preparation practices in every sector of the food system. Trends in food consumption in recent years indicate that the energy content of food is higher now than ever before. This is demonstrated by a comparison of the energy input to the food system with the index of farm output. Between 1960 and 1970, the energy input to the food system increased 51 percent whereas the index of farm output increased only 13 percent (Steinhart and Steinhart, 1974). The food and therefore energy lost at each successive stage of processing in the food system is cumulative. This can best be illustrated by the following example: For each pound of ingredients found in bread which is wasted, approximately 2,538 BTU's are lost, compared to the 7,874 BTU's lost in processing which includes mixing, baking, and packaging. For each pound of bread damaged in shipping, the BTU's lost is estimated to equal 8,300 (Nasby and Gongolez, 1975).

Having recognized that energy is a vital resource and that cost is now of prime economic importance, effective energy management programs take on special significance. To determine total energy consumption of the food service operation, the evaluation of energy consumption of each component of the system should be the prime target of responsible management.

Fuel and Equipment Selection

The food preparation area is indicated to be the largest area of energy consumption in a food service system. Major energy forms used in this area are gas, electricity, and steam. Fuel oil is used in some operations for cooking, but its primary use in the food and lodging industry is for steam generation. Several major companies are using electric equipment in all their new installations in anticipation of a possible natural gas shortage (Stoll, 1975). The natural gas shortage has already hit some areas of the United States as indicated in a survey that reported that 12 utilities out of the 46 who responded were unable to add new commercial customers (Mayland, 1976).

Total energy consumption in the United States has doubled every twenty years with electricity consumption growing twice as fast, thus consuming an increasing amount of primary resources (Tansil, 1973). This increase in electricity usage occurred even though prices have risen in some parts of the country 5 percent to 10 percent each year for the past three years; this increase paralleled inflation. An energy audit is suggested before any meaningful energy conservation program can be implemented. To do this, a systematic approach should be taken by

tabulating and charting energy utilization and costs, identifying all high-energy using equipment, procedures, and products. From this, ways to improve, replace, or use other less energy consuming methods can be identified, evaluated, and adapted (Katz, 1975).

With natural gas becoming short in supply and more electrical equipment being purchased by food service operators, research is necessary to determine which type of electrical equipment is least energy intensive. The Federal Energy Administration is currently asking for a factual status report on food system equipment efficiency labeling. "The efficiency of commercial cooking equipment is the biggest blank area we have today" (Hobson, 1976b).

The electrical commercial cooking equipment chosen for this study were those found in many food service operations: the deep fryer, braiser, bake oven, and convection oven. The microwave oven was not selected because of its operational limitations even though microwave cookery has been suggested as a way to reduce energy usage (McFeatters, 1976). However, microwave heating has been reported as not satisfactory for meat cookery (Kylen et al., 1964; Ream et al., 1974) as compared to conventional methods. Other problems have been (1) that cooking time and evenness vary with every size, shape, moisture content, and density of food; (2) products do not brown properly; and (3) cooking is not consistent throughout the oven cavity (Avery, 1975). Other studies indicated large cooking losses and considerable shrinkage (Carpenter et al., 1968). Crews and Goertz (1973) found increased cooking loss and decreased water-holding properties when testing ground turkey pectoral muscles in a microwave oven. Cooking time rather than internal temperature is the only means of controlling cooking heat in a microwave oven (Van Zante, 1973).

For this study, the internal temperature was the indicator of when to remove the food product from the cooking equipment. Energy consumption data were recorded immediately following cooking.

Literature on energy related subjects within the food and lodging industry was limited. Most of the available information on current topics was reported in trade publications and individual reports.

CHAPTER III

PROCEDURE

Energy utilization characteristics for selected electrical commercial food service equipment were determined to provide data to establish the cost of energy in the preparation of food products. A methodology was developed which food service operators could use to estimate energy consumption when cooking food products with an electric: deep fryer, braiser, bake oven, and convection oven. The main purpose of this research was to determine which of the four pieces of electrical commercial food service equipment was least energy intensive while producing the most acceptable product.

The actual energy consumed was measured by attaching a kilowatt-hour meter to each piece of equipment used. Timing of the on-time of the thermostat signal light was conducted by using a Fisher Heuer 1/100 second stopwatch. For each piece of equipment, the total time the thermostat signal light remained on was recorded and used to calculate the amount of kilowatt-hours (kwh) consumed. The results of this thermostat signal light kwh calculation technique were compared to the kilowatt-hour meter reading figures to determine if there was any significant difference. The thermostat signal light kwh calculation technique was used to develop an inexpensive methodology for users of electrical commercial food service equipment to estimate the amount of energy consumed while cooking various food products.

The total amount of Magnolia Farms brand chicken needed for each replication was requisitioned from the Food Service Department, the

University of Tennessee, Knoxville. Upon receipt the boxed chicken, packed in polyethylene bags, was stored immediately in a Victory two-door upright freezer (Model FA 2DS). The thermostat of the freezer was set at 0° F., which gave an actual temperature range of 2° F. to 6° F. The frozen chickens were stored in the freezer until they were removed, divided into 20-pound batches, and placed in the electric commercial food service equipment for cooking.

Readings were taken from the kilowatt-hour meters connected to the bake and convection ovens at the beginning and end of a pilot study and eleven replications. Readings were taken from the kilowatt-hour meters connected to the deep fryer and the braiser at the beginning and end of a pilot study and four replications; then the meters were disconnected. After the meters were disconnected from the deep fryer and the braiser, energy consumption data were calculated using the thermostat signal light timing technique. Eleven replications were conducted using each of the four pieces of equipment to cook 20 pounds of frozen pre-cooked breaded (fpb) chicken quarters. Additionally, five other food products were each tested once in the same manner to check accuracy of the methodology. These five food products were: pork steak, corn dog, veal cutlet, fresh chicken quarters, and fresh chicken drumsticks.

A pilot study was conducted to calibrate the four pieces of equipment. This was done to insure that the thermostat settings for cooking the chicken would be 350° F. for all equipment (West et al., 1966). The convection oven and the two-pan bake oven had thermostats that were accurate at 350° F. ± 15°. The braising pan thermostat had to be set at

400° F. to achieve a 350° F. ± 12° shortening temperature. The deep fryer thermostat had to be set at 365° F. to achieve a 350° F. ± 10° shortening temperature.

Data were collected while conducting eleven replications occurring at varying times on seven different days. For each replication, the chicken was cooked to an end point temperature of 180° F. (Anon., 1975a). Four chicken breasts cooked in each piece of equipment were removed to be used as samples and stored in a refrigerator for two to three hours. The cooled chicken samples were used to evaluate selected quality related characteristics. These characteristics were color, tenderness, juciness, flavor, and overall acceptability.

The kwh consumption, as measured by a kilowatt-hour meter, of each piece of equipment was compared to the product of the equipment kilowatt (kw) rating multiplied by the time the thermostat signal light was on. The total time the chicken was cooked in each piece of equipment was correlated with the total time the thermostat signal light was on during cooking to determine if a relationship existed between actual energy consumed and cooking time.

I. COMMERCIAL FOOD SERVICE EQUIPMENT

The four types of electrically heated commercial food service equipment used in this study were: General Electric convection oven (Model CN90A), rated at 11.0 kw; General Electric two-pan bake oven (Model CN50), rated at 6.2 kw; Groen braising pan (Model FPC-4), rated at 14.3 kw; and a Toastmaster deep fryer (Model 14C4), rated at 12.5 kw.

II. PURCHASING SPECIFICATIONS OF PRODUCTS

One thousand pounds of United States Department of Agriculture inspected chickens were purchased from the Knoxville Poultry and Egg Company in Knoxville, Tennessee. Frozen pre-cooked breaded chicken quarters as marketed under the Magnolia Farms brand label were obtained. The specifications stated: young (seven-week-old) fryer parts, tumbled in dry batter mix (not to exceed 30 percent pick-up), averaging 13 ounces per half after breading, cooked over steam until an internal temperature of 160° F. is reached, then frozen. The batter-breading mix recipe was a confidential formula with the ingredients listed as: cereal, water, salt, spices, flavoring, dehydrated honey, and monosodium glutamate.

Fourteen hundred pounds of shortening was obtained from Swift's Edible Oil Company, a division of Swift and Company. The shortening used was marketed under the "Pour N Fry" label. The ingredients were listed on the label in the following order: choice vegetable oils, methyl silicone--an anti-foaming agent added, BHA, BHT, added to preserve freshness.

III. MEASUREMENT OF ENERGY CONSUMPTION

A General Electric kilowatt-hour meter (Type U65S) was used to record the kwh consumed by the braiser. The meter was connected between the wall receptacle and the braiser. The braiser plug was connected to the meter and the meter plug was connected to the braiser wall receptacle. Three Sangamo Electric Form 125-watt meters (Type S2S) were used to record the kwh consumed by the convection oven, two-pan bake oven, and the deep fryer. The meters were connected at the fuse panel for this equipment.

The meters were read and the information recorded before turning on the food service equipment and after the equipment was turned off. The beginning kwh reading was subtracted from the kwh reading after cooking the chicken and the difference recorded.

Convection Oven

Two shelves were inserted in the oven chamber at equal distances from the top, bottom, and each other. The thermostat was set at 350° F., and the main power switch was turned on to preheat the oven chamber. When the temperature signal light came on, a stopwatch was activated to measure the warm-up time. When the temperature signal light went off, the total time was recorded. While the oven was preheating, 20 pounds of fpb chicken quarters were distributed evenly, skin side up, on two standard 18-inch x 26-inch roll pans.

After the preheat time was recorded, the two pans of chicken quarters were placed in the oven and the thermostat left at 350° F. When the oven doors were closed, a stopwatch was activated to measure the total time required to bring the internal temperature of the chicken to 180° F. Copper-constantan thermocouples attached to a Honeywell Electronik Multipoint temperature recorder (Model 16) measured ambient temperature of the oven and internal temperature of the chicken quarters.

Two thermocouples were inserted in the fpb chicken quarters which were located in opposite sides of each pan. The thermocouples were centered into the leg muscles of the chicken horizontally and the fpb chicken quarters cooked until an internal end point temperature of 180° F. was reached. When the fpb chicken quarters were placed in the oven, a

second stopwatch was used to measure the on-time of the thermostat signal light. The stopwatch was activated each time the thermostat signal light was on and the total time recorded after the internal temperature of the thermocoupled chicken quarters reached 180° F. When the chicken quarters reached an internal temperature of 180° F., the power switch was shut off and the two pans of quartered chickens were removed from the oven. An identical procedure for obtaining an internal end point temperature of 180° F. was used for the chicken cooked in the bake oven.

Two-Pan Bake Oven

Two 18-inch x 26-inch roll pans were inserted on the oven deck upside down. The top and bottom switches were set on high and the thermostat turned on to 400° F. When the oven signal light came on, a stopwatch was activated to measure the time necessary to preheat the oven. When the oven signal light went off, the time on the stopwatch was recorded.

After the preheat time was recorded, the thermostat was adjusted to 350° F. and the two pans of chicken quarters centered evenly on the inverted roll pans in the oven. When the oven door was closed, a stop-watch was activated to measure total time needed to raise the internal temperature of the chicken quarters to 180° F. Copper-constantan thermocouples attached to a Honeywell Electronik Multipoint temperature recorder (Model 16) measured ambient temperature of the oven and internal temperature of the chicken quarters.

Braising Pan

Fifty pounds of fresh shortening was poured into the braising pan and the thermostat turned on to 400° F. When the thermostat signal light came on, a stopwatch was activated to measure the warm-up time. When the thermostat signal light went off, the total time was recorded. While the braising pan was preheating the shortening, 20 pounds of fpb chicken quarters were divided into two pans.

After the preheat time was recorded, the two pans of fpb chicken quarters were emptied into the hot shortening and the chicken quarters evenly distributed along the bottom of the braiser. When the chickens were placed into the braiser, a stopwatch was activated to measure the total time required to bring the internal temperature of the chicken to 180° F. Copper-constantan thermocouples attached to a Honeywell Electonik Multipoint temperature recorder (Model 16) measured the temperature of the shortening and the internal temperature of the chicken quarters.

Two thermocouples were inserted in chicken quarters which were in opposite ends of the braiser. The thermocouples were centered into the leg muscles of the chicken vertically and the chicken quarters cooked until an internal end point temperature of 180° F. was reached.

When the fpb chicken quarters were placed in the braiser, a second stopwatch was used to measure the on-time of the thermostat signal light. The stopwatch was activated each time the thermostat signal light was on and the total time recorded after the internal temperature of the thermocoupled chicken quarters reached 180° F. When the chicken quarters reached an internal temperature of 180° F., the thermostat was turned off and the cooked quartered chickens were removed from the braiser.

Deep Fryer

Thirty pounds of fresh shortening was poured into the deep fryer and the thermostat turned to 365° F. When the thermostat signal light came on, a stopwatch was activated to measure the warm-up time. When the thermostat signal light went off, the total time was recorded. While the deep fryer was preheating the shortening, 20 pounds of fpb chicken quarters were measured and divided into three batches of approximately 6 2/3 pounds each.

After the preheat time was recorded, a batch of 6 2/3 pounds of chicken quarters was placed in a fry basket and lowered into the hot shortening. When the chickens were placed into the hot shortening, a stopwatch was activated to measure the total time required to bring the internal temperature of the chicken to 180° F. Copper-constantan thermocouples attached to a Honeywell Electronik Multipoint temperature recorder (Model 16) measured the temperature of the shortening and the internal temperature of the chicken quarters.

Two thermocouples were inserted in chicken quarters which were in opposite ends of the fryer. The thermocouples were centered into the leg muscles of the chicken vertically and the chicken quarters cooked until an internal end point temperature of 180° F. was reached.

When the fpb chicken quarters were placed in the deep fryer, a second stopwatch was used to measure the on-time of the thermostat signal light. The stopwatch was activated each time the thermostat signal light was on and the total time recorded after the internal temperature of the thermocoupled chicken quarters reached 180° F. This procedure was followed three times.

When the third batch of chicken quarters reached an internal temperature of 180° F., the thermostat was turned off and the total cooking time recorded.

IV. QUALITY AND ACCEPTABILITY TESTS

After cooking, sixteen chicken breasts were chosen for uniformity in size, shape, condition, and appearance of the breading. After each replication, the samples were stored for two to three hours in a Victory two-door upright refrigerator (Model RA2DS). The thermostat of the refrigerator was set at 36° F., which gave an actual temperature range of 34° F. to 40° F. The samples were stored in half size four-inch deep steam table pans, covered with aluminum foil, and were identified by code numbers selected from a random digit table (Robbins and Ryzin, 1975). Four samples of chicken cooked in each piece of equipment were used to determine acceptability of selected quality related characteristics.

Sensory Evaluation

A seven-member panel assisted in the research. The panel members, both men and women, were selected from members of the University of Tennessee, Knoxville food service staff. Panel members were instructed how to identify quality characteristics during a pilot session before the initiation of the research. Several panel members had participated in other studies and were familiar with the quality characteristics to be evaluated.

Fifteen minutes before the panel members were to convene, the chicken samples cooked in each piece of equipment were removed from the

refrigerator. Twelve of the chilled chicken breasts, three of which were cooked in each piece of equipment, were deboned and cut into three equal portions to be used as taste samples. Four chicken breasts, one cooked in each piece of eqiupment, were used as whole samples to be judged on color characteristics.

A seven-point descriptive Hedonic scale (Amerine et al., 1965; Larmond, 1970) was used to evaluate color, tenderness, juiciness, and flavor of the taste samples; and a five-point descriptive Hedonic scale was used to evaluate overall acceptability of the taste samples (form in Appendix A). Terms for color ranged from very desirable to very undesirable. Terms for tenderness ranged from very tender to very tough. Terms for juiciness ranged from very juicy to very dry. Terms for flavor ranged from very desirable to very undesirable. Terms for overall acceptability ranged from very good to very poor. A similar seven-point descriptive scale was used to evaluate the color of the whole sample (form in Appendix A).

The taste samples were presented to the panelists one at a time, and they were instructed to evaluate the taste sample for all the quality attributes in the order listed on the score card. The taste samples were presented on a white five-inch bread plate with a glass of water provided in the booth for the panelist to rinse his or her mouth at the completion of each sample evaluation. A regular fork and dinner knife as well as a napkin also were provided.

After evaluating the four taste samples, the panelists were instructed to proceed to a separate area to evaluate the color of four whole samples. Samples of the whole chicken quarters, one from each batch cooked in the different types of equipment, were placed on a

14-inch x 16-inch serving tray and displayed under natural white colored fluorescent lights. The panelists were instructed to evaluate the color of the whole samples one at a time.

Descriptive terms for color, tenderness, juiciness, and flavor were transposed to numerical data using a scale of one to seven, seven being the most desirable and one being the least desirable for analysis of data. The descriptive terms for overall acceptability were transposed to numerical data using a scale of one to five, five being the most desirable and one the least desirable.

V. ANALYSIS OF DATA

An analysis of variance was used to calculate differences attributed to the four different pieces of electrical commercial food service equipment for each of the six quality characteristics of the cooked chicken.

Actual energy consumed by the four different types of electrical commercial food service equipment was measured by kilowatt-hour meters. These readings were compared to the kw consumption as determined by the stop watch record of the on-time of the thermostat signal lights. The actual energy consumed was correlated with the total cooking time by using a multiple regression equation. A percentage of predictability of energy consumption was obtained by using total cooking time.

The average readings of the kwh used by each piece of equipment for the eleven replications were analyzed to determine which piece of electrical equipment used in this study was least energy intensive with regards to cooking 20 pounds of fpb chicken quarters. Additionally, these readings were correlated with the average taste panel scores to determine

which equipment cooking method for chicken was most acceptable and least energy intensive.

Analysis of data was used to determine a method for food service operators to predict or estimate energy consumption of electrical commercial food service equipment.

CHAPTER IV

RESULTS AND DISCUSSION

The following objective measurements were made on the four types of electrical commercial food service equipment to determine their energy utilization characteristics: warm-up time in minutes, cooking time of the fpb chicken quarters in minutes, and the on-time of the thermostat signal light in minutes when cooking fpb chicken quarters. The null hypothesis was that there is no relationship between cooking time and the on-time of the thermostat signal light.

Equipment kwh utilization was determined by kilowatt-hour meter readings and the thermostat light timing technique. One-way analysis of variance was calculated for comparison of kwh consumption. Pearson product-moment correlation coefficients were computed to indicate the relationship of chicken acceptability and energy consumption. One-way analysis of variance was calculated for the sensory evaluation of quality characteristics of color, tenderness, juiciness, flavor, and overall acceptability. A 0.05 level of significance was established for all analyses of variance.

I. RELATIONSHIP OF COOKING TIME TO THERMOSTAT TIME

A multiple regression analysis was conducted to determine if a relationship existed between cooking time and the on-time of the thermostat signal light. Table 1 contains the multiple R values, R square values, F ratios, and degrees of freedom for the four selected pieces of equipment.

Table 1. Relationship Between Cooking Time and On-Time of the Thermostat Signal Light

Type of Equipment	Multiple R Value	R Square Value	F Ratio[a]	Degrees of Freedom
Deep fryer	.622	.387	5.67	1,9
Braiser	.994	.988	772.74	1,9
Bake oven	.942	.888	71.19	1,9
Convection oven	.728	.530	10.15	1,9

[a]A minimum F ratio of 5.12 is necessary for statistical significance at $P < 0.05$.

The data in Table 1 are significant at the $P < 0.05$ level and the null hypothesis is rejected because a relationship exists between cooking time and on-time of the thermostat signal light. These data indicate a wide variation between cooking time and the on-time of the thermostat signal light of the four pieces of equipment. Further investigation is necessary to determine the cause of the variation. The R square value or coefficient of determination (Kerlinger, 1973) indicates a definite association between cooking time and on-time of the thermostat signal light. The predictability percentage from cooking time to on-time of the thermostat signal light was: deep fryer 38.7, braiser 98.8, bake oven 88.8, and convection oven 53.0. This indicated that cooking time can be used to predict the on-time of the thermostat signal light for the braiser and bake oven.

Figures 2 through 5 (Appendix B) picture the data points and regression lines for cooking time and on-time of the thermostat signal light. This

information was recorded while cooking 20 pounds of fpb chicken quarters in the electric food service equipment selected for this study. Complete data are presented in Table A-1, Appendix B.

II. EQUIPMENT ENERGY CONSUMPTION

A technique was developed for estimating kwh consumption of electrical food service equipment by measuring the on-time of the thermostat signal light. The technique was used to estimate kwh consumption of each piece of equipment used in this study. The results were compared with kilowatt-hour meter readings, and the thermostat signal light timing technique was found to be a good method of estimating kwh consumption. The difference ranged from 0.00 kwh to 0.50 kwh and the larger difference can probably be attributed to the difficulty of accurately reading the meters. The kilowatt-hour meters used in this study did not measure the kwh in tenths; and as a result, estimates of the pointer location between kwh numerals were made. Table 2 presents the averages of kwh consumption. Complete data relating to meter readings, thermostat time, and kwh consumption is found in Tables A-2 through A-5, Appendix B. The thermostat time technique of determining kwh consumption was tested using the five additional food products and found to be as accurate as when cooking fpb chicken quarters. Table A-6 contains the kwh consumption comparison data for the five other food products.

A one-way analysis of variance was calculated for warm-up kwh and chicken cooking kwh consumption for each piece of equipment used in this study. The data are contained in Tables A-7 and A-8 in Appendix B and are statistically significant at the 0.05 level for both analyses.

Table 2. Averages of kwh Consumption by the Thermostat Signal Light Timing Technique and Kilowatt-hour Meter Readings for fpb Chicken Quarters

Equipment	Meter Reading kwh Consumption	Thermostat Signal Light: Minutes of Time on: Warm-up	Cooking	Total	% of 1 Hr	Kw Rating of Equip.	Estimated kwh Consumption (rating x %)	Difference* in kwh Consumption
Deep Fryer	5.0	6.4	17.2	23.6	39.3	12.5	4.9	0.1
Braiser	8.2	23.4	10.6	34.0	56.6	14.3	8.1	0.1
Bake Oven	5.0	18.7	29.2	47.9	79.8	6.2	4.9	0.1
Convection Oven	4.9	9.1	17.5	26.6	44.4	11.0	4.9	0.0

*Between kilowatt-hour meter reading and thermostat signal light timing technique.

The means for warm-up time, cooking time, and total time, warm-up kwh consumption, cooking kwh consumption, and total kwh consumption are found in Table 3. Complete data for these items are found in Tables A-9 and A-10 in Appendix B.

The braiser was most energy intensive for warm-up and least energy intensive for cooking. The deep fryer was least energy intensive for warm-up and most energy intensive for cooking. A comparison of total kwh consumption indicated that the braiser was most energy intensive, the deep fryer and bake oven similar, and the convection oven least energy intensive when adding warm-up and cooking kwh consumption.

Although it was not a specific objective of this reaseach to study equipment utilization time, the measuring of equipment warm-up

Table 3. Means for Warm-up Time, Cooking Time, and Total Time, Warm-up kwh Consumption, Cooking kwh Consumption and Total kwh Consumption

	Time (Min.)			kwh		
Equipment	Warm-up	Cooking	Total	Warm-up	Cooking	Total
Deep Fryer	6.4	22.5	28.9	1.3	3.6	4.9
Braiser	23.4	11.7	35.1	5.6	2.5	8.1
Bake Oven	18.7	47.4	66.1	1.9	3.0	4.9
Convection Oven	9.1	26.6	35.7	1.7	3.2	4.9

time and cooking time to determine energy consumption provided data of interest. The deep fryer required the least amount of time to warm-up and the braiser the most time to warm-up. The braiser cooked the chicken in the shortest time, whereas the bake oven required the longest time. For total utilization time, the deep fryer needed the least amount to cook 20 pounds of fpb chicken quarters, whereas the bake oven required almost twice the time of the braiser and convection oven. These data are important for food service operators to know for equipment scheduling for food production.

III. PRODUCT ACCEPTABILITY

A one-way analysis of variance was used to compare the sensory evaluations of quality characteristics as judged by the taste panel. The Pearson product-moment correlation coefficient was computed to determine if a relationship existed between cooking kwh consumption and overall acceptability. Table 4 contains the one-way analysis of variance data for quality characteristics. Complete data for taste panel scores are found in Tables A-11 and A-12, Appendix B.

The analysis in Table 4 indicates a significant difference for color of the whole and taste samples of chicken quarters cooked in the four pieces of electrical commercial food service equipment. Table 5 contains the means for sensory evaluation of quality characteristics.

The color of chicken cooked in the bake oven was scored as lower in desirability than chicken cooked in the three other types of equipment. The quality characteristics of tenderness, juiciness, flavor, and overall

Table 4. Taste Panel Evaluations for Quality Characteristics of fpb Chicken Quarters by One-way Analysis of Variance

Variable	df	Sum of Squares	Mean Squares	F Ratio[a]
Color-Whole	3,20	40.88	13.63	77.34
Color-Taste	3,24	33.70	11.23	56.58
Tenderness	3,24	0.46	0.15	0.45
Juiciness	3,24	0.24	0.08	0.20
Flavor	3,24	0.39	0.13	0.54
Overall Acceptance	3,24	1.14	0.38	2.71

[a]An F ratio of 3.01 is necessary for the data to be statistically significant at the 0.05 level.

Table 5. Means of Taste Panel Scores for Quality Characteristics

Equipment	Color Whole	Color Taste	Tenderness	Juiciness	Flavor	Overall Acceptance[a]
Deep Fryer	5.9	6.1	5.3	4.7	5.4	3.7
Braiser	6.3	6.4	5.3	4.7	5.6	3.9
Bake Oven	2.9	3.6	5.6	4.8	5.3	3.4
Convection Oven	5.4	5.2	5.3	4.6	5.5	3.6

[a]A scale of 1 to 7 was used for all characteristics except for overall acceptance where a scale of 1 to 5 was used. (1 was least desirable.)

acceptability were not judged significantly different by the taste panel; therefore, this indicated that chicken cooked in the four pieces of equipment were judged as similar in these quality characteristics.

IV. CORRELATION OF PRODUCT ACCEPTABILITY WITH ENERGY CONSUMPTION

The Pearson product-moment correlation coefficient was computed to determine if a relationship existed between kwh consumption and sensory acceptance scores of the taste panel for fpb chicken quarters. Table 6 provides the means of cooking kwh and overall acceptance and the correlation coefficient for the four types of electrical commercial food service equipment.

Low kwh consumption and high product acceptance is desirable. For this study no significant relationship existed between cooking kwh

Table 6. Means of Cooking kwh Consumption and Acceptance Scores and Correlation Coefficients

Equipment	Cooking kwh	Overall Acceptance[a]	Correlation Coefficient[b]	Degree of Significance[c]
Deep Fryer	3.6	3.7	0.23	.31
Braiser	2.5	3.9	0.47	.15
Bake Oven	3.0	3.4	-0.16	.37
Convection Oven	3.2	3.6	0.02	.49

[a]Seven replications each.

[b]$\frac{\text{Covariance in kwh and acceptance}}{\text{Product of their standard deviations}}$

[c]Based upon the results there appears to be no significant linear relationship.

consumption and overall acceptance of the chicken cooked in the four types of electrical commercial food service equipment.

Table 7 provides the means of total kwh for warm-up and cooking and overall acceptance and the correlation coefficient for the four types of electrical commercial food service equipment.

Low total kwh consumption and high product acceptance is desirable. For this study no significant relationship existed between total kwh consumption and overall acceptance of the chicken cooked in the four types of electrical commercial food service equipment.

V. OBSERVATIONS

The null hypothesis that there is no relationship between chicken cooking time and the on-time of the thermostat signal light was

Table 7. Means of Total kwh Consumption for Warm-up and Cooking and Acceptance Scores and Correlation Coefficients

Equipment	Total kwh	Overall Acceptance	Rep.[a]	Correlation Coefficient[b]	Degree of Significance[c]
Deep Fryer	4.9	3.7	6	-0.03	.48
Braiser	8.1	3.9	7	0.48	.14
Bake Oven	4.9	3.4	7	-0.01	.49
Convection Oven	4.9	3.6	7	-0.02	.48

[a]Replications.

[b] $\frac{\text{Covariance in kwh and acceptance}}{\text{Product of their standard deviations}}$

[c]Based upon the results there appears to be no significant linear relationship.

rejected for all the equipment used in this study. The multiple regression analysis indicated that there is a linear relationship between chicken cooking time and the on-time of the thermostat signal light. The data suggest that the braiser had the highest level of kwh predictability and the deep fryer the least (Table 1, page 29).

Food service operators, using five to ten replications, could estimate kwh consumption with reasonable accuracy for any food product using similar electric commercial food service equipment. After determining the means of the on-time of the thermostat signal light for any food product, kwh consumption for the particular electrical equipment could be calculated using its power rating. The technique of using the on-time of the thermostat signal light to calculate electrical equipment kwh consumption is a reliable method of estimating energy utilization. The most reliable method would be to install meters on all equipment; however, the thermostat signal light timing technique requires only a stopwatch and personnel to record the data.

The formula to predict on-time of the thermostat signal light from cooking time as developed by this study was: cooking time in minutes multiplied by the b slope plus the Y intercept equals the on-time of the thermostat signal light. Table 8 provides the data for predicting the on-time of the thermostat signal light for the four pieces of electric commercial food service equipment used in this study.

The method of estimating cooking kwh consumption of electrical commercial food service equipment from cooking time:

1. Measure the cooking time (CT) and the on-time of the thermostat signal light (TT) immediately after placing food products into the equipment. Two timing devices are required.

Table 8. Means of Cooking Time, b Slope, Y Intercept, and Predicted On-Times of the Thermostat Signal Light for the Four Pieces of Electrical Commercial Food Service Equipment

Equipment	Means of Cooking Time	b Slope	Y Intercept	Predicted On-time of Thermostat Signal Light
Deep Fryer	22.5	.37	8.83	17.1
Braiser	11.7	1.04	-1.61	10.5
Bake Oven	47.4	.51	5.04	29.1
Convection Oven	26.6	.28	10.09	17.4

2. Record the total cooking time in minutes and the total on-time of the thermostat signal light immediately after removing the food products from the equipment.
3. Conduct five replications using the same equipment, thermostat setting, and food product. The food product should be of the same size, shape, weight, and beginning temperature for each replication. Additionally, the ending internal temperature should be similar for each replication.
4. Use linear regression analysis to determine relationship between CT and TT.
5. Should a linear relationship exist, a mathematical formula for predicting TT from CT can be calculated.

6. That formula is: Multiply CT by the b slope and add the Y intercept to derive TT.
7. TT in minutes divided by 60 determines percentage of one hour TT was on.
8. Multiply the percentage by the kw rating of the equipment. The result is estimated cooking kwh consumption for that food product, in that equipment, at that temperature.

The limitations of data gathered for this study were the lack of testing sufficient replications of other food products to determine energy consumption patterns of each piece of equipment.

VI. RECOMMENDATIONS

Similar electrical equipment should be used to test other food products to provide data to compare with the results of this study.

Different manufacturer's brands of a similar type of electrical equipment as selected for this study should be used with a similar product as chosen for this study to determine which brands are least energy intensive.

Similar types of equipment as selected for this study using gas as a fuel should be studied using a similar product as chosen for this study to determine which fuel is least energy intensive.

Energy consumption characteristics of all commercial food service equipment should be compared to determine maximum equipment load of food products with least energy expenditure.

Energy consumption data calculated in BTU's should be posted on

all standardized recipes to provide energy utilization information for planning of food production.

The methodology developed by this study should be used to help estimate all the energy consumption in the food preparation area. The data gathered could be used to develop budgets and to forecast costs.

All equipment in the food preparation category (prepreparation, preparation, holding, service) should be studied to determine energy utilization characteristics.

Energy consumption data for the food preparation area should be separated into meal periods. From this information, the energy cost per meal served or per customer could be calculated.

The energy costs of lighting, heating, air conditioning, ventilation, sanitation, and refrigeration for the food preparation area should be calculated. These cost data could be added to the food preparation energy costs to determine total energy costs per meal period or per customer.

Food service operators should conduct an energy audit to compare their results with the results of any other studies and the Midwest Research Institute's energy breakdown studies to determine if a similarity exists. With enough operators contributing results, a standard for energy consumption could be developed.

Energy saving procedures such as defrosting food prior to cooking and the use of ambient or waste heat could be investigated.

CHAPTER V

SUMMARY

The control of energy consumption has become important due to major energy price increases and potential decreased availability. The knowledge of how and where energy is being utilized is a prerequisite for the establishment of an energy management program. A total energy audit will help determine which areas and processes are energy intensive and which merit attention. Once energy consumption of food products is determined, the energy costs can be calculated and menus priced accordingly. Should energy availability become limited, it will be possible to change to the least energy intensive, most profitable products (Gatts et al., 1974).

The objectives of this study were:

1. To develop a simple methodology which food service operators could use to estimate energy consumption when cooking food products in electrical commercial food service equipment.
2. To determine which type of electrical commercial food service equipment when cooking 20 pounds of frozen pre-cooked breaded (fpb) chicken quarters is least energy intensive and produces the most acceptable product with least energy consumption.

The electrical commercial food service equipment chosen for this study were those found in many food service operations. Energy utilization characteristics of the equipment were compared while cooking 20 pounds of fpb chicken quarters.

Kilowatt-hour meters were attached to each piece of equipment to measure energy consumption. A technique was developed to estimate energy consumption of each piece of equipment by using a stopwatch to measure the on-time of the thermostat signal light. Results of the two methods were almost identical in determining kwh consumption.

Twenty pounds of fpb chicken quarters were cooked in each piece of equipment to an end point temperature of 180° F. A seven-member taste panel assisted in the research by providing sensory evaluation of the cooked chicken quarters. The quality characteristics scored by the panel were: color, tenderness, juiciness, flavor, and overall acceptability.

A multiple regression analysis was conducted to determine if a relationship existed between cooking time and the on-time of the thermostat signal light. A linear relationship existed. The predictability percentage from cooking time to thermostat signal light time was: deep fryer 38.7, braiser 98.8, bake oven 88.8, and convection oven 53.0. This indicated that cooking time can be used to predict the on-time of the thermostat signal light with some degree of accuracy for the braiser and bake oven.

A one-way analysis of variance was calculated for warm-up and cooking kwh consumption for each piece of equipment. The braiser was most energy intensive for warm-up and least energy intensive for cooking. The deep fryer and ovens were similar in energy consumption for warm-up and the deep fryer was most energy intensive for cooking. For total kwh consumption, the braiser was highest and the convection oven was lowest.

Warm-up time in minutes was: deep fryer 6.4, braiser 23.4, bake oven 18.7, and convection oven 9.1. The deep fryer required the least amount of time to warm-up and the braiser the most time to warm-up. The average cooking time in minutes was: deep fryer 22.5, braiser 11.7, bake oven 47.4 and convection oven 26.6. The braiser cooked the chicken in the shortest amount of time while the bake oven required the longest time. The total utilization time indicated that the deep fryer needed the least amount of time, 28.9 minutes, whereas the bake oven required almost twice the time, 66.1 minutes, of both the braiser and convection oven.

The color of chicken cooked in the bake oven was scored as lower in desirability than chicken cooked in the three other types of equipment. The quality characteristics of tenderness, juiciness, flavor, and overall acceptability were not judged significantly different by the taste panel; therefore, this indicated that chicken cooked in the four pieces of equipment were judged as similar in these quality characteristics.

Pearson product-moment correlation coefficient data indicated that no significant relationship existed between kwh consumption and sensory acceptance scores.

The methodology developed by this research of estimating energy consumption from the on-time of the thermostat signal light and predicting that time from cooking time could be used by any operator of similar electrical commercial food service equipment. The formula to predict on-time of the thermostat signal light from cooking time as developed by this study was: cooking time in minutes multiplied by the b slope plus the Y intercept equals the on-time of the thermostat signal

light. The kwh consumption could then be converted to BTU's and placed on the standardized recipe to provide energy utilization information for planning of food preparation.

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APPENDIXES

APPENDIX A

REPORTING FORMS

SCORE CARD - TASTE SAMPLE

NAME____________________________ DATE____________ SAMPLE NO.__________

Evaluate the sample for all the quality attributes *in the order given.* A glass of water is provided to rinse your mouth at the completion of evaluation of the sample. Check ( ) the term that best describes each characteristic of the sample.

COLOR

____Very desirable
____Desirable
____Slightly desirable
____Neither desirable nor undesirable
____Slightly undesirable
____Undesirable
____Very undesirable

TENDERNESS

____Very tender
____Tender
____Slightly tender
____Neither tender nor tough
____Slightly tough
____Tough
____Very tough

JUICINESS

____Very juicy
____Juicy
____Slightly juicy
____Neither juicy nor dry
____Slightly dry
____Dry
____Very dry

FLAVOR

____Very desirable
____Desirable
____Slightly desirable
____Neither desirable nor undesirable
____Slightly undesirable
____Undesirable
____Very undesirable

OVER-ALL ACCEPTABILITY (Consider all the characteristics by which you would usually evaluate a food.)

____Very good
____Good
____Fair
____Poor
____Very poor

COMMENTS:

SCORE CARD - WHOLE SAMPLE

NAME____________________________________ DATE______________

COLOR	SAMPLE NO.			
Very desirable				
Desirable				
Slightly desirable				
Neither desirable nor undesirable				
Slightly undesirable				
Undesirable				
Very Undesirable				

APPENDIX B

OBJECTIVE AND STATISTICAL DATA

Table A-1. Cooking Time and On-time of the Thermostat Signal Light for the Four Pieces of Equipment

	Deep Fryer		Braiser		Bake Oven		Convection Oven	
Rep[a]	CT[b]	TT[c]	CT	TT	CT	TT	CT	TT
1	24.0	18.6	13.4	12.3	57.5	34.4	30.0	19.0
2	24.8	17.7	13.6	12.6	40.0	23.7	22.0	16.4
3	25.2	17.3	13.5	12.4	39.4	25.4	23.1	15.8
4	26.1	18.0	12.7	11.4	42.6	26.8	25.8	18.5
5	21.9	19.4	12.2	11.3	54.5	31.4	28.0	18.8
6	24.4	17.9	10.6	9.4	44.0	28.8	26.2	18.1
7	21.7	17.3	10.7	9.6	44.0	27.3	31.3	18.1
8	19.4	16.3	10.3	9.1	49.0	29.4	23.2	16.1
9	20.5	14.6	10.2	9.1	53.0	32.2	27.3	16.3
10	20.2	16.5	11.4	9.9	48.0	29.6	25.3	17.0
11	19.8	15.1	10.5	9.2	49.0	32.1	29.9	18.1

[a]Replication.

[b]Cooking time in minutes.

[c]On-time of the thermostat signal light in minutes.

Table A-2. Kilowatt-hour Consumption Comparison of Meter Reading with Thermostat Timing Technique for the Deep Fryer

Date	Total Cooking Time of Product in Min.	Meter Kwh Reading: Begin	Meter Kwh Reading: End	Meter Kwh Reading: Consumed	Thermostat Signal Light: Minutes of Time On: Warm-up	Thermostat Signal Light: Minutes of Time On: Cooking	Thermostat Signal Light: Minutes of Time On: Total	Thermostat Signal Light: % of 1 Hr	Kw Rating of Equip.	Kwh Consumed (rating x %)	Difference in kwh Consumed
4-26	24.0	173.3	178.1	4.85	5.00	18.60	23.60	39	12.5	4.88	.03
4-26	24.8	178.4	182.0	3.60		17.70	17.70	29	12.5	3.63	.03
5-1	25.2	250.8	255.9	5.06	7.51	17.30	24.80	41	12.5	5.13	.07
5-3	26.1	269.0	274.1	5.10	7.00	18.00	25.00	42	12.5	5.20	.10
5-11	21.9	a				19.37		32	12.5	3.87	
5-24	24.4				6.65	17.87	24.50	41	12.5	4.90	
5-24	21.7					17.27		29	12.5	3.45	
5-29	19.4				6.50	16.30	22.80	38	12.5	4.75	
5-29	20.5					14.55		24	12.5	3.03	
5-31	20.2				5.91	16.52	22.43	37	12.5	4.70	
5-31	19.8					15.12			12.5	3.20	

[a] Meter was removed 5-10-76; data not available.

Table A-3. Kilowatt-hour Consumption Comparison of Meter Reading with Thermostat Timing Techinque for the Braiser

Date	Total Cooking Time of Product in Min.	Meter Kwh Reading			Thermostat Signal Light				Kw Rating of Equip.	Kwh Consumed (rating x %)	Difference in kwh Consumed
					Minutes of Time On						
		Begin	End	Consumed	Warm-up	Cooking	Total	% of 1 Hr			
4-26	13.40	78.2	87.2	9.0	28.80	12.30	38.10	63	14.3	9.00	.00
4-26	13.60	89.0	92.0	3.0		12.60	12.60	21	14.3	3.00	.00
5-1	13.50	112.5	121.8	9.3	27.00	12.40	39.40	66	14.3	9.39	.09
5-3	12.70	119.0	127.0	8.0	23.00	11.40	34.40	57	14.3	8.15	.15
5-11	12.20	a			23.00	11.30	34.30	57	14.3	8.17	
5-24	10.60				22.53	9.35	31.88	53	14.3	7.59	
5-24	10.70					9.58	9.58	16	14.3	2.28	
5-29	10.31				20.06	9.13	29.19	49	14.3	6.96	
5-29	10.20					9.07		15	14.3	2.16	
5-31	11.44				22.34	9.90	32.24	53	14.3	7.68	
5-31	10.45					9.18		15	14.3	2.19	

[a]Meter was removed 5-10-76; data not available.

Table A-4. Kilowatt-hour Consumption Comparison of Meter Reading with Thermostat Timing Technique for the Bake Oven

Date	Total Cooking Time of Product in Min.	Meter Kwh Reading Begin	Meter Kwh Reading End	Meter Kwh Reading Consumed	Thermostat Signal Light Minutes of Time On Warm-up	Thermostat Signal Light Minutes of Time On Cooking	Thermostat Signal Light Minutes of Time On Total	Thermostat Signal Light % of 1 Hr	Kw Rating of Equip.	Kwh Consumed (rating x %)	Difference in kwh Consumed
4-26	57.5	10.0	15.3	5.3	17.45	34.41	51.86	86	6.2	5.35	.05
5-1	40.0	17.0	21.7	4.7	18.70	23.68	42.38	71	6.2	4.38	.32
5-3	39.4	21.6	26.7	5.1	19.00	25.42	44.42	74	6.2	4.60	.50
5-11	42.6	26.7	31.6	4.9	20.10	26.75	46.85	78	6.2	4.89	.01
5-11	54.5	31.7	37.0	5.3	16.00	31.36	47.36	79	6.2	4.90	.40
5-24	44.0				17.95	28.78	46.73	78	6.2		
5-24	44.0	62.3	72.2	9.9	19.65	27.30	46.95	78	6.2	9.68	.22
5-29	49.0				19.53	29.37	48.90	82	6.2		
5-29	53.0	73.2	84.6	11.4	18.15	32.15	50.30	84	6.2	11.25	.15
5-31	48.0				20.10	29.61	49.71	83	6.2		
5-31	49.0	84.5	95.8	11.3	18.47	32.10	50.57	84	6.2	10.97	.33

Table A-5. Kilowatt-hour Consumption Comparison of Meter Reading with Thermostat Timing Technique for the Convection Oven

Date	Total Cooking Time of Product in Min.	Meter Kwh Reading			Thermostat Signal Light				Kw Rating of Equip.	Kwh Consumed (rating x %)	Difference in kwh Consumed
		Begin	End	Consumed	Minutes of Time On: Warm-up	Cooking	Total	% of 1 Hr			
4-26	30.00	8.5	14.0	5.5	10.58	19.00	29.58	50	11	5.50	.00
5-1	22.00	13.9	18.8	4.9	10.59	16.40	27.00	45	11	4.95	.05
5-3	23.10	19.6	24.0	4.4	8.50	15.80	24.30	41	11	4.45	.05
5-11	25.80	24.0	29.0	5.0	8.70	18.50	27.20	45	11	4.99	.01
5-11	28.00	29.0	33.9	4.9	8.63	18.84	27.47	46	11	5.03	.07
5-24	26.20	56.1	64.3	8.2	8.65	18.05	26.70	46	11	8.22	.02
5-24	31.30					18.10			11		
5-29	23.20	64.3	71.8	7.5	8.45	16.10	24.55	41	11	7.48	.02
5-29	27.31					16.28			11		
5-31	25.30				8.85	16.95	25.80	43	11		
5-31	29.85	71.8	79.8	8.0		18.06		30	11	8.04	.04

Table A-6. Averages of kwh Consumption by the Thermostat Signal Light Timing Technique and Kilowatt-hour Readings for the Other Five Food Products

Equipment	Meter Reading kwh Consumption	Thermostat Signal Light: Minutes of Time On			Thermostat Signal Light	Kw Rating of Equip.	Estimated kwh Consumption (rating x %)	Difference[a] in kwh Consumption
		Warm-up	Cooking	Total	% of 1 Hr			
Deep Fryer	4.18	6.97	13.10	20.07	33.5	12.5	4.18	0.00
Braiser	6.88	21.74	7.15	28.89	48.2	14.3	6.89	0.01
Bake Oven	3.92	17.82	20.30	38.12	63.5	6.2	3.94	0.02
Convection Oven	4.38	8.66	15.26	23.92	39.9	11.0	4.39	0.01

[a]Between kilowatt-hour meter reading and thermostat signal light timing technique.

Table A-7. One-way Analysis of Variance for Equipment Warm-up kwh Consumption

Source of Variance	df	Sum of Squares	Mean Squares	F Ratio[a]
Equipment	3	83.21	27.74	327.61
Replications	28	2.37	0.08	
Totals	31	85.58		

[a]A minimum F ratio of 2.95 is necessary for the data to be statistically significant at the 0.05 level.

Table A-8. One-way Analysis of Variance for Cooking kwh Consumption

Source of Variance	df	Sum of Squares	Mean Squares	F Ratio[a]
Equipment	3	6.35	2.12	23.29
Replications	40	3.64	0.09	
Totals	43	9.99		

[a]A minimum F ratio of 2.84 is necessary for the data to be statistically significant at the 0.05 level.

Table A-9. Equipment Warm-up Time and Warm-up kwh Consumption

	Deep Fryer		Braiser		Bake Oven		Convection Oven	
Rep.[a]	T[b]	kwh	T	kwh	T	kwh	T	kwh
1	5.00	1.04	25.80	6.15	17.45	1.80	10.58	1.94
2	7.51	1.56	27.00	6.44	18.70	1.93	10.59	1.94
3	7.00	1.46	23.00	5.48	19.00	1.96	8.50	1.56
4			23.00	5.48	20.10	2.08	8.70	1.60
5					16.00	1.65	8.63	1.58
6	6.65	1.39	22.50	5.36	17.95	1.85	8.65	1.59
7					19.65	2.03		
8	6.50	1.35	20.06	4.78	19.53	2.02	8.45	1.55
9					18.15	1.88		
10	5.91	1.23	22.34	5.32	20.10	2.08	8.85	1.62
11					18.47	1.91		

[a]Replication.

[b]Warm-up time in minutes.

Table A-10. Fpb Chicken Cooking Time and Cooking kwh Consumption

	Deep Fryer		Braiser		Bake Oven		Convection Oven	
Rep.[a]	T[b]	kwh	T	kwh	T	kwh	T	kwh
1	24.0	3.88	13.4	2.93	57.5	3.55	30.0	3.48
2	24.8	3.69	13.6	3.00	40.0	2.45	22.0	3.01
3	25.2	3.60	13.5	2.96	39.4	2.62	23.1	2.90
4	26.1	3.75	12.7	2.72	42.6	2.77	25.8	3.39
5	21.9	4.04	12.2	2.69	54.5	3.24	28.0	3.45
6	24.4	3.73	10.6	2.24	44.0	2.98	26.2	3.32
7	21.7	3.60	10.7	2.29	44.0	2.82	31.2	3.32
8	19.4	3.40	10.3	2.17	49.0	3.04	23.2	2.95
9	20.5	3.04	10.2	2.17	53.0	3.33	27.3	2.99
10	20.2	3.44	11.4	2.36	48.0	3.06	25.3	3.12
11	19.8	3.15	10.5	2.19	49.0	3.32	29.9	3.32

[a]Replication.

[b]Cooking time in minutes.

Table A-11. Means of Taste Panel Scores for Color and Tenderness of Cooked Chicken Quarters

	Rep.[a]	Deep Fryer	Braiser	Bake Oven	Convection Oven
Color Whole	2	5.71	6.43	3.29	5.71
	3	6.00	5.86	2.43	4.71
	4,5	5.57	6.14	3.43	6.14
	6,7	5.57	6.86	2.71	5.57
	8,9	6.43	5.86	3.00	5.29
	10,11	6.43	6.71	3.00	5.43
Color-Taste	1	5.57	6.86	2.86	5.43
	2	6.57	6.14	3.29	5.29
	3	6.16	6.71	3.71	4.71
	4,5	6.00	6.57	4.14	6.14
	6,7	6.57	6.57	3.29	5.00
	8,9	6.29	6.00	4.57	5.00
	10,11	6.14	6.00	3.57	5.29
Tenderness	1	6.29	5.83	5.71	4.57
	2	4.71	5.71	6.00	5.86
	3	5.86	5.86	5.43	5.50
	4	4.14	6.00	5.43	5.57
	6	5.86	5.00	6.00	5.86
	8	5.00	4.00	5.71	5.00
	10	5.71	5.29	5.43	5.29

[a]Replication number.

Table A-12. Means of Taste Panel Scores for Juiciness, Flavor, and Acceptability of Cooked Chicken Quarters

	Rep.[a]	Deep Fryer	Braiser	Bake Oven	Convection Oven
Juiciness	1	4.86	5.14	4.14	4.29
	2	4.71	4.43	4.86	4.71
	3	4.57	5.00	5.57	4.50
	4	4.14	5.43	4.43	4.43
	6	5.86	4.86	5.57	4.71
	8	4.00	3.00	4.29	4.29
	10	5.29	5.29	5.14	5.29
Flavor	1	6.00	6.14	5.57	5.29
	2	5.29	5.57	5.00	5.86
	3	5.00	5.86	5.14	5.50
	4	4.86	6.43	6.14	5.71
	6	6.29	5.57	5.00	5.57
	8	5.14	4.43	5.57	4.86
	10	5.71	5.86	5.14	5.71
Acceptability	1	4.00	4.57	3.43	3.29
	2	3.29	3.71	3.43	3.86
	3	3.67	4.00	3.43	3.50
	4	3.43	4.43	3.71	4.00
	6	4.57	3.86	3.14	3.57
	8	3.57	3.00	3.57	3.43
	10	3.86	4.29	3.29	3.71

[a]Replication number.

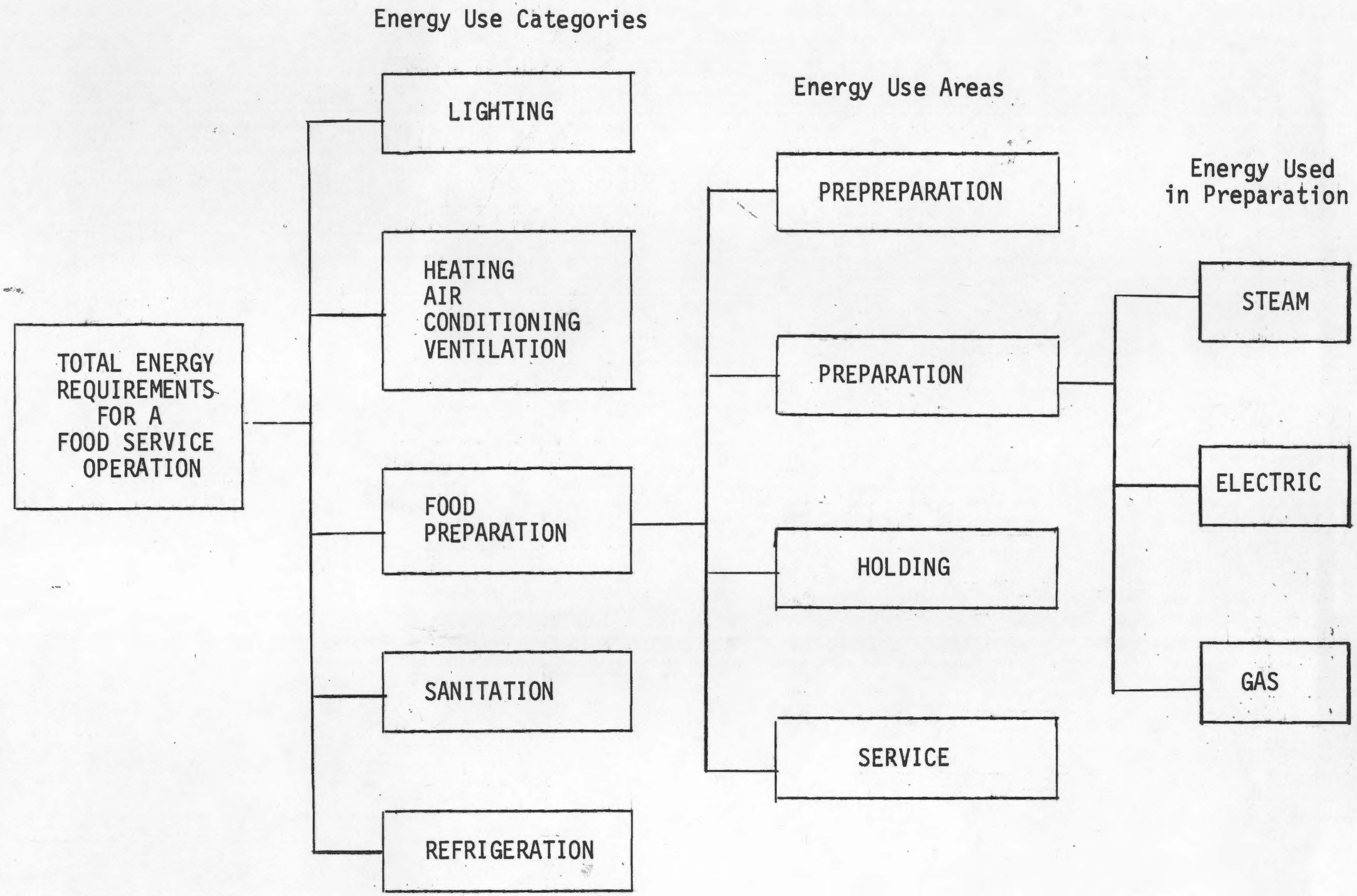

Figure 1. Energy Use in Food Preparation

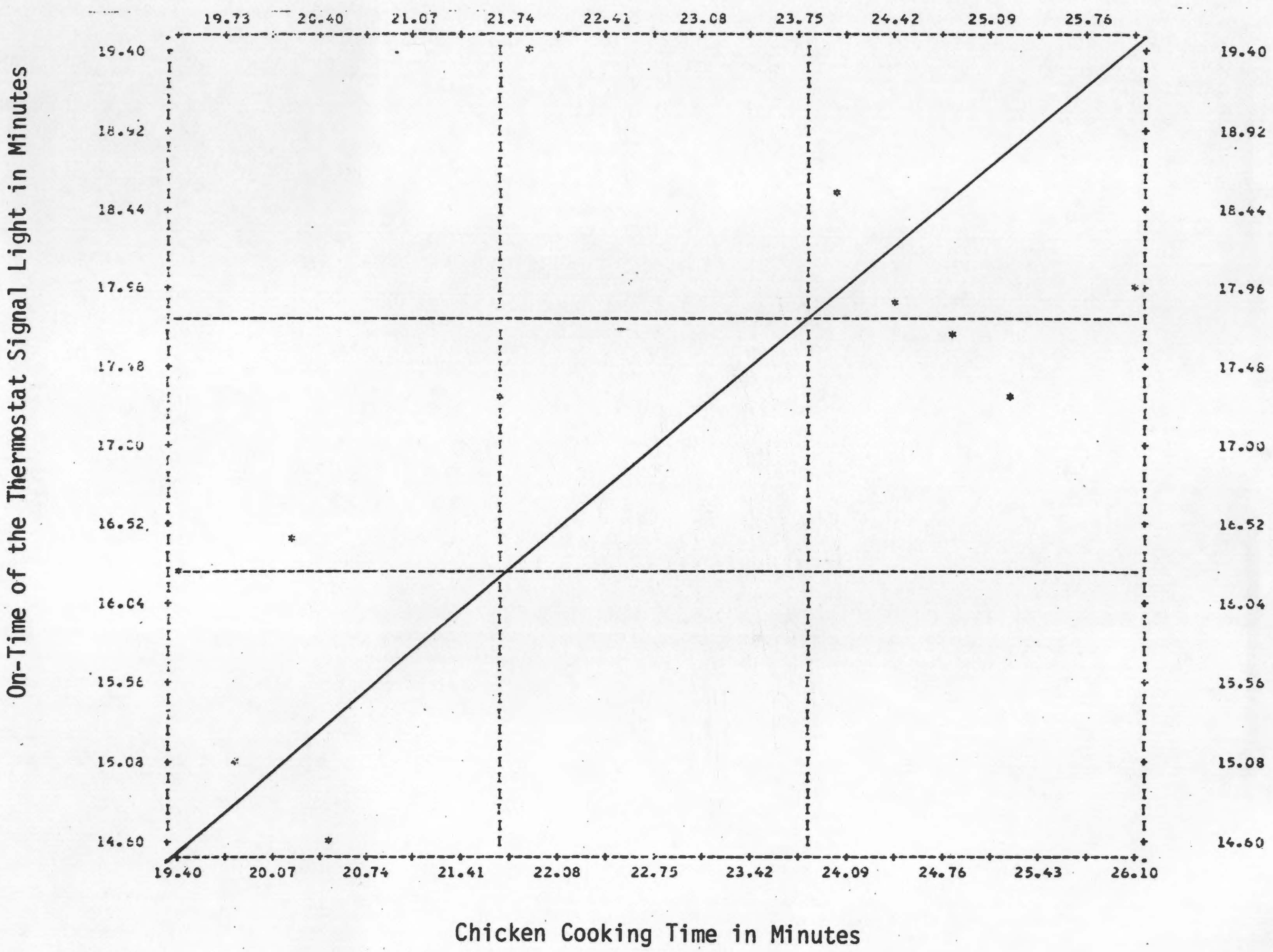

Figure 2. Linear Relationship of Cooking Time and Thermostat Time for the Deep Fryer.

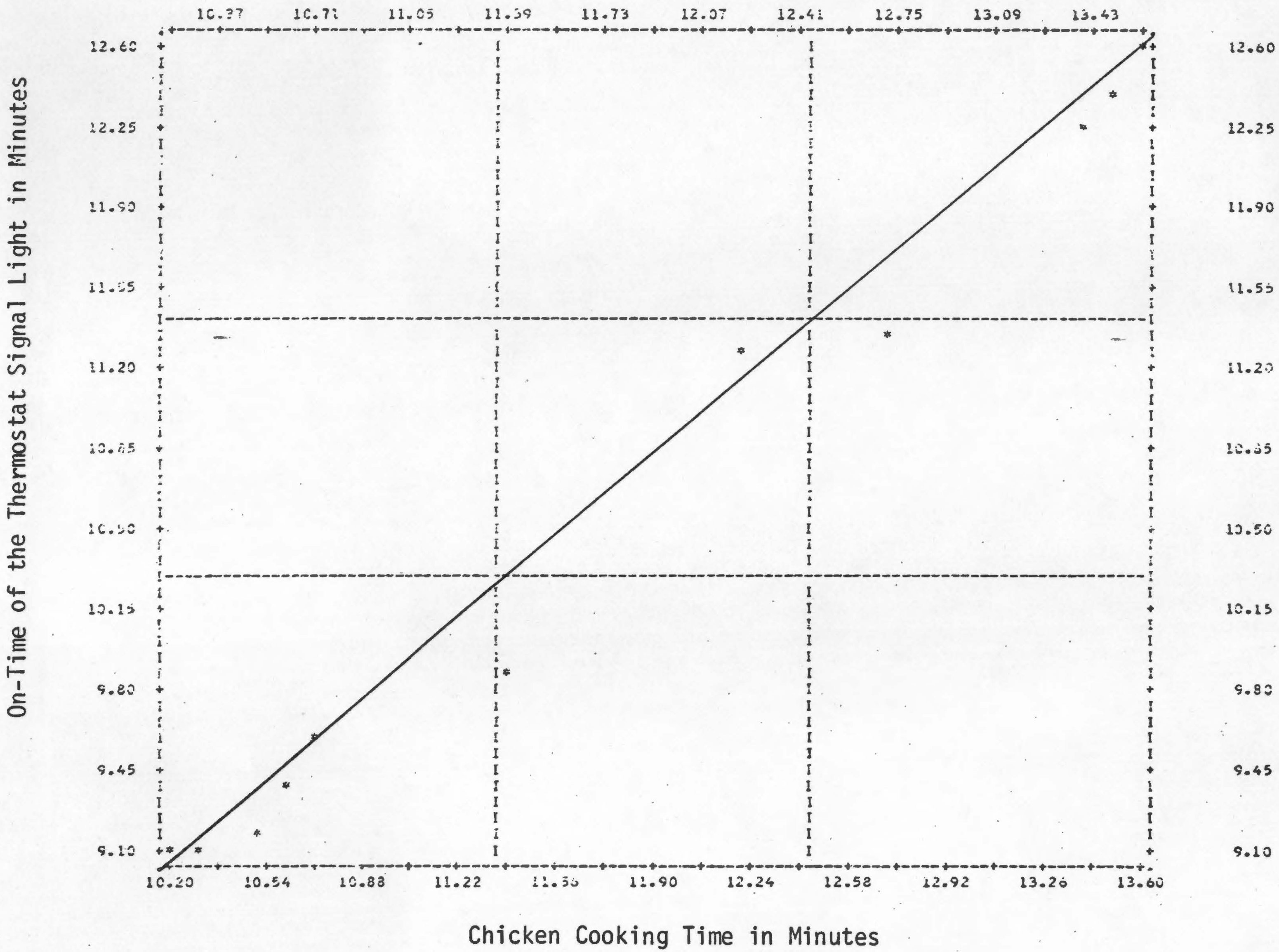

Figure 3. Linear Relationship of Cooking Time and Thermostat Time for the Braiser.

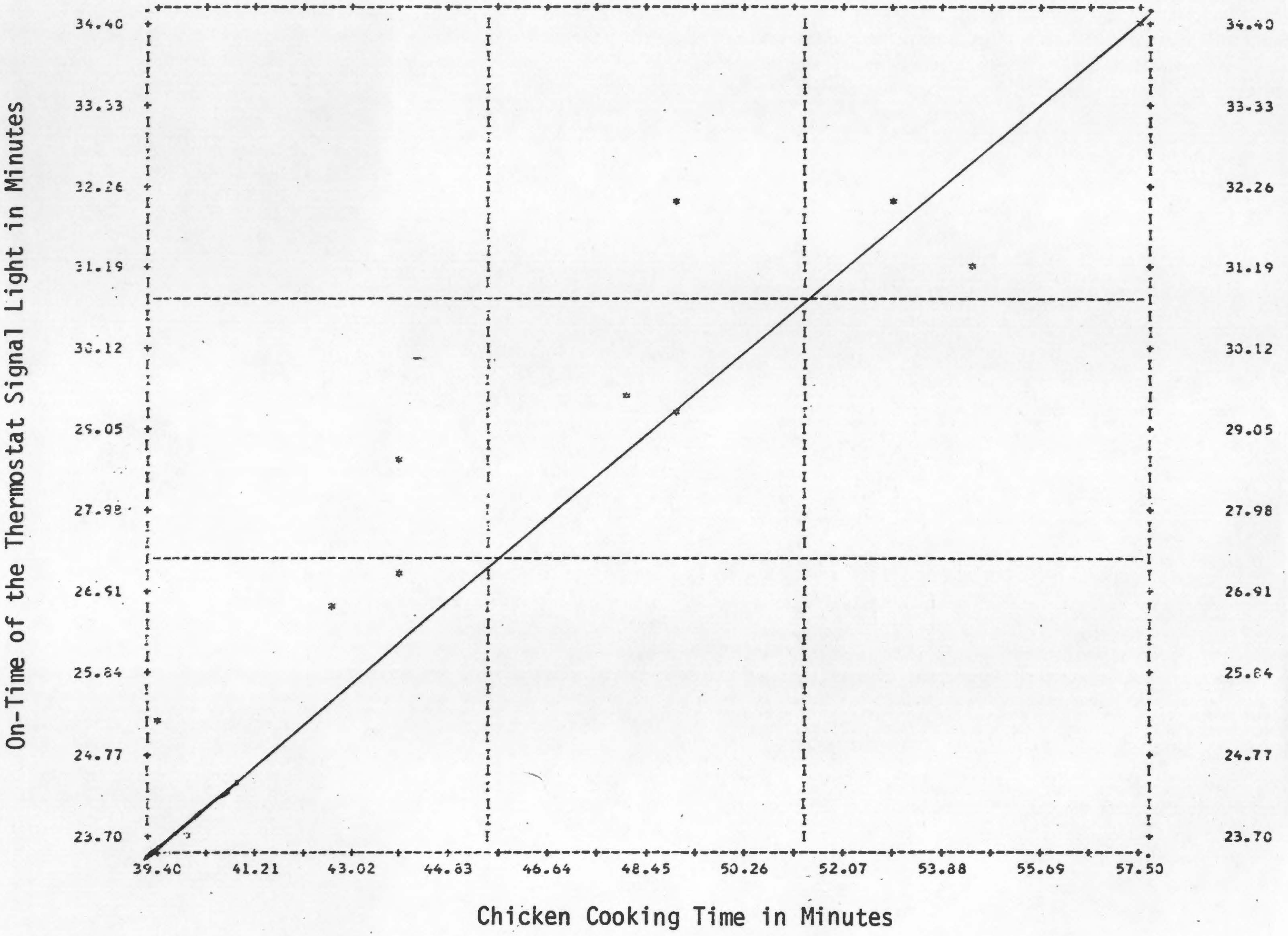

Figure 4. Linear Relationship of Cooking Time and Thermostat Time for the Two-Pan Bake Oven.

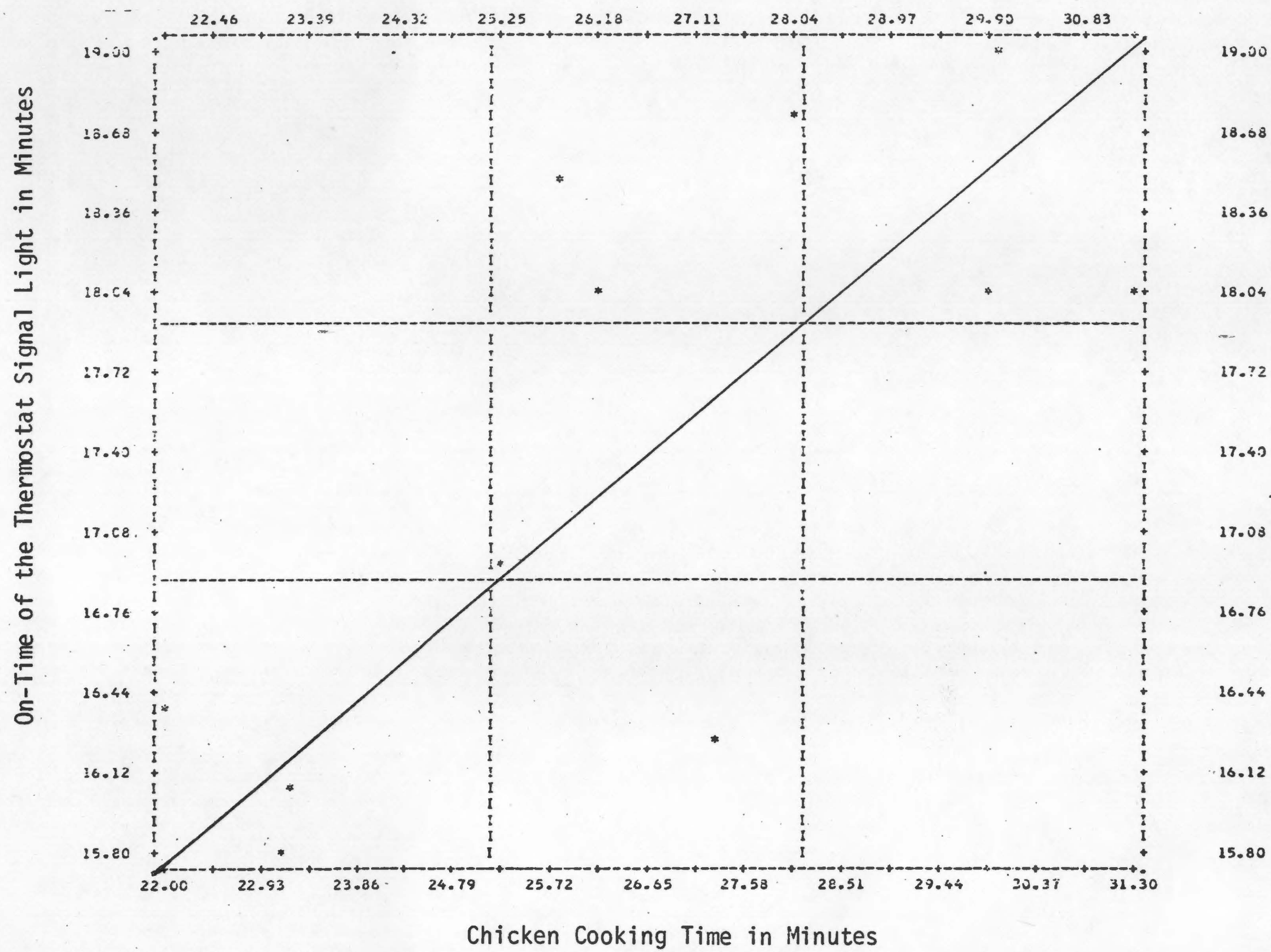

Figure 5. Linear Relationship of Cooking Time and Thermostat Time for the Convection Oven.

VITA

Frank Romanelli was born in Dearborn, Michigan, on July 6, 1930. He was graduated from Fordson High School in January 1948, and earned a Bachelor of Arts degree from Michigan State University in June 1958. His major was Hotel Administration, and he was voted the outstanding graduate in his class by the Hotel School faculty and students. The Master of Business Administration degree was received from West Texas State University in May 1970. The Business School faculty voted him the honor graduate of his class. Graduate work was continued at the University of Houston.

His food and lodging industry career spanned 15 years and included various supervisory and management positions in restaurants, hotels, motor hotels, city and country clubs, contract university food services, military feeding, and summer resorts.

His college teaching career began in 1963 at Del Mar College in Corpus Christi, Texas, where he was the first instructor-director and developer of the nationally recognized Restaurant Management program. In 1968 he opened a similar program at Amarillo College in Texas. From 1970 until the present time, Frank has been an assistant professor at the Hilton School of Hotel and Restaurant Management, University of Houston, Texas.

He is currently a hospitality education and industry consultant, speaker, and author. He is a member of Delta Sigma Pi, the international business and commerce fraternity and Sigma Pi Eta, the hotelman's national honor society.

Frank is married to the former Peggy Conner. They have two sons, The Reverend Dean and Kevin Romanelli.