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TURBOT FILLET SECTIONS COOKED BY MICROWAVE AND CONVENTIONAL HEATING METHODS: OBJECTIVE AND SENSORY EVALUATION

A Dissertation

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Degree

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Karen Madeira

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DEDICATION

The author dedicates this dissertation

to her late father,

Joaquim Madeira.

His fond memory and appreciation for education

were inspiration for the completion

of this project and degree.

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ABSTRACT

Energy and time conservation in food preparation is of concern to consumers and the microwave oven is one appliance that has been credited with energy and time savings. Although consumption of fish by consumers has been increasing, little has been reported on the microwave-cooking of fish. Therefore, an investigation was designed to compare the energy requirements of, the effects of heating on, and the acceptability of turbot, an underutilized species of fish, cooked in a microwave oven with that baked conventionally.

The microwave oven cooked the fish significantly faster, required less cooking power and energy, and demonstrated greater relative efficiency than did the conventional oven. The evaporative loss was less, and the solid-drip loss and total cooking losses were greater for fish cooked in the microwave oven than were those for fish heated conventionally. Kramer shear values for the conventionally heated turbot were higher than those for the microwave-heated fish.

A 7-member trained sensory panel found no differences in flakiness and moistness of the turbot cooked in the 2 ovens, but found that microwave-heated fish was softer and less chewy than was the conventionally heated fish. Differences were found also due to replication, panelist, and interactions.

Significant relationships were found between sensory scores for hardness and chewiness and between sensory flakiness and 3 measurements: fillet section thickness, raw weight, and raw moisture content.

Hardness and chewiness were each related to Kramer shear values, solid-drip loss, and total cooking losses.

A 39-member consumer panel indicated no significant difference ($P = 0.08$) in acceptability of turbot heated by the 2 cooking methods. Samples were rated in the middle of a 9-point hedonic scale. Most of the consumer panelists reported that they ate fish at least 2-3 times per month, generally baked or broiled it, and ate fish in restaurants almost as much as they did at home. Out of 12 fish species, cusk, monk-fish, orange roughy, and sculpin were species with which respondents were least familiar.

In conclusion, microwave cooking of turbot was more time and energy efficient than was conventional cooking and resulted in turbot of comparable eating quality.

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CHAPTER I

INTRODUCTION

Energy availability and conservation have become increasingly important to consumers. As a result, the energy requirements of preparing food by traditional means such as cooking in a conventional oven have been questioned. It generally is thought that the use of microwave heating is one way to reduce energy expenditures for food preparation (Van Zante, 1973). In addition to energy requirements, initial and repair costs of appliances and conservation of time are important aspects of food preparation for consumers. The microwave oven has been credited with reduced operating cost (AHAM, 1980a) and reduced cooking times when microwave heating was used in conjunction with conventional oven cooking (Lovingood and Goss, 1980).

Microwave heating is a more efficient method of cooking because less energy is lost during heating than is lost when using a conventional oven. Only about 14% of the energy available in a conventional oven is absorbed by the oven load, while 46% of the energy heats the oven and the remainder is lost through the oven walls and vent (Erickson, 1978). Also, microwave ovens do not require preheating as do conventional ovens, and they have the advantage of automatic timing to terminate the energy expenditure. It has been estimated that microwave ovens require only 25-75% as much energy as do conventional ovens in food preparation (McNeil and Penfield, 1983; Ludvigson and Van Valkenburg, 1978; Voris and Van Duyne, 1979).

The energy savings associated with microwave heating are dependent on a number of factors, including type of food and the size of load placed in the oven. Therefore, it is important to study microwave heating for a variety of foods. Reducing energy consumption is important, but if the more energy-efficient heating method produces foods that are not acceptable to the consumer, the energy savings may become secondary when considering a heating method for food preparation.

Research reports on the eating quality of fish in general and fish prepared with microwave heating are limited, despite the fact that fish and fish products are important food sources. Wesson et al. (1979) investigated the ability of inland populations to discriminate quality of fish and seafood products, but did not explore the use of microwave heating. Kapsalis and Maller (1980) tested microwave heating for use in research designed to categorize fish species according to consumer and instrumental measures, but concluded that the method was inappropriate for their project because of methodological problems resulting from uneven heating. Baldwin and Snider (1971) researched factors influencing spatter of carp during microwave cooking, but did not address consumer acceptability. In a study of frozen storage of deboned minced fish flesh, Nakayama and Yamamoto (1977) used underutilized fish species and microwave heating in their work. However, they did not report the effects or comparison of cooking methods in preparing the fish. In order to make sound recommendations to consumers on how to prepare fish using microwave heating as a possible fast, economical cooking method,

additional research is needed with both utilized and underutilized fish species.

The objectives of the present study of an underutilized species of fish were as follows:

1. To characterize and compare physical and chemical properties of fish heated in microwave and conventional ovens. The properties included weight, pH, moisture content, cooking losses, and Kramer shear values.
2. To compare the energy requirements, cooking power, and relative efficiencies of microwave and conventional oven methods of heating fish.
3. To characterize and compare the sensory properties, as determined by a trained sensory panel, of fish cooked by microwave and conventional heating (i.e., flakiness, moistness, hardness, and chewiness).
4. To study relationships between objective measurements and sensory attributes, and among sensory attributes evaluated by a trained panel, of fish cooked conventionally and in a microwave oven.
5. To characterize a consumer panel and compare consumer acceptability of fish cooked in conventional and microwave ovens.

To meet these objectives, the present investigation was focused on comparing the effects of microwave heating and conventional heating on the eating quality and energy requirements involved in cooking an underutilized fish species (Reinhardtius hippoglossoides) commonly referred

to as Greenland turbot. Fillet sections baked in a conventional oven at 176°C (350°F) were cooked to an internal temperature of 82°C (180°F). Fillet sections cooked in the microwave oven were cooked according to times selected to give fillet quality comparable to that of turbot cooked in the conventional oven.

Cooking times, cooking losses, and cooked moisture contents resulting from both cooking methods were compared. The energy requirements of the microwave oven and the conventional ovens were investigated. The wattage and cooking power were determined for each oven. The relative efficiencies, with and without preheating wattage, of the conventional ovens were compared to the relative efficiency of the microwave oven.

As an important aspect of cooked fish quality (Cardello et al., 1982a), texture was evaluated by both objective and sensory methods. A modified version of the Kramer shear cell attached to an Instron Universal Testing Machine was used to evaluate hardness. A 7-member sensory panel was trained to evaluate flakiness, moistness, hardness, and chewiness, using characteristic definitions and procedures for evaluation developed in the study. A consumer panel also evaluated the turbot cooked by both methods on hedonic scales. Demographic data and information on fish and microwave oven use also were collected from the consumer panel.

CHAPTER II

REVIEW OF LITERATURE

I. ENERGY CONSUMPTION AND MICROWAVE OVENS

Residential use in the United States accounts for one-fourth of the national total energy consumption. One of the largest energy expenditures of the residential sector is for food preparation (Erickson, 1978). It also has been reported that 11% of the residential energy consumption, estimated to be 20% of the national total, is for food preparation (Berg, 1973).

Rhee and Drew (1977) explained that energy requirements and the cost of operating appliances used for food preparation are not primary considerations for most consumers. However, energy utilization, energy efficiency, and initial and repair costs of appliances are becoming factors that consumers evaluate when purchasing appliances. As lifestyles and family structures have changed, conservation of time for food preparation also has become of primary importance to some consumers. Reduction of cooking time is therefore a consideration in the purchase and use of appliances for food preparation (Drew and Rhee, 1978). In a survey of 2,000 homeowners, two-thirds of the families polled did not know the cost of operating major appliances, but were willing to spend slightly more for appliances if substantial energy savings were possible (Consdorf, 1978).

Microwave ovens have been credited with energy savings and reduction of cooking time. The Federal Trade Commission exempted microwave

ovens from energy cost or efficiency labeling, which is required for other appliances. This decision was based on the fact that a microwave oven typically uses less than 100 kilowatt hours (kwh) per year with operating costs ranging from $3.00 to $5.00 per year (AHAM, 1980a).

It has been projected that during 1985, 32.5 billion kwh of electricity could be saved by using microwave ovens in place of conventional ovens (Ludvigson and Van Valkenburg, 1978). Microwave ovens use 0.006% of the total energy consumed in the U.S. while conventional ranges use 0.15% (AHAM, 1980b). It also has been estimated that microwave ovens require only 25-75% as much energy as do conventional ovens (Ludvigson and Van Valkenburg, 1978; Voris and Van Duyne, 1979). It was reported recently that a microwave oven required 77% as much energy as was required by a conventional oven to cook boneless turkey breasts (McNeil and Penfield, 1983). These results fall within the estimates of other authors.

When a microwave oven was used in combination with a conventional oven in meal preparation, it was shown that energy use could be reduced by 24% (Lovingood and Goss, 1980). Ludvigson and Van Valkenburg (1978) concluded that a family of 4 could save more energy when microwave cooking replaced conventional oven cooking than when it was substituted for surface unit cooking. A 17% energy savings was reported by Butel (1975) when a microwave oven was used only for foods for which it was the most energy efficient and the remainder of the foods in standard USDA money-saving menu II were prepared with conventional cooking methods. In the same study, a 40% energy savings was reported when food

items that must be cooked conventionally (oven and surface units) were eliminated from the menu being tested. In contrast, further investigation provided evidence that indicated that a 30% increase in energy was required when foods that are usually cooked on the surface unit of a conventional range, such as broccoli and other vegetables, were cooked in the microwave oven. Butel (1975) concluded that microwave oven manufacturers' claims of 75% energy savings cannot be substantiated without qualification.

Hassoun (1982) pointed out the many discrepancies found in reports of microwave energy savings, as illustrated above, and suggested that additional research information on energy used by microwave ovens compared to that of other appliances would be helpful in aiding consumers in the selection of the most efficient method for food preparation.

In an Arizona survey of owners of microwave ovens (Gast et al., 1980), it was concluded that the predominant use of the microwave oven was for warming and defrosting food. Vegetables were the most commonly cited food prepared in the microwave oven, but beef, chicken, and pork were prepared also in the microwave oven. Only 35.7% of the respondents, however, prepared fish in the microwave oven in contrast to 65, 57, and 46% who cooked beef, chicken, and pork, respectively, in the microwave oven.

II. TYPES OF OVEN HEATING

Conventional Oven

Heat is radiated from the heating elements in a conventional oven to the oven walls, and then to the air within the oven. The outside of

the food is heated by the oven air and conduction transfers the heat inside the food. Preheating is required to maintain an even oven temperature since oven air is relatively still and cools as it moves (Van Zante, 1973).

Microwave Oven

Microwave oven cooking involves dielectric heating which differs from that of the conventional oven. The interior of the microwave oven remains at room temperature because all of the energy emitted in the oven is absorbed by the food. Some heat may be transferred to the container holding the food and part of the oven in contact with the container and, as well as, the air immediately surrounding the heated food (Anon., 1972).

A magnetron tube is the energy-emitting device in a microwave oven. The magnetron emits electromagnetic waves that are nonionizing and cause a rise in temperature within the food. This rise in temperature occurs as a result of the movement of dipole and polar food molecules as they attempt to align themselves with the rapidly alternating high-frequency field created by the waves emitted in the oven. As the charged particles in the food vibrate, frictional heat is produced, resulting in cooking of the food. Transfer of the heat throughout the food then occurs through conduction and convection (Anon., 1972; Lorenz, 1976; Van Zante, 1968, 1973; Ziprin and Carlin, 1976).

III. U.S. FISH CONSUMPTION

Fish and fish products are important food sources. Seafood is available year round as a result of modern preservation methods and greater local availability. The consumption of fish products in the United States increased 3.6% from 1960 to 1980 (Prescott, 1981).

In a recent study of consumer expenditure patterns for fish and shellfish, it was found that in the past 30 years, fish and shellfish expenditures of consumers represented 5.3-8.2% of their total meat, poultry, and seafood expenditure (Capps, 1982). In the same study, data from a survey of 10,000 households from 1972 to 1974 were used to determine that fish and shellfish are normal goods. A 10% increase in income resulted in a 1.68% increase in expenditure for fish. A 10% increase in cost of fish resulted in a 4.6% decrease in fish consumption, reflecting the price inelasticity of demand for fish. The variables shown to be significantly related to expenditure for fish were geographic region, population density, race, marital status, industry of household head, cost of fish, household size, and income. Seasonality, occupation of household head, property ownership status of household head, employment status of female household head, and education were not significant influences (Capps, 1982).

Although there are more than 500 species of fin fish and shellfish commercially available in the U.S. (USDC, undated), most are underutilized and only, approximately, 150 species are sold commonly to consumers (Stillings and Thompson, 1978). Offensive nomenclature and

consumer unfamiliarity and inexperience in preparing common and underutilized fish species have contributed to underusage. Efforts to counteract this situation have been made by the U.S. Fisheries Service (Stillings and Thompson, 1978; USDC, undated), and USDA and USDHEW (1980) who also recommended, in the Dietary Guidelines for Americans, that consumers increase their consumption of fish.

IV. FACTORS AFFECTING QUALITY OF COOKED FISH

A variety of parameters have been investigated in attempts to identify those factors primarily responsible for influencing the quality of fish as perceived by quality control inspectors and consumers. Environmental, chemical, physical, and sensory components have been the focus of research reports in the literature. Early as well as recent investigators dealt mainly with frozen storage quality of raw fish and chemicophysical factors affecting it (Andersson and Danielson, 1961; Awad et al., 1969; Barrett et al., 1965; Cowie and Little, 1966, 1967; Deng et al., 1977; Kelleher et al., 1982; Love, 1958a,b, 1962; Love and Ironside, 1958; Mills, 1975; Olley et al., 1967). The emphasis of the following discussion is on texture and the effects of heating method on the eating quality of cooked fish. Discretion was used in selecting aspects of the literature for review that were pertinent to these areas of interest within the scope of this study.

Effects of Different Heating Methods and Heat on Fish Muscle

There is a general lack of research reported in the literature in which the effects of different cooking methods on the eating quality of

fish were compared. No evidence was found of studies that were focused specifically on comparing the effects of microwave cooking to those of other cooking methods. However, the effects of heating fish have been studied using several cooking methods, and microwave heating has been used in fish studies that focused on parameters other than cooking method.

As part of a broad study of the quality of various foods covered with plastic film and cooked in 915-MHz and 2450-MHz microwave ovens, haddock, salmon, and perch were evaluated for appearance, color, fork texture, mouthfeel, moisture, flavor, and overall preference (Armbruster and Haefele, 1975). The results indicated that at 915 MHz no spattering occurred without a covering, while the cooking time was significantly shortened from 9 to 5 min for perch baked with a cover at 2450 MHz. The effect of cover on sensory properties could not be determined on the basis of the results presented.

In another report on the effects of frozen storage on chemical and sensory evaluation of deboned minced fish flesh of underutilized species, microwave heating was used to prepare samples for sensory testing (Nakayama and Yamamoto, 1977). In this study, 20-g cores cut from frozen fish blocks were cooked at repeated intervals of 16-sec exposures on the defrost setting, followed by 35-sec equilibrating periods for a total of 3 min and 40 sec. The effects of microwave cooking were not discussed or compared to other cooking methods, however.

In an extensive research project designed to categorize fish species according to consumer and instrumental measures of edibility, Kapsalis and Maller (1980) explored the use of microwave cooking in

preliminary work. They concluded that it was not appropriate for their study because specimen dimensions changed too much for proper objective testing of texture, and nonuniform cooking was too severe.

Baldwin and Snider (1971) investigated factors that influenced spatter of fresh and frozen carp during microwave cooking. They found no significant differences in fat content, moisture content, or spattering among 3 lateral sections of fish. Moisture content and spatter amount were found to be positively correlated, and amount of spatter and fat content were negatively correlated.

In early studies, Charley (1952), and Charley and Goertz (1958) dealt with baking and the effects of 4 electric oven temperatures and 4 internal temperatures on cooking losses and palatability of fresh salmon steaks. In the first study, oven temperatures of 177, 204, 232, and 260°C (350, 400, 450, and 500°F) were used. In the later study, the same oven temperatures were investigated as in the first, but a single end point temperature of 70°C was used. Charley (1952) found no significant differences in evaporative loss and total cooking losses associated with the 4 oven temperatures when an internal temperature of 75°C was used. However, differences among fish were found in evaporative and drip losses. Also, a greater amount of drip loss was associated with heating at 500°F than with other oven temperatures used. Percentage of press fluid did not differ with oven temperature, but internal temperature significantly affected the yield of press fluid. Steaks cooked to 85°C yielded less than those cooked to 70°C and 75°C, and those cooked to 80°C yielded less than those cooked to 70°C.

Charley (1952) also reported that salmon steaks baked to an internal temperature of 70°C ranked lower in flavor and overall desirability than did steaks cooked to the other internal temperatures. However, palatability scores of steaks cooked to 75°C and 80°C did not differ. Using larger salmon steaks than in the first study, Charley and Goertz (1958) found that anterior cuts of the fish were ranked highest in flakiness and lowest in tenderness, while posterior cuts were rated least flaky and most tender.

Dyer and Fraser (1964) compared the palatability of frozen cod fillets of various qualities cooked by baking, steaming, and frying. They also were concerned with determining the best cooking method for detecting sensory quality differences in the fillets. They found there was better discrimination of textural differences when samples were baked rather than cooked by the other methods. Steaming was considered possibly to be a suitable method for testing also.

In a more recent study, deep-fat frying, pan-frying, and baking of lake trout, white sucker, and bluegill were compared in relation to lipid content and composition (Mai et al., 1978). Method of cooking, presence or absence of breading, the original lipid content, and size of fillet influenced weight changes. Weight losses due to baking resulted primarily from moisture loss.

The effect of temperature on fish muscle was reported by Ward et al. (1977). They found that with increasing temperature, the amount of liquor released under pressure increased and was dependent on the species and quality of the fish used. Deng (1981) reported that with

heating, toughening followed by softening of fish muscle occurred at 55°-85°C. Similarly, in a review on the changes in fish structure during heating, Sikorski (1979) noted that albumins and globulins were denatured with loss of enzyme activity along with changes in number and distribution of SH groups, and cross-linking of S-S groups. Coagulation, change in fish color, and partial hydration also were observed. Shrinkage of connective tissue fibers was accompanied by hydration and gelation of collagen. Up to 25% drip was formed and partial hydrolysis and autoxidation of lipids, which interacted with proteins, occurred with heating. An increase in pH of 0.3-0.6 was reported.

Dunajski (1979) noted in a review that fish collagen is very prone to thermal change and therefore the time factor in heating fish muscle is not very important. It was reported that fish collagen becomes solubilized and loses its structure at 60°C. Dunajski (1979) contended that method of cooking, dry or moist, was not very important in influencing the final texture of fish muscle because fish collagen is very prone to thermal changes and reaches doneness after only a few minutes of heating at 70-80°C.

Texture

It has been reported that the ultimate determinants of cooked fish quality and consumer acceptance are flavor and texture (Boyd and Wilson, 1976; Laslett and Bremner, 1979). Several investigators suggested that the single most influential factor in overall acceptance of fish appears to be flavor (Howgate, 1977; Lamb, 1975; Rasekh et al., 1970), and

Lindsay (1980) identified intensity of off-flavor as the most influential factor affecting overall consumer preference of yellow perch. However, in a 1979 study by Wesson and coworkers on the discrimination of quality of a variety of fish and fish products by inland consumer populations, the importance of fish texture to consumers was determined. When oxidized, off-flavors, or "fishy" flavors were of only low to moderate intensity, texture became an extremely influential determinant of preference. The authors concluded that texture should receive considerable attention in the assessment of consumer preference and acceptability of fish. They stated that textural aspects should receive equivalent attention to that of flavor in fish products.

Szczesniak (1972) reported that texture was cited by teenagers 25% more often than flavor was, as the reason for disliking fish and seafood. Cardello et al. (1982b) hypothesized from multidimensional scaling of data derived from characterizing fish, that trained and consumer panelists used texture as one of 3 determining dimensions in their evaluation processes.

Texture of cooked fish is affected by many factors including species, age, size within species, nutritional state, and a wide range of environmental influences (Gibson et al., 1977; Korschgen and Baldwin, 1971; Love, 1958c, 1979a,b). However, due to the consumer-related nature and scope of the present study, these areas will not be discussed because consumers do not typically have control over or have information regarding these factors. However, the structure of fish muscle, which is basic to its textural characteristics (Dunajski, 1979), will be discussed here.

Unlike mammals, the main part of fin fish is composed of a few long muscle sheets with a metameric, or segmented, structure. The trunk of the fish is divided into myotomes, or flakes, separated by sheets of connective tissue called myocommata. Myocommata are delicate, thin, and more evenly distributed in fish than is connective tissue in warm-blooded animals. Fibers extend, parallel to the long muscle axis, between adjacent myotomes, and are inserted into sheets of connective tissue (Dunajski, 1979; Howgate, 1977). Howgate (1977) noted that these intrinsic properties give rise to the textural quality of flakiness as perceived by consumers. He also noted that fibers are relatively short, usually less than 20 mm long with a diameter range of 0.02-1.00 mm. Dunajski (1979) reported that fibers were no longer than about 12 mm, even in large fish. According to Dunajski, right and left fillets of a round-bodied fish do not differ in texture, but those of flatfish may differ.

A unique feature of fish flesh is its low connective tissue content, which is approximately 3% in bone fish. Easy disintegration of fish muscle upon heating, because of the low connective tissue content, consequently results in leaving muscle fibers as the main textural element in cooked fish meat (Dunajski, 1979). Thermal denaturation of fish collagen results in total loss of binding properties of the connective tissue and forces of attraction become so weak that the muscle falls apart after heating and the fibers become the sole elements of resistance. Beyond 60°C, the solubilization temperature of fish collagen, any textural changes that occur are related to the

denaturation of myofibrillar fish proteins. In eating, nearly all of the energy required to prepare a piece of fish for swallowing is used for mastication of the fibers (Dunajski, 1979). Toughness was reported to reach a plateau at 50-60°C and a maximum at 70°C; fish was reported to be mushy at 90°C when pH was high (Dunajski, 1979).

The pH of raw fish has been associated with changes in texture and toughness of cooked fish and has been cited to be of primary importance to sensory textural quality (Barrett et al., 1965; Boyd and Wilson, 1976; Love, 1979a; Olley et al., 1967). A negative relationship between pH of raw fish and toughness of cooked fish has been well documented (Bremner et al., 1978; Cowie and Little, 1966; Kelley et al., 1966; Kramer and Peters, 1981). Cowie and Little (1966) stated that raw fish muscle pH values were a better guide to toughness of cooked muscle than were protein solubility figures. Love et al. (1974) found that post-mortem pH correlated highly with texture of cooked fish. Dunajski (1979) stated that pH is the most important factor affecting rheology of fish muscle, especially at pH 5.7-6.7, but above that there is a gradual decrease in the effect of pH. The importance of characterizing the pH of raw fish is essential, then, prior to investigating the effects of heating with microwaves or other cooking methods. Characterizing pH of raw fish prior to treatment is important from another standpoint also. Variation within fish species has been documented, as mentioned previously, and Howgate (1977) reported that nearly all variation in texture between individual fish within a species can be attributed to the pH of raw fish muscle.

Reports on instrumental measurement of textural quality of cooked fish have been limited as a result of sampling problems associated with the structure of the fish flesh (King et al., 1979; Kapsalis and Maller, 1980). Most instruments are not suitable for fish and therefore have only rarely been used to measure the texture of fish (Dunajski, 1979).

However, a modified version of the Kramer shear compression cell was cited as an appropriate instrument to use (Dunajski, 1979; Awad and Diehl, 1975; Kramer and Peters, 1981). It was suggested that a thin-bladed version of the cell (Dunajski, 1979), or a cell with fewer blades be used (Awad and Diehl, 1975). A small-size sample of 10-15 g was suggested for use in the modified cell (Dunajski, 1979). Gill et al. (1979) used a modified 4-bladed version of the Kramer compression cell (66mm x 28mm) to measure maximum peak force and peak slope as a measure of cohesiveness and chewiness, respectively, of red hake and haddock. Both measures were significantly correlated with toughness scores of a trained sensory panel. Tough samples yielded higher and steeper slopes.

In a study of the compressive deformability modulus of raw and cooked fish flesh, Johnson et al. (1980) reported that a concave downward curve resulted for cooked fish samples. Compression was measured using an Instron Universal Testing Machine.

Other instruments have been used for measuring texture of cooked fish, as reported in the literature. An instrument similar to the Kramer shear cell (Dassow et al., 1962), a punch and die instrument (Kapsalis and Maller, 1980, 1982), and a 2-plate compression system on the Ottawa Texture Measuring System (Wong et al., 1978) were among them.

High correlations between Kramer shear values and sensory results and between drip loss as a percentage of starting frozen weight and sensory results were reported for rockfish (Patashnik et al., 1976).

A high correlation between sensory evaluation by a highly trained panel and objective evaluation with a texturometer, equipped with a driving probe, was found by Main et al. (1972). They determined that the best conditions for obtaining the high correlation were use of a probe with a diameter of 0.05 in, a probe speed of 5 inches per min, and a gap of 0.080 in.

A modified sclerometer was used to measure toughness of raw fish by Buttkus and Tarr (1962). The sclerometer measured the distance a plunger fell at a constant force during a constant time interval. Tenderness was found to be directly proportional to the percentage penetration. However, this method used on raw fish was not statistically correlated with any sensory evaluations of cooked samples.

V. PREDICTION AND SENSORY EVALUATION OF EATING QUALITY OF COOKED FISH

Few detailed studies have been reported on sensory testing methods for fresh or frozen fish (Mills, 1975). Although other authors have suggested that chemical and physical test results can be indicators of quality of fish, sensory evaluation has been cited as the ultimate method for predicting consumer acceptability of fish (Bossey and Talabi, 1981; Shewan et al., 1953; Iyer, 1972).

If chemical, physical, or instrumental methods are employed in evaluating fish quality, the results usually are compared with sensory

assessment values. Certain standard chemical and physical measures have been used to measure textural changes and to predict fish quality. However, in many studies, correlations between objective test results and sensory evaluation have been questionable. Cell fragility and protein solubility tests once were commonly used to measure textural changes in cold-stored fish. Love and Mackay (1962) defined cell fragility as the ease with which muscle cells could be ruptured with an homogenizer, and described the related method for measuring deteriorative changes that occur during cold-storage of fish. The method involved the use of optical density readings as a measure of cell fragility and as a predictor of degree of toughness of cooked fish muscle. Highly fragile cells produced a dense homogenate and a high optical density reading. Low cell fragility and corresponding low optical density were interpreted as an indication of toughening of fish muscle cells and used as a predictor of toughness of cooked fish.

Conflicting views were found in later reports that provided evidence that the relationship between cell fragility and sensory evaluation of toughness of cooked fish muscle was questionable (Kelley et al., 1966; Olley et al., 1967). A similar conflicting report was found regarding the protein solubility test for toughness and sensory evaluation of toughness of cooked fish (Olley et al., 1967).

Licciardello et al. (1979) also determined that typical chemical test results were not highly correlated with sensory scores in determining quality of frozen minced fish blocks. Shewan and Ehrenberg (1957) found that total volatile bases could not be used to predict eating

quality of cod with a high degree of precision. Nakayama and Yamamoto (1977) found no clear relationship between TBA (thiobarbituric acid) values and sensory assessment of odor and flavor of deboned fish. Similarly, Bossey and Talabi (1981) found that chemical assessment methods for measuring TMA (trimethyl amine) and FFA (free fatty acids) were less reliable than sensory methods for evaluating the quality of raw and cooked West African croaker in storage studies. As indicated in the literature, these tests mentioned may not be reliable predictors of sensory scores in the evaluation of cooked fish quality.

The use of trained sensory panels has been reported in the literature for evaluation of the quality of raw and cooked fish. Ehrenberg and Shewan (1953), in assessing the quality of white fish, concluded that explicit training of a sensory panel with agreement of terminology was a chief factor in attaining accuracy of results. Agreement on terminology was also the criteria for completion of training of judges using a 5-point descriptive scale to evaluate the quality of oven-baked roundnose grenadier which had been subjected to long-term frozen storage (Botta et al., 1982). Other references to the use of trained sensory panels can be found in the literature (Botta and Shaw, 1976; Crawford and Finch, 1968; Korschgen and Baldwin, 1971; Ostrander et al., 1976).

Experienced and consumer panels also have been used to evaluate cooked fish. A consumer sensory test for preference for blue whiting and whiting was conducted by Hamilton and Bennett (1981) using a 7-point hedonic scale for texture, flavor, appearance and acceptability. Samples were fried, steamed, or incorporated into fish pies. The results

showed no significant differences within products or between fish types. In another study (Ostrander et al., 1976), pen-reared salmon and trout were evaluated by trained and consumer panels, and although the trained panel found significant differences in fish muscle characteristics using a modified profile technique, the consumer panel did not indicate a significant difference in preference for the two fish species.

In a previously mentioned study (Wesson et al., 1979), in which discrimination of quality and preference of seafood by inland populations investigated, a trained panel readily discriminated between fish products with and without oxidized or off-flavors. Consumer panels in the same investigation preferred fish without off-flavors. Consumers had a lower image of southern catfish than of ocean cod, but upon tasting, preference scores for both fish species were similar. The authors indicated that species prejudices may be overcome when the product is introduced in a popular form and is of acceptable quality. It was noted also that slightly fishy or oxidized flavors were tolerated when textural quality was acceptable. Consumers unfavorably discriminated against dark color and softer texture of minced cod and the authors concluded that textural and possibly color characteristics were determining factors in consumer preference. It was mentioned that acceptance of fishy flavor intensities may be dependent on experience with seafood and geographic location. Some of the fish in this study were deep-fat fried; this cooking method may mask fishy flavors. The authors, therefore, suggested that fishy flavors may be more apparent to consumers who use common preparation techniques like broiling, baking, or moist heating.

Acceptability testing for such characteristics as flavor, odor, texture, and appearance on hedonic scales has been used extensively to evaluate cooked fish (Babbit et al., 1976; Barret et al., 1965; Connell and Howgate, 1968, 1969). However, only a few studies have dealt in depth with well-defined and well-developed sensory evaluation of fish using descriptive testing. Descriptive and texture profiling in particular have been chief methods used for this type of evaluation (Baines and Shewan, 1965; Cardello et al., 1982a,b; Hicks et al., 1978; Kapsalis and Maller, 1980, 1982; King et al., 1979; Weddle, 1979).

As part of a retail marketing effort proposed by the National Marine Fisheries Services of the U.S. Department of Commerce, Kapsalis and Maller (1980, 1982) developed an extensive standardized sensory methodology for evaluating texture and appearance of cooked fin fish. In a descriptive report of that study and associated work, Cardello et al. (1982a) identified hardness, flakiness, chewiness, fibrousness, moistness, and oily-mouthfeel as important attributes for characterizing 17 species of North Atlantic fish. A 7-point category scale for evaluating intensity of the attributes was found to be reliable and easily used. High correlations among hardness, cohesiveness, and chewiness scores indicated that consumers may have been evaluating fish on the basis of a single underlying perceptual construct described as toughness. These three related attributes were not, however, significantly correlated with the other attributes tested, indicating high independence among them. It was concluded also that visual flakiness and in-the-mouth flakiness could be interchanged in the sensory evaluation

of cooked fish texture. Using multidimensional analysis, the authors also determined the best-fitting solution to the data set and generated a 2-dimensional spacial map. This map showed relationships among the fish species tested, based on similarities of sensory texture and appearance attributes. The solution accounted for over 91% of the variability in the sensory scores for the 17 fish species.

Cardello et al. (1982b) conducted a series of sensory experiments to assess the relationships between judgments of texture of foods by trained and consumer panelists, and used different species of fin fish in their analyses. As part of their results, a useful category system was developed in relation to sensory dimensions found to be important to consumers for evaluating cooked fish. Using multidimensional scaling, three dimensions of importance for scaling fish for similarities were identified. The first was related to the color of cooked fish and was described as a light-dark dimension. The second dimension was a textural one related to perceived flakiness. Overall flavor was the third dimension. Results of the study showed that the consumer and trained panelists did not weight the importance of any of the 3 dimensions differently in their evaluations. Trained panelists, however, showed greater perceptual range when judging 6 attributes (hardness, flakiness, chewiness, fibrousness, moistness, and oily-mouthfeel) of 18 fish species, than did consumers. Their greater sensitivity was attributed to experience in evaluating those attributes.

As evidenced by the literature search, the number of reports of research on the effects of cooking method on and the eating quality of

fish was limited. Evidence of research on microwave heating of commonly and uncommonly used species of fish was even more limited. Therefore, study of the effects of microwave heating on fish quality in comparison with those of other cooking methods, and the acceptability of microwave-heated fish to consumers is warranted.

CHAPTER III

PROCEDURE

I. FISH SELECTION AND STORAGE

An underutilized species of fish commonly referred to as Greenland turbot (Reinhardtius hippoglossoides), a flatfish of reported mild flavor was used. Bulk frozen turbot fillets were purchased during July, 1983, from Travis Meat and Seafood Co., Powell, Tennessee, in 25-lb boxes that had been distributed by the Public Quick Freezing and Cold Storage Co., Jacksonville, Florida, and dated October 10, 1982. The boxes of fish were transported by car to The University of Tennessee, Knoxville, Nutrition and Food Sciences Department.

The fillets were weighed and sixteen weighing between 500 and 700 g were selected for trained panel and objective evaluation. From those 16 fillets, 4 were assigned randomly to each of 4 replications. In addition, 3 fillets weighing between 700 and 800 g were selected from the lot for testing by a consumer panel. Selection of fish within these frozen weight ranges made it possible to assign half of each fillet to microwave heating and half to conventional heating.

Prior to storage, the fillets were characterized by side (left or right) of the fish. Greenland turbot is noted to lie on its left side, having its eyes on the right side (Leim and Scott, 1966). Ten of the fillets for trained panel and objective tests were right sides and 6 were left sides. All fillets for consumer testing were right sides. The fillets were individually wrapped in heavy-gauge aluminum foil and

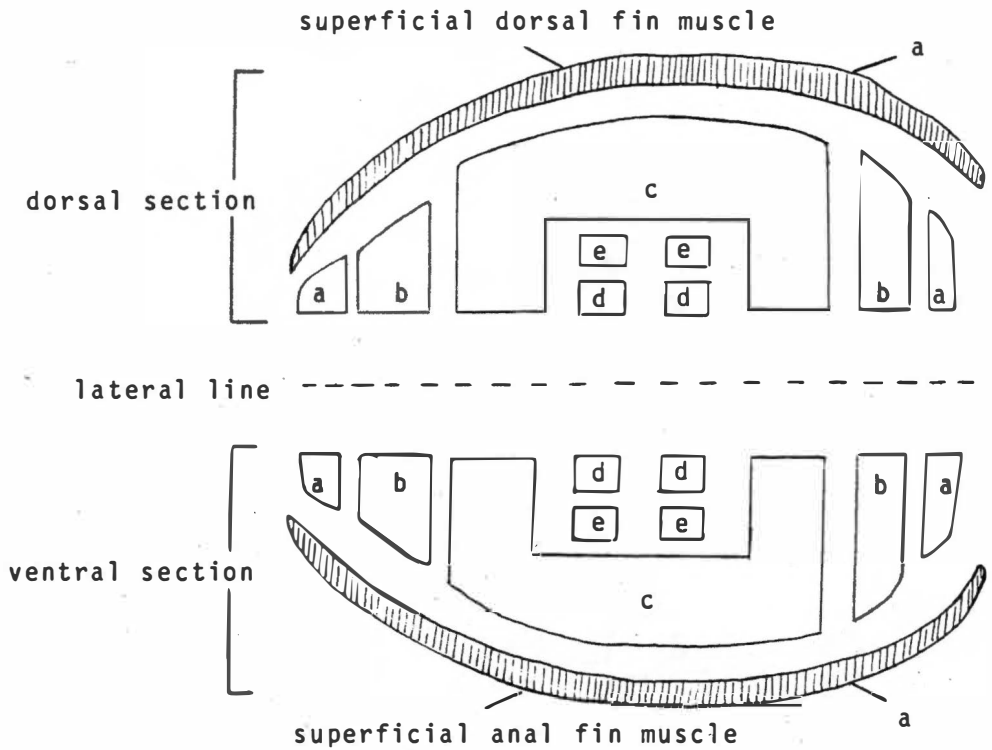
labeled according to weight and side. Fillets were stored at -22°C in a Gibson food freezer (Model 80-4079) until the day prior to use.

II. PREPARATION AND SAMPLING FOR COOKING

Prior to preparation for each of the 4 replications (23-24 hr), 4 fillets were thawed in a Hotpoint refrigerator (Model 9EB12) at 4°C. Two fillets were thawed for cooking in the morning and two were thawed for cooking in the afternoon.

Each thawed fillet was unwrapped, rinsed with tap water, patted with a paper towel to remove excess moisture, and weighed. The superficial dorsal and anal fin muscles (Lagler et al., 1962) were removed and the extreme ends of each fillet, which were subject to freezer burn, were cut off and discarded (Figure 1). Each trimmed fillet was cut lengthwise with a knife along the lateral line into 2 pieces (dorsal and ventral). Each fillet piece was cut to a length of 20 cm. The remaining ends were shredded by hand, mixed together in a plastic container, and reserved for pH and moisture determinations (Figure 1). The 20-cm sections of the fillet were weighed and measured for thickness with a Vernier caliper at the thickest point of the anterior end of the fillet section.

One of the resulting sections of each fillet was assigned to microwave heating and the other to conventional heating according to a balanced design for each replication. Each prepared fillet section was positioned in a preweighed 2-l rectangular (16 x 28 cm) glass baking dish. The dishes for samples that were to be cooked by microwave heating were preweighed with a piece of plastic wrap. The dishes to be used



a. Discarded

b. Used for raw pH and raw moisture content

c. Used for Kramer shear test and cooked moisture content

d. Samples for one trained panelist

e. Samples for a second trained panelist

Fig 1--Sampling plan for objective measurements and trained sensory panel evaluation of turbot fillets cooked in conventional and microwave ovens.

in the conventional oven were weighed without wrap. All dishes with fillet sections were covered and refrigerated at 4°C until time of cooking.

III. COOKING PROCEDURES

Conventional Oven

The prepared fillet sections were removed from the refrigerator 15 min prior to cooking. Two ovens were used and each was preheated to 350°F ± 2° (176°C) (AHEA, 1980). The oven temperatures were monitored by a copper-constantan thermocouple placed in the center of each oven and attached to a Honeywell Temperature Recorder. A thermocouple probe was positioned in the thickest portion of each fillet section.

The baking dish was not covered during cooking and was placed in the center of the central oven rack. Cooking time was monitored from the time the dish was placed on the oven rack to the time the end point temperature was reached. When the internal temperature of the fillet section reached 82°C (180 ± 1°F), the oven was turned off and the dish was removed from the oven. The probe was removed after a decline in the internal temperature of the fish was observed. Post-oven temperature rise, period of the rise, and cooking time were recorded.

Microwave Oven

The dishes containing the fillet sections designated for microwave heating were removed from the refrigerator 15 min prior to cooking. The right hand corner of the plastic wrap covering the dish was turned back to vent steam. The wrap was used to prevent spattering and loss of fish fragments during cooking (General Electric, 1977).

The high power level of the microwave oven (output = 464 watts) was used. Cooking times were selected at the time of fillet preparation on test days according to the thickness of the fillet sections. The cooking times required to heat fillet sections of given thicknesses to internal temperatures within a range of 77-88°C (170-190°F) were established during preliminary study. Table 1 shows the cooking times used.

The established cooking times, corresponding to fillet thickness, resulted in fillets that were comparable in quality and degree of doneness to that of fish cooked to an internal temperature of 82°C (180°F) in a conventional oven. The resulting temperature range, therefore, was considered acceptable.

Approximately half way through the cooking period, the dish was rotated 180 degrees (General Electric, 1977). At the end of the cooking time, the dish was immediately removed from the oven, the wrap turned back, and a thermocouple probe placed in the thickest portion of the fillet section approximately halfway into the muscle. The post-oven temperature rise and time were recorded.

IV. OBJECTIVE EVALUATION

pH

Two 5-g shredded samples were taken from the portions of fish that were reserved from each raw fillet during preparation for cooking (Figure 1). Each 5-g sample was combined with 50 ml of distilled water (Connell and Howgate, 1969) and was blended for 3 min in a 500-ml covered glass cup on a Waring Blendor. The slurry was poured into a

Table 1--Microwave cooking times determined for turbot fillet sections of various thicknesses

Thickness (mm)	Cooking time (min)
15	2.25
16	2.25
17	2.75
18	2.75
19	3.00
20	3.00
21	3.00
22	3.25
23	3.50
24	3.50
26	3.75

glass beaker and immediately tested for pH using an Orion pH meter with a single electrode. Little variation in pH along turbot fillets was found in preliminary work, therefore, composite samples were used to characterize each fillet according to pH.

Moisture

Two 2-g shredded samples were taken from the portions of fish that were reserved from each raw fillet during preparation for cooking (Figure 1). Total moisture was determined on both samples to characterize the moisture content of each raw fillet. Samples were dried for 16-18 hr at 100°C to constant weight according to standard AOAC methods (AOAC, 1980).

Raw moisture samples were stored at -22°C prior to testing. All cooked moisture samples for each replication were dried on the replication day. Raw moisture samples were tested the following day; all moisture tests were completed within 2 days of each replication.

Cooking Losses

Since disintegration of fish muscle and fragment spattering may occur with heat treatment, total cooking losses evaluated included solid-drip loss and evaporative loss. Weights were taken immediately after cooking and after each cooked fillet section was drained for 30 sec on a wire turner held above the baking dish. Details of calculations for cooking losses are given in Appendix A.

Kramer Shear Values

After each cooked fillet section was weighed for cooking loss determination and sensory evaluation samples were cut, the remainder of each section was placed in a glass container and flaked (Figure 1). Two forks were used in a cross-cutting motion to flake the fish, which then was transferred to a petri dish and covered.

Three 10-g samples of flaked cooked fish were weighed by difference from the petri dish for each fillet section. Samples were held in plastic 3.5-oz cups covered with aluminum foil until tested for peak force. Each sample was transferred, using a metal spatula, into a modified Kramer shear cell; arranged to cover the bottom; and tested on an Instron Universal Testing Machine. The modified cell contained only 4 blades and had plexiglass inserts positioned inside to block off the unused portion of the original cell. The dimensions of the cell were 2 x 7 x 10.5 cm.

Preliminary work was conducted to test the suitability of the modified cell. No drag, indicated by a flat line, was observed on the chart when the test cell was operated empty. This indicated that artifact effects were not produced (DeMan et al., 1979). Samples (5, 10, 12.5, and 15 g) of flaked cooked fish were tested in the cell to determine the appropriate weight of flaked fish for use in the modified Kramer shear cell. The 10-g flaked sample was found to be most suitable. The 5-g sample was unsuitable because it did not adequately cover the bottom of the cell. Samples greater than 10 g were not appropriate, either, because use of them resulted in plateaus in the

force-distance curves. A plateau was evidence that shear force no longer was being measured while the cell blades still were shearing through the sample, due to the excessive magnitude of the cell load (Szczesniak et al., 1970).

These preliminary test results were supported by findings in the literature. Dunajski (1979) recommended flaking of cooked fish that was to be tested in a Kramer shear cell because dismembering the cooked muscle improved the homogeneity of the samples, and increased the randomness of fiber orientation. The author also recommended limiting samples to 10-15 g to reduce artifact effects caused by compression, friction, and extrusion forces accompanying the shearing of samples.

A load cell of 50 kg was used on the Instron. The chart and crosshead speed were 100 and 50 mm, respectively, and the range setting was 10. The force needed to push the blades through the sample and cell was recorded as force-distance curves. The peak height of each curve in kg of force was considered to be a measure of hardness (Szczesniak et al., 1970).

V. ENERGY COMPARISON

The conventional ovens were electric, self-cleaning Frigidaire, Super Models Rse-36L (115/230-120/240 volts, 60 cycles, 10.8 K.W.) for use on A.C. only. The microwave oven was a General Electric, Model JET880VI (60 Hz, 120 volts, 1.25 K.W.), for household use on A.C. only. These ovens were considered to be representative of those used by consumers. General Electric, maker of the microwave oven used, is one of

the largest manufacturers of microwave ovens, producing 13% of the domestic market (Anon., 1980). Market data for the conventional ovens were not available.

Duncan appliances meters with Kh values of 3.6 and 0.33 were attached to the conventional and microwave ovens, respectively. In order to compare the energy requirements of the 2 types of ovens, the relative efficiencies were determined by the following equation:

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

The cooking power was the energy required to actually cook the fillet sections. The power input was the energy required for cooking the food and operating the oven (Korschgen et al., 1980). The preheating time and watt hours (wh) used during preheating were determined for each oven during preliminary work. Relative efficiencies and wattage used, with and without preheating, were determined for the conventional ovens and compared to the relative efficiency and wattage of the microwave oven.

The wattage and cooking power of the conventional ovens were determined by the Rotating Disc Method (Luetzelschwab, 1980) as shown in Appendix B (I, II). Cooking power of the microwave oven was determined by calorimetric computation for water loads (Gerling, 1978; Van Zante, 1973) as detailed in Appendix B (III, IV).

VI. TRAINED SENSORY PANEL EVALUATION

Panel Selection

Fifteen people were approached individually and asked if they would participate, based on their liking of fish, interest, willingness to be trained if selected, and availability at the projected time of data collection. The recruits were graduate students from the NFS Department, ranging in age from 22 to 43. Fourteen agreed to participate in the screening process. From these, 9 panelists were selected for training according to the following process.

For screening, a series of fish triangle tests was administered to each prospective panelist according to a sequential analysis procedure (Cross et al., 1978). The sequential analysis procedure uses criteria for panel selection based on minimum and maximum correct decisions. Panelists were selected on the basis of the number of correct identifications they made, according to the recommendations of Cross et al. (1978). Seven out of 12, or 9 out of 16 correct answers were established as the final minimal limits for acceptance of panelists. These minimal limits were accepted because of the difficulty of the test and were within or near the limits recommended (60% correct) by the American Society for Testing and Materials (ASTM, 1968).

Frozen Freshore brand cod and perch portions purchased at a Krogers Supermarket were used for samples. Four portions of each species were baked in each of two covered rectangular glass dishes in preheated electric ovens at 190°C (375°F) for 25 min. After baking, the fish was

drained; all portions of each type of fish were combined and flaked with a metal pancake turner. Half of each fish lot was spread in a glass dish and heated, uncovered in a microwave oven on high power for 2 min on the first and last days, and 3 and 4 min on the second and third days, respectively. This procedure was designed to create textural differences of different degrees, which were of primary importance in this study. Each dish was turned halfway through the heating time. Upon removal from the oven, samples were allowed to cool and then covered with foil and labeled for serving.

On the first day of testing, cooked samples were transferred to 1000-ml beakers. This procedure was discontinued for the remainder of the sessions because the fish tended to become soggy with standing, minimizing differences between samples. The fish was left in the glass baking dishes and covered with foil on the other test days.

Approximate 5-g samples were placed in coded paper souffle cups. Each triangle was presented on a plate under red light, with water, 3 unsalted oyster crackers, and a plastic spoon. Each panelist received 2 cod sample sets and 2 perch sample sets each day. Sets were presented singly in random order and samples within sets were randomly arranged on each plate.

General instructions (Appendix C) were posted in each sensory booth and each panelist received a score card with each sample set (Appendix C). Fresh fruit was offered to panelists at the end of each test session.

The results from the screening are shown in Appendix C. Notices of acceptance or rejection were distributed to participants after the sessions were completed (Appendix C).

Panel Training

The 9-member panel met for 10 sessions over a 3-week period. Training involved the use of a modified version of texture profiling and included orientation (Appendix D), group discussions, group and individual sensory testing, and review sessions. All group sessions were tape recorded and the tapes were made available to panelists for review.

Based on the literature, 4 sensory texture attributes were selected by the author and used in the training. The attributes were chosen from sensory dimensions that have been described as important to consumers in the acceptability of fish (Cardello et al., 1982a; Kapsalis and Maller, 1980). The characteristics under consideration were flakiness, hardness, moistness, and chewiness.

Preliminary work had been conducted to establish suitable examples of the attributes to be evaluated by the panel. Cod and monk fish; grouper and turbot; cod and haddock; and haddock and turbot were the fish chosen as examples of the high and low extremes of flakiness, hardness, moistness, and chewiness, respectively. These fish were chosen on the basis of descriptive characterizations of fish species established by Kapsalis and Maller (1982). The fish samples were presented to panelists in group sessions and served as a means of demonstrating extremes of the characteristics and used to develop definitions

of the characteristics and procedures for evaluation to be used in testing.

The panel acted as a unit in decision making and interaction was encouraged during the group sessions. The author acted as a group leader while the panel held the main decision-making responsibility for finalizing characteristic definitions, procedures for evaluation of characteristics, and score card format.

After the panel determined suitable definitions and procedures for all characteristics, trial sensory evaluation tests using turbot samples were conducted according to the criteria established by the panel.

Panelists were not told what type of fish or treatments were being employed during the trial testing. Each panelist evaluated samples from one turbot fillet which was split along the lateral line. Each fillet section was cooked, either by microwave or conventional oven. Duplicate center samples of fish (2.5 x 4.0 cm) from each heat treatments were coded with 3-digit numbers and presented singly in random order to each panelist. Conditions of the sensory evaluation were similar to those used for panel selection, with the exception of the use of white light. The definitions and procedures formerly established by the panel were posted in the sensory booths. In addition, panelists were verbally instructed not to retaste for any characteristic.

Three test replications were completed to determine panelist reliability. The resulting data were analyzed statistically using analysis of variance, and panelist reliability was established for all

panel members. Panelists were given these results of the testing in a group session on the last day of training prior to the review sessions.

Six days prior to the collection of data, a panel review session was held. Definitions and procedures were reviewed for each characteristic and 4 coded samples of turbot were evaluated by each of the panelists. The samples were cooked and tested in random order as described for the actual data collection. Results were shared among panelists and group discussion followed. The procedure for evaluating flakiness was modified to be less rigid as a result of problems associated with cutting uniform samples for the panelists. The final definitions, procedures for evaluation, and score card are shown in Appendix D.

Sensory Evaluation

Two of the originally trained panelists could not participate in the evaluation because of scheduling problems. Therefore, the final panel was composed of 7 graduate students (2 men; 5 women) ranging in age from 22 to 43, from the Nutrition and Food Sciences Department.

At 11:00 a.m. 4 panelists evaluated the fish samples prepared in the morning, and at 3:00 p.m. 3 panelists evaluated samples prepared in the afternoon. Samples were evaluated in individual sensory booths under white light. Two sessions were held each day and the same panelists performed the evaluations at the same times for each replication.

Four 3-digit coded samples (2 conventional and 2 microwave) were presented singly in random order to each panelist. Samples were kept

covered until evaluated and were served at room temperature. Stainless steel forks, unsalted oyster crackers, and water were provided. The definitions and procedures for evaluating the characteristics established during the training were posted in each booth for reference during testing. Flakiness, moistness, hardness, and chewiness were evaluated using the established definitions and procedures. The score cards developed during training were used for the evaluation.

Sampling

Four samples approximately 2.5 x 4.0 cm were cut from the same general area of each cooked fillet section. The location of samples on each fillet section is shown in Figure 1 (page 28). Two laterally adjacent samples were presented to each panelist from a fillet section cooked by each heat treatment for each replication. During the study, panelists received an equal number of samples from the dorsal and the ventral side of the lateral line of the fillet. Since there were only 7 panelists to evaluate 4 fillets each day, 1 of the 4 fillets was evaluated by only 1 person instead of 2. Therefore, for the afternoon sessions, each of the 3 panelists was given samples from the "odd" fillet at least once during the 4 replications.

VII. CONSUMER SENSORY PANEL

Thirty-nine panelists were recruited from faculty, students, and staff of the College of Home Economics and the Department of Food Technology and Science. Volunteers were recruited by mail (Appendix E)

two weeks before testing. Two days before the test a reminder was sent to panelists (Appendix E). Three sessions were held for the consumer panel: 2:30 p.m. on Tuesday, and 10:30 a.m. and 2:30 p.m. on the following Thursday. Each panelist attended 1 of the 3 sessions.

The three turbot fillets reserved for consumer testing were handled and stored as previously described with modification in procedure for preparation. Fillet sections were cut to a length of 24-29 mm. Fillets were randomly assigned for use in panel sessions; 1 fillet was used per session. Fillet sections were randomly assigned to type of oven used for cooking. One conventional oven and the microwave oven were used to cook the fillet sections. Cooking procedures were the same as those used for the trained panel. Cooking times, post-oven temperature rise time, and maximum internal temperature of the fillet sections were recorded. No other objective measurements were taken on fillets or fillet sections other than pH which was measured for whole fillets for characterization of the fish.

After cooking and draining, each fillet section was flaked with two stainless steel forks in the baking dish. Approximate 5-g samples were placed in white plastic souffle cups coded with 3-digit random numbers. The cups were covered with aluminum foil until time of presentation to panelists. Four single samples (2 conventional, 2 microwave) were presented in random order to panelists in individual sensory booths under white light. Water and unsalted oyster crackers were served to panelists; white plastic forks were used as utensils. General instructions (Appendix E) were posted in each sensory booth and each panelist

received a score card (Appendix E) with each sample. The panelists were requested to indicate like/dislike of each sample by placing a check next to the appropriate phrase. Panelists were instructed to rinse their mouths and eat one oyster cracker between samples. Juice was offered to panelists after testing.

After the fourth sample, a questionnaire (Appendix E) was distributed pertaining to demographics, frequency of use and familiarity with fish, and availability of various types of ovens to the panelists.

VIII. EXPERIMENTAL DESIGN

The experimental design for both the objective measurements and the consumer sensory panel was a randomized complete block design. It included subsampling with oven as the primary main effect.

The experimental design for the trained sensory evaluation, in general was a split-plot design. Differences between cooking methods (oven) were considered to be the whole-plot effects. Differences among panelists and the interaction between panelist and oven were the split-plot effects. However, since all panelists did not evaluate a sample from each fillet, the split-plot effects were estimated from an incomplete block arrangement.

IX. STATISTICAL ANALYSES

The data from the objective testing and from the trained sensory panel were analyzed statistically using the Statistical Analysis System (SAS) (SAS Institute, 1982a,b). The main effects, statistically tested,

for objective measurements were oven and replication. The main effects for the trained panel data were oven, replication, and panelist. The interactions studied for the trained sensory panel data were oven x replication, panelist x replication, panelist x oven, and oven x replication x panelist.

Proc ANOVA was used for analyses of variance of the means of all trained sensory panel and objective measurements except wattage, cooking power, and relative efficiencies. Proc GLM (General Linear Model) was used for analyses of variance of the forenamed variables because of missing data for watt hours for cooking of 1 fillet section in the conventional oven.

In order to determine if the sampling plan was appropriate for objective and sensory evaluations, mean differences between left and right turbot sides, according to oven treatment and pooled data, were tested for significance using Proc TTEST. In addition, to test the appropriateness of the sampling plan for the trained panel, Proc TTEST was used to identify significant mean differences between sensory scores for laterally adjacent samples (anterior and posterior), and for vertically adjacent samples (proximal and distal to the lateral line) of each fillet section.

Proc CORR was used to determine correlation coefficients between sensory variables means for flakiness, moistness, hardness, and chewiness. The same statistical procedure was used to obtain correlation coefficients between each sensory characteristic mean and the means of the respective variables: pH; fillet section thickness; fillet

section raw weight; raw moisture content; cooked moisture content; cooking losses; and Kramer shear values.

The results from the hedonic tests from the consumer sensory panel were analyzed for variance of the means using Proc GLM (SAS Institute, 1982b). The ANOVA procedure was not used because the number of panelists in each of the 3 sessions differed. The main effects tested were oven and session; the interaction studied was oven x session. To test for repeatability of judgments by panelists and for appropriateness of the sampling plan, differences in scores for duplicate samples of fish cooked in each oven were tested for significance using Proc TTest. Data from the questionnaire responses were summarized using Proc FREQ (SAS Institute, 1982a).

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter the results of the current study are presented according to the order in which the data were collected. Discussion of objective measurements and energy requirements for cooking the turbot fillets used for the trained sensory panel are presented first. A discussion of the trained panel sensory results then is followed by a section devoted to the discussion of the correlation coefficients that were derived from the objective and trained panel data. The final portion of this chapter deals with results and discussion of the consumer panel and questionnaire data. A probability of 0.05 was used as the level for determining significant differences reported here. Values reported in the text are means ± standard errors.

I. OBJECTIVE MEASUREMENTS AND ENERGY COMPARISONS FOR FISH USED FOR TRAINED SENSORY PANEL

Characteristics of Turbot Fillets

The mean pH of the turbot fillets used in the present study was 6.9 ± 0.1. The pH values ranged from 6.7 to 7.2. The mean moisture content of the uncooked fillets was 71.11 ± 8.51%, ranging from 67.16 to 79.50%. The frozen weights of the whole fillets, as purchased, ranged from 504 to 672 g, with a mean of 593 ± 13 g. The mean weight loss of the whole fillets, after thawing, was 55 ± 4 g, which represented a mean loss of 9 ± 1%. This weight loss should be taken into consideration by consumers who are determining the quantity of frozen turbot to purchase

because weight loss associated with thawing may be considerable. The mean raw weight of all the prepared fillet sections used for the trained sensory panel was 178 ± 4 g (179 ± 6 for conventional and 178 ± 6 g for microwave). The mean thickness of all the fillet sections was 18 ± 0 mm and ranged from 15 to 23 mm. The dorsal and ventral sections of the fillet were significantly different in thickness (19 ± 1 and 18 ± 0 mm, respectively) and in weight (190 ± 5 and 166 ± 4 g, respectively). These differences confirmed the need to balance the assignment of fillet sections to oven treatment.

Effects of Sampling Plan on Objective Measurements

Differences between left and right fillets used for objective and sensory measurement were investigated to determine if the sampling plan was appropriate for the present study. Values for the microwave and the conventional ovens were analyzed separately for differences between right and left fillets. Results of t tests indicated that there were no significant differences for any objective measurement. Therefore, the data for the two ovens were pooled and retested. Pooled data means and standard errors, which did not differ, are presented in Table 2.

Dunajski (1979) noted in a review on fish texture, that differences may be evident between right and left fillets of flatfish, but no reports were cited to verify this. Flatfish are usually white on the side on which they lie (the blind side). The difference in pigmentation indicates that the flatfish swims strictly on its blind side. However, the flatfish of the species used in this study are noted to have their

Table 2--Means and standard errors of objective measurements on left and right fillets of turbot cooked in conventional and microwave ovens[a]

Objective measurement	Fillet			
	(n)	Left	(n)	Right
pH	12[b]	6.9 ± 0.01	20[c]	6.9 ± 0.1
Raw moisture content (%)	12[b]	71.44 ± 3.7	20[c]	70.91 ± 2.4
Cooking time, without preheating (min)	12[d]	15.3 ± 3.9	20[e]	15.9 ± 3.0
Cooking time, with preheating (min)	12[d]	22.8 ± 6.2	20[e]	23.4 ± 4.7
Cooking time (min/kg)	12[d]	89.8 ± 22.7	20[e]	86.9 ± 16.5
Energy consumed, without preheating (wh)[g]	12d	135.83 ± 24.49	19f	135.68 ± 18.99
Energy consumed, with preheating (wh)[g]	12d	345.08 ± 87.34	19f	333.37 ± 67.92
Cooking power (wh)[g]	12[d]	34.74 ± 5.40	19[f]	33.59 ± 4.08
Relative efficiency, without preheating (%)	12[d]	30.27 ± 2.87	19[f]	29.11 ± 2.17
Relative efficiency, with preheating (%)	12[d]	22.86 ± 4.65	19[f]	22.64 ± 3.48
Cooked moisture content (%)	24[d]	65.06 ± 0.42	40[e]	65.97 ± 0.45
Evaporative loss (%)	12[d]	8.71 ± 1.26	20[e]	8.49 ± 0.96
Solid-drip loss (%)	12[d]	7.52 ± 1.53	20[e]	7.78 ± 1.17
Total cooking losses (%)	12[d]	16.23 ± 0.70	20[e]	16.28 ± 0.54
Kramer shear values (kg)	36[d]	2.6 ± 0.1	60[e]	2.6 ± 0.01

[a]$\bar{t}$ tests showed no significant differences between means for left and right fillets ($P > 0.05$).

[b]Number of measurements taken on 6 whole fillets.

[c]Number of measurements taken on 10 whole fillets.

[d]Number of measurements taken on 6 fillet sections cooked in the conventional oven and 6 fillet sections cooked in the microwave oven.

[e]Number of measurements taken on 10 fillet sections cooked in the conventional oven and 10 fillet sections cooked in the microwave oven.

[f]Number of measurements taken on 9 fillet sections cooked in the conventional oven and 10 fillet sections cooked in the microwave oven.

[g]Watt hours.

eyes on the right side and to be pale gray on the blind side (Leim and Scott, 1966). This implies that they may swim with a more vertical orientation than do other flatfish. This observation may have implications for fewer structural differences in sides and increased bilateral use of muscles when compared with other species of flatfish. This characteristic may account for the lack of differences in sides found in the present study. The same results may not occur with other species of flatfish which suggests that turbot may be a suitable flatfish to use in further research where differences between fish samples should be minimized. According to the present findings, using different sides of the flatfish did not introduce additional experimental error in the study. These results suggest that either side of the flatfish, turbot, may be used for experimentation without controlling for side.

Temperature and Cooking Times

The temperatures of the conventional ovens were monitored during use. The oven temperatures generally deviated ±1.25°C (±3°F) from the calibrated oven setting of 176°C (350°F). The preheating times for the conventional ovens were 15.36 min and 14.71 min, respectively.

It was not possible to record the internal temperature of fillet sections during or at the end of the cooking process in the microwave oven because of lack of a thermometer designed to accurately record internal temperature of fillet sections of the limited thickness used in this study. The maximum internal end-point temperatures of fillet sections were recorded upon removal from the microwave oven. The mean

maximum internal end-point temperatures of sections cooked in the microwave oven was 88°C, within a range of 75-94.5°C (167-202°F). A post-oven rise in the internal temperature was observed for all fillet sections cooked in the microwave oven. The mean period of post-oven, or standing time, temperature rise for the microwave-heated fish was 0.82 ± 0.03 min. The evidence of a rise in internal temperature that was observed with the microwave oven after the thermocouple was placed into the fish coincides with reports that post-oven temperature rises in foods occur commonly after microwave heating (Van Zante, 1973).

The maximum internal temperature of fillet sections cooked in the conventional oven was 82°C, within a range of 82-83.5°C (180-182°F). No post-oven rise in internal temperature of the turbot was observed with the conventional oven.

The mean end-point temperatures attributed to cooking methods differed. This occurred because of the difficulty associated with accurately determining microwave cooking times for fillet sections of different dimensions. It was impossible to precisely determine cooking times necessary to effect the exact desired internal end-point temperature that was obtainable using the conventional oven. Lorenz (1976) noted that it is impossible to determine the time of heating in the microwave oven, very accurately, in order to achieve the same degree of doneness of a food as that obtained with the conventional oven. The same author also mentioned the difficulty associated with measuring the internal temperature of food inside a microwave oven, stating that it was impossible to do so. In light of the situation, the resulting

microwave range of end-point temperatures was considered acceptable in the present study, based on the cooking times established in preliminary work.

The ANOVA mean squares for cooking times are presented in Table 3. The means for the same data appear in Table 4. Cooking time in the conventional oven, with or without preheating time included, was significantly longer than in the microwave oven. Cooking time on a per-kilogram basis also was lower for the microwave oven than for the conventional oven, reflecting a faster rate of heating. Although no corresponding data for fish were found in the literature, the findings of this study are similar to those reported on turkeys cooked by microwave and conventional ovens (McNeil and Penfield, 1983). Similar results were reported for top round roasts cooked in microwave and conventional ovens (Voris and Van Duyne, 1979). Longer cooking times also were required to cook beef-soy loaves in a conventional oven than in a microwave oven (Ziprin and Carlin, 1976); the loaves in the investigation were more comparable in size to the fillet sections used in the present study than the foods in the other studies cited.

Although the time to cook fillet sections differed with oven, no significant differences were found among replications for cooking time or rate of heating. The interaction between oven and replication was not significant for either variable, also (Table 3).

Cooking Losses

Table 5 contains the ANOVA results for cooking loss measurements. Differences in evaporation, solid-drip, and total cooking losses of

Table 3--Mean squares and significance of F ratios for cooking times for turbot fillet sections cooked in conventional and microwave ovens

Source of variation	df	Mean squares		
		Cooking time without preheating	Cooking time with preheating	Minutes/kg
Total	31			
Oven	1	5319.70*	13331.40*	0.16774*
Replication	3	0.37	0.37	0.00016
Oven x replication[a]	3	0.06	0.06	0.00016
Error[b]	24	7.84	8.30	0.00012

*P < 0.001.

[a]Error term for oven.

[b]Error term for replication and oven x replication.

Table 4--Means of cooking times for turbot fillet sections cooked in conventional and microwave ovens[a,b]

Variable	Oven	
	Conventional	Microwave
Cooking time without preheating (min)	28.55x ± 0.88	2.77y ± 0.09
Cooking time with preheating (min)	43.59x ± 0.91	2.77y ± 0.09
Minutes/kg	160.42x ± 4.02	15.62y ± 0.24

[a]Mean and standard error of values for 16 fillet sections.

[b]Means within a row followed by the same letter do not differ at $P > 0.001$.

Table 5--Mean squares and significance of F ratios for cooking losses of turbot fillet sections cooked in conventional and microwave ovens

Source of variation	df	Mean squares		
		Evaporative loss	Solid-drip loss	Total cooking losses
Total	31			
Oven	1	462.76**	761.38**	36.89*
Replication	3	1.21	2.53	3.41
Oven x replication[a]	3	0.90	1.25	2.24
Error[b]	24	3.67	2.17	5.13

[a]Error term for oven.

[b]Error term for replication and oven x replication.

*P < 0.05.

**P < 0.001.

turbot were attributable to oven but not to replication or to oven x replication. The means for cooking losses of the fillet sections are presented in Table 6. There were greater percentages of solid-drip loss and total losses but less evaporative loss in the fillet sections cooked in the microwave oven than in those cooked conventionally. The greater solid-drip loss probably is associated with the tendency of fish to spatter and fragment during microwave heating as observed by other researchers (Baldwin and Snider, 1971; General Electric, 1977). Since the air within the conventional oven is heated during the cooking process, greater evaporative losses are expected than result from microwave heating, which does not directly involve heating the air within the oven.

Lorenz (1976) reported that nearly every investigator who compared conventional and microwave heating of meat products provided data that indicated considerably higher moisture loss associated with microwave cooking. This was supported by work by Ziprin and Carlin (1976) who reported greater total and evaporative losses for beef-soy loaves cooked in a microwave oven than for those cooked conventionally. However, evaporative and total cooking losses of turkey roasts cooked in a microwave oven were not greater than those of roasts cooked conventionally (McNeil and Penfield, 1983). Greater loss in moisture of foods cooked in microwave ovens was explained by Apgar et al. (1959) who attributed the greater loss to a greater rise in post-oven temperature which caused more dehydration and greater shrinkage.

Table 6--Means of objective tests of turbot fillet sections cooked in conventional and microwave ovens[a]

Variable	Oven	
	Conventional	Microwave
Cooked moisture content[b] (%)	65.46x ± 0.45	65.80x ± 0.48
Evaporative loss[c] (%)	12.38z ± 0.61	4.77w ± 0.16
Solid-drip loss[c] (%)	2.81z ± 0.19	12.56w ± 0.48
Total cooking losses[c] (%)	15.19x ± 0.60	17.33y ± 0.48
Kramer shear values[d] (kg)	2.88z ± 0.08	2.34w ± 0.06

[a]Means in a row followed by like letters do not differ at $P > 0.05$ (x,y); $P > 0.001$ (z,w).

[b]Mean and standard error of 2 values for each of 16 fillet sections.

[c]Mean and standard error of values for 16 fillet sections.

[d]Mean and standard error of 3 values for each of 16 fillet sections.

Cooked Moisture Content

The mean moisture contents of fillet sections heated by the two cooking methods did not differ significantly (Tables 6 and 7). The ANOVA results also indicated that there were no significant differences for the main effect of replication or for the interaction of oven x replication as shown in Table 7. Similar results were reported for top round roasts cooked in a microwave oven (Voris and Duyne, 1979). However, Ziprin and Carlin (1976) reported results for beef-soy loaves that indicated that loaves cooked in a microwave oven had significantly lower moisture contents than did those heated conventionally.

Kramer Shear Values

The ANOVA results and means for Kramer shear values are presented in Tables 7 and 6, respectively. The mean peak force, a measure of hardness (Szczesniak et al., 1970), required to compress and shear the turbot cooked in the conventional oven was significantly greater than that required for the microwave-heated samples. The turbot cooked in the microwave oven was softer than was the conventionally cooked turbot. No studies were found in the literature in which shear values of fish cooked by the 2 heating methods used in the present study were compared. However, the lower shear values associated with microwave heating may be explained possibly by the findings of Deng (1981) who investigated the effect of temperature on fish alkaline protease, protein interaction, and texture quality of mullet. It was shown that shear force values of fish cooked for a short time (<5-10 min) at high temperatures (55-85°C)

Table 7--Mean squares and significance of F ratios for cooked moisture content and Kramer shear values for fillet sections cooked in conventional and microwave ovens

Source of variation	Cooked moisture content		Kramer shear values	
	df	Mean squares	df	Mean squares
Total	63		95	
Oven	1	1.84	1	6.99*
Replication	3	14.03	3	0.63
Oven x replication[a]	3	1.28	3	0.04
Error[b]	56	6.79	88	0.23

[a]Error term for oven.

[b]Error term for replication, and oven x replication.

*$P < 0.001$.

were lower in comparison with those of fish cooked for longer times (>10 min) at lower temperatures (35 and 45°C). The softening effect of enzyme activity, optimal at 65°C, was attributed with masking the toughening effect of protein-protein interactions in the cooked fish. The longer period of time it took for the turbot cooked in the conventional oven to reach the end-point temperature than that cooked in the microwave, may have resulted in more protein-protein interactions responsible for toughening (Deng, 1981), than developed in the turbot cooked in the microwave oven. This possibly might have resulted in a lessening of the softening effect of the enzyme activity at the optimal temperature, which was reached later in the cooking process of the conventional oven.

The results also indicated that there were no significant differences in Kramer shear values for replication. The interaction of oven x replication also was not significant (Table 7).

Energy Comparison

The analyses of variance results for the comparisons of energy requirements for the two ovens are presented in Table 8. The least-squares means for energy consumed, cooking power, and relative efficiency are shown in Table 9. The results indicated that the energy consumed to cook the turbot fillet sections in the conventional oven, with or without preheating, was significantly greater than that used by the microwave oven. The microwave oven required approximately 73% less energy than the conventional oven without preheating watt hours included

Table 8--Mean squares and significance of F ratios for energy values for conventional and microwave ovens used to cook turbot fillet sections

Source of variation	df	Mean squares				
		Energy consumed, without preheating	Energy consumed, with preheating	Cooking power	Relative efficiency, without preheating	Relative efficiency, with preheating
Total	30					
Oven	1	192128.21**	2546196.81**	4645.19*	1928.67**	6865.03**
Replication	3	30.73	52.24	37.24	6.20	1.99
Oven x replication[a]	3	141.61	200.98	75.00	3.85	0.75
Error[b]	23	302.99	506.29	189.31	33.45	4.66

[a]Error term for oven.

[b]Error term for replication, and oven x replication.

*P < 0.01.

**P < 0.001.

Table 9--Least-squares means of energy values for conventional and microwave ovens used to cook turbot fillet sections[a,b]

Variable	Oven	
	Conventional	Microwave
----------Without preheating of conventional oven----------		
Energy consumed (wh)[c]	217.10x ± 4.53	58.94y ± 4.35
Cooking power (wh)[c]	46.47z ± 3.58	21.88w ± 3.44
Relative efficiency (%)	21.31x ± 1.50	37.15y ± 1.45
----------With preheating of conventional oven----------		
Energy consumed (wh)[c]	634.73x ± 5.85	58.94y ± 4.35
Relative efficiency	7.26x ± 0.56	37.15y ± 1.45

[a]Least-square mean and standard error for 16 fillet sections.

[b]Least-squares means followed by like letters do not differ at $P > 0.01$ (z,w) and $P > 0.001$ (x,y).

[c]Watt hours.

and approximately 91% less energy when watt hours from preheating were included.

The cooking power, or total energy actually needed to cook the turbot was greater in the conventional oven than in the microwave oven (Table 9). The relative efficiency of the microwave oven (Table 9), also, was approximately 30 and 16% greater than that of the conventional oven with and without preheating, respectively. The microwave oven, therefore, required approximately 91% less total energy than did the conventional oven with preheating, as well as being 30% more energy efficient in cooking the turbot fillet sections.

No studies were found in the literature in which cooking power and relative efficiencies of conventional and microwave ovens when cooking fish were compared. However, the same microwave oven used in the present study required less total energy and was more efficient (44%) in cooking turkey roasts than a conventional oven (32%) in a study by McNeil and Penfield (1983). Korschgen et al. (1980) reported that a microwave oven used less total energy to cook beef rib roasts than did a conventional oven. However, in the same study, no difference was found between the relative efficiencies of both ovens. This may have been attributed to the type of load (large roasts) cooked in the microwave oven and the use of a combination of oven settings for cooking in the microwave oven, which resulted in decreasing the efficiency.

No significant differences were found among replications or for the interaction of oven x replication for energy consumer, cooking power, and relative efficiency. These results are presented in Table 8.

II. TRAINED SENSORY PANEL

Sources of variation in the sensory scores assigned to turbot samples by the trained sensory panel are presented in the ANOVA table (Table 10). The means of the scores for the sensory attributes of the fillet sections cooked in the 2 ovens are presented in Table 11. No significant differences were found by panelists in flakiness and moistness of samples with respect to the type of oven used to cook the turbot.

The magnitude of the scores for flakiness and moistness suggested that the turbot was relatively flaky and moist on a scale of 1-21. The results for moistness may be contrary to a report by Howgate (1977) in which he described turbot as being drier and more fibrous than other flatfish, which were reported to be drier and more fibrous than cod. Cod was described as soft, tender, juicy, and fairly fibrous. However, the author did not define the descriptive words in terms of sensory scores, and comparison of those characteristics for turbot with those of the present study is speculative.

Visual flakiness, although mentioned in the literature (Kapsalis and Maller, 1982) has been rarely defined and is a complex attribute to evaluate because there may be flakiness between flakes or flakiness between fibers within flakes of cooked fish muscle. The associated difficulty and/or confusion in evaluating flakiness may have contributed to panelist differences in scoring samples (Table 12), in addition to differences attributed to the interaction of the main effects (Table 10).

Table 10--Mean squares and significance of F ratios for scores of sensory attributes of turbot fillet sections cooked in conventional and microwave ovens

Source of variation	df	Mean squares			
		Flakiness	Moistness	Hardness	Chewiness
Total	111				
Oven	1	1.29	67.58	172.51**	209.01**
Replication	3	18.06	15.22*	143.79***	30.49***
Panelist	6	176.14*	119.07*	69.48	127.49*
Oven x replication[a]	3	7.12	7.65	2.18	1.39
Panelist x replication[b]	18	29.72*	41.70***	40.19***	35.92***
Oven x panelist	6	3.89	5.48	7.07	16.86**
Oven x panelist x replication[c]	18	8.00	7.58	5.18	3.24
Error[d]		56	11.89	4.76	7.17 3.92

[a]Error term for oven.

[b]Error term for panelist.

[c]Error term for oven x panelist.

[d]Error term for replication, panelist x replication, and oven x panelist x replication.

*P < 0.05.

**P < 0.01.

***P < 0.001.

Table 11--Means of scores for sensory attributes of turbot fillet sections cooked in conventional and microwave ovens[a,b,c]

Variable	Oven	
	Conventional	Microwave
Flakiness	14.9x ± 0.06	15.1x ± 0.06
Moistness	15.8x ± 0.4	14.2x ± 0.7
Hardness	11.8z ± 0.6	9.3w ± 0.5
Chewiness	13.7z ± 0.5	10.9w ± 0.6

[a]Means in a row followed by like letters do not differ at P > 0.05 (x,y) and P > 0.001 (z,w).

[b]Mean and standard error of 56 values for 16 fillet sections.

[c]Scale of 1-21 used to score responses. Flakiness: 1 = low flakiness; 21 = high flakiness. Moistness: 1 = low moisture release; 21 = high moisture release. Hardness: 1 = soft; 21 = hard. Chewiness: 1 = little preparation; 21 = much preparation.

Table 12--Means of scores assigned by trained panelists for sensory attributes of turbot fillet sections cooked in conventional and microwave ovens[a,b,c]

Panelist	Attribute			
	Flakiness	Moistness	Hardness	Chewiness
1	10.8x ± 1.3	14.1x ± 1.2	13.0x ± 1.3	15.4x ± 0.9
2	10.1x ± 1.2	11.2x ± 1.0	10.0x ± 0.9	9.9xy ± 0.9
3	18.1y ± 0.4	15.3x ± 0.7	12.4x ± 0.8	14.9x ± 0.8
4	15.8xy ± 1.0	17.3x ± 0.6	7.9x ± 1.0	8.1y ± 1.0
5	18.0xy ± 0.2	18.0x ± 0.4	12.5x ± 1.3	11.6xy ± 1.2
6	17.2xy ± 0.6	17.3x ± 0.7	9.2x ± 1.2	14.9x ± 0.7
7	14.9xy ± 1.3	11.9x ± 1.2	8.6x ± 0.7	11.2xy ± 0.6

[a]Means in a column followed by the same letters do not differ at $P > 0.05$.

[b]Mean and standard error of 2 values for each of 2 cooking methods for each of 4 replications.

[c]Scale of 1-21 used to score responses. Flakiness: 1 = low flakiness; 21 = high flakiness. Moistness: 1 = low moisture release; 21 = high moisture release. Hardness: 1 = soft; 21 = hard. Chewiness: 1 = little preparation; 21 = much preparation.

Although differences in moistness of samples were not attributed to type of oven used in cooking, the results (Table 10) indicated that there were differences among panelists in scoring moistness. However, further analysis with the Tukey's range test (Larmond, 1977) did not show where these differences were among panelists (Table 12). Replication and oven x replication also contributed to differences found in moistness of the turbot (Table 10). However, the range test applied to find where the differences in replication were, proved inconclusive. This may indicate that fish differences were present, but small, among replication and that, combined with differences in how panelists scored moistness, resulted in interaction differences.

Differences in hardness and chewiness of the turbot were attributed to oven used, to replication, and to panelist x replication (Table 10). Samples cooked in the conventional oven were scored significantly higher than those cooked in the microwave oven (Table 11), indicating that the microwave-heated fillet sections were perceived to be softer and less chewy than those heated conventionally. The differences in hardness and chewiness attributed to replication and the interaction of replication x panelist indicated the presence of fish sample differences among replications and complex interaction between those differences and how panelists varied in scoring the characteristics during the 4 replications.

In addition to the sources of variation in chewiness scores mentioned, other significant sources of variation were panelist and oven x panelist (Table 10). These results indicated that chewiness as defined

in this study, was a difficult parameter for panelists to evaluate and some panelists were scoring it differently than others. It is evident from the individual panelist's mean scores presented in Table 12, that although significant differences did exist, there appeared to be more concurrence among panelists in scoring than not.

The interaction of oven x panelist was significant because 2 of the panelists found differences in samples cooked by the 2 heating methods, with respect to chewiness, and 5 of them did not. The 2 panelists who found differences, indicated that the conventionally heated samples were more chewy than those heated in the microwave oven.

Chewiness was defined by Szczesniak et al. (1963) as a secondary texture parameter composed of hardness, cohesiveness, and elasticity, all of which are primary parameters. The complexity of chewiness as a texture attribute was further substantiated by the results in the same study, which suggested that cohesiveness and elasticity were the more difficult primary parameters to perceive. The presence of panelist differences and significant interactions for chewiness of turbot in the present study may indicate that the panelists did not have a clear understanding of the definition for that attribute.

No significant differences were found between sensory scores for laterally adjacent samples (posterior and anterior) on fillet sections, as indicated from t tests applied to the data. No differences were found between vertically adjacent samples (distal and proximal to the lateral line) of fillet sections for flakiness and hardness. Because no differences were found, these data are not presented.

However, the mean (and standard error) of chewiness scores for the samples distal to the lateral line on the fillet sections (12.1 ± 0.5) was significantly lower than that of samples proximal to the lateral line (12.4 ± 0.6) at $P < 0.05$. The mean (and standard error) of scores for moistness of the distal samples (16.0 ± 0.05) was significantly higher ($P > 0.05$) than that of the proximal samples (14.0 ± 0.6). This indicated that samples cut along the lateral line were perceived to be drier and chewier than samples cut further away from the lateral line on fillet sections. The proximal samples were thicker and contained larger flakes than did the distal samples which were located closer to the fin of the fish. This may have contributed to the differences found, since larger flakes are composed of larger fibers which may have seemed more chewy and drier to panelists than the smaller fibers of the smaller flakes.

Charley (1952) reported significant differences in sensory scores for salmon steaks cut from different areas along the same fish. Gibson et al. (1977) noted that different portions of fish muscle differ in composition, and because of this they presented comparable sections of catfish fillets to panelists in a study of storage treatment of fish. These reports and the results of the present study indicate that careful consideration must be given to the sampling plan used for sensory evaluation of fish.

IV. CORRELATIONS PERTAINING TO TRAINED SENSORY EVALUATION AND OBJECTIVE MEASUREMENTS

The study of relationships between objective and sensory data and among sensory attributes is of interest because of the limited amount of related information that has been reported in the literature. Pearson Product Moment correlation coefficients for trained sensory panel scores for flakiness, moistness, hardness, and chewiness are presented for oven and pooled data in Table 13. Significant relationships were found between hardness and chewiness for individual ovens and for pooled data. As hardness scores increased, chewiness scores did also. This finding was supported by the work reported on chewiness as a parameter secondary to hardness, previously mentioned (Szczesniak et al., 1963), and by another report of similar high correlations among hardness, chewiness, and cohesiveness of fish species (Cardello et al., 1982a).

Correlation coefficients for sensory attributes and objective measurements of the cooked fillet sections appear in Table 14. No significant correlation was found between pH and any sensory attribute. It has been suggested that above a pH of 6.7, there may be a decrease in the effect of pH on fish muscle texture (Dunajski, 1979). The mean pH of the turbot in this study (6.9 ± 0.1) was above that value. This and the fact that the range in pH (6.7-7.2) was relatively small may have accounted for the lack of significant relationships between pH and sensory scores.

The thickness and weights of the raw fillet sections were each significantly related to flakiness. As thickness and weight of fillet

Table 13--Pearson Product Moment correlation coefficients (r) for trained panel scores for sensory attributes of turbot fillet sections cooked in conventional and microwave ovens

	Attribute			
Attribute	Flakiness	Moistness	Hardness	Chewiness
----------Conventional oven----------				
Flakiness	1.00			
Moistness	.06	1.00		
Hardness	.04	-0.00	1.00	
Chewiness	.03	.12	.66*	1.00
----------Microwave oven----------				
Flakiness	1.00			
Moistness	.13	1.00		
Hardness	.06	-0.04	1.00	
Chewiness	.14	.03	.73*	1.00
----------Pooled----------				
Flakiness	1.00			
Moistness	.18	1.00		
Hardness	.19	.13	1.00	
Chewiness	.05	.22	.74*	1.00

*P < 0.001.

Table 14--Pearson Product Moment correlation coefficients (r) for sensory attributes and objective measurements of turbot fillet sections cooked in conventional and microwave ovens

Objective measurement	Sensory attribute			
	Flakiness	Moistness	Hardness	Chewiness
pH	.28	-.02	-.22	-.23
Fillet section thickness	.62***	.05	.27	.11
Fillet section raw weight	.61***	.09	.33	.25
Raw moisture content	-.40*	-.22	-.49*	-.35
Cooked moisture content	-.07	-.04	-.31	.04
Kramer shear values	-.11	-.14	.67***	.55**
Evaporative loss	-.12	.22	.18	.29
Solid-drip loss	-.01	-.26	-.46**	-.55**
Total cooking losses	-.23	-.18	-.67***	-.67***

*P < 0.05.

**P < 0.01.

***P < 0.001.

sections increased, panelists' scores for flakiness also increased. This may be attributed to the fact that the size of flakes is proportionate to the size of the fish; larger fish have larger flakes. The size of every fish sample presented to panelists was approximately the same. Therefore, those samples from smaller fillets (i.e., with smaller flakes) contained more flakes with more locations for connective tissue than did those from larger fillets, and were more apt to stay intact during cutting of samples for presentation to panelists. Panelists, therefore, may have perceived samples which were not intact or those with fewer, larger flakes to be more flaky than intact samples or those with many, smaller flakes.

Significant negative correlations also were found between percentage raw moisture content and flakiness and between percentage raw moisture content and hardness. The more moist the raw fish was, the less flaky and softer panelists perceived the cooked turbot to be. Love et al. (1974) indicated that a significant correlation was found between moisture content and sensory texture scores for hardness of cod muscle. The correlation between raw moisture content and chewiness was approaching significance. This result supports the previously mentioned relationship between hardness and chewiness.

The other significant correlations presented in Table 14 apply to both hardness and chewiness. Kramer shear values were significantly related to both sensory parameters. As Kramer shear values increased, hardness and chewiness scores increased. These correlations (Table 14) indicated that the Kramer shear cell was accurately measuring differences that panelists were perceiving. Szczesniak et al. (1963) indicated

that there was a high correlation between objective measurement with a texturometer and sensory scores for hardness and chewiness of various foods.

The findings of the present study also are in accordance with those of Rasekh et al. (1970) who indicated a significant correlation (+.78) between shear force values and firmness of tuna rated by an expert panel. Negative correlations were found between total cooking losses and hardness and chewiness, respectively (Table 14). As the losses from the turbot sections increased, the fish was perceived to be softer and less chewy.

V. CONSUMER SENSORY PANEL AND QUESTIONNAIRE

Characterization of Fish and Cooking Measurements

The 3 turbot fillets used for the consumer panel were all left fillets and weighed 718, 732, and 764 g (frozen), respectively. The mean weight and thickness of the prepared raw dorsal fillet sections were 277 g and 25 mm, respectively; those for the ventral sections were 245 g and 22 mm, respectively. The mean length for both dorsal and ventral sections was 26 cm. The mean pH of the 3 fillets used was 6.89, ranging from 6.87 to 6.91. This pH was similar to that of fillets used for the trained panel. The mean cooking time for the conventionally cooked fish was 33.64 min and that for fish cooked in the microwave was 3.25 min. The mean internal end-point temperatures of the fillet sections cooked in the conventional and microwave ovens were both 82°C

(180°F). The end point temperatures of the 3 fillet sections heated in the microwave oven (79.5°, 80°, 86.5°C) seemed to reflect more uniformity in fillet thickness. They also reflected more appropriate cooking times for the weights and thicknesses of fillet sections than did those used for sections evaluated by the trained panel. Those times resulted in a greater range of end point temperatures for that phase of the study. The period of time of post-oven temperature rise of fillet sections cooked in each oven were comparable to those of fish cooked for the trained sensory panel.

Sensory Results

The results of analyses of variance for the consumer sensory panel data are presented in Table 15. The consumer panel did not prefer the turbot cooked in the microwave over that cooked in the conventional oven ($P = 0.076$), as indicated by the sensory score means. The means and standard errors of the scores were 5.3 ± 0.2 and 4.9 ± 0.2 for conventionally and microwave-cooked samples, respectively. The magnitude of the scores indicated that the turbot was neither liked nor disliked (1 = like extremely, 9 = dislike extremely).

The hedonic scores for the turbot may have been lower than they might have been if the samples had been seasoned or served warm. If the samples had been in a more familiar form, other than flaked, scores may have been higher, also.

Some panelists commented that the samples cooked by the 2 heating methods seemed oily, but not unpleasantly so. Others indicated that the

Table 15--Mean squares for hedonic scores[a] for turbot fillet sections cooked in conventional and microwave ovens

Source of variation	df	Mean squares
Total	155	
Oven	1	6.61
Session	2	8.78
Oven x session[b]	2	0.57
Error[c]	150	3.29

[a]ANOVA showed no significant differences ($P > 0.05$).

[b]Error term for oven.

[c]Error term for session and oven x session.

microwave samples were too "mushy" or too wet, which was probably related to the fact that the microwave samples had evaporative losses than did the conventionally cooked samples.

Questionnaire Results

The 39 consumer panelists responded to a questionnaire designed to characterize the panel. The majority of the panelists were women (64%). The ages of the panelists were fairly evenly distributed. Thirty-one percent were in the age range 18-24; 28% were aged 25-34; 21% were aged 35-44; and 21% were 45 years or over. Most of the respondents (51%) lived in single family dwellings and 82% of the people ate most of their meals at home. Nearly all the panelists (95%) had conventional ovens in their homes, and 38% had microwave ovens. However, only 13% reported having a convection oven at home. Approximately half (49%) of the respondents reported that they had lived near a large body of water.

Most respondents, 80%, ate fish at least 2-3 times per month or more as shown in Table 16. This percentage was not unexpected since only people who said they liked fish were invited to complete the questionnaire and participate in the sensory evaluation.

Attitudes and demographic characteristics of more than 1,700 regular and irregular users of fresh finfish in Ohio were reported by Sanchez and Konopa (1974). The authors defined regular users of fish as those people who reported eating fish at home once a month or more often. Irregular users of fish were those who used fish less than once a month at home. Approximately 38% of the respondents in that study

Table 16--Frequency of eating fish as reported by 39 respondents

Frequency of eating	% of respondents
1 or more times per week	36
2-3 times per month	44
1 time per month	10
6-10 times per year	5
less than 6 times per year	5
never	0

were regular users of fish; this lower percentage, compared to that in the present study, reflected the fact that liking of fish was not a criteria for selection in the survey taken in Ohio.

It was interesting to note that about 56% of the respondents reported that most of the fish they ate was prepared in their or someone else's home and about 44% reported that most of the fish that they ate was prepared in a full and/or fast-service restaurant. Only 23% of those surveyed reported that they never prepared fish at home. Of those who did prepare fish at home (82%), 72% reported that the form in which they prepared fish was that of fillets.

A majority of respondents who prepared fish at home reported that they used a conventional oven to do so, as shown in Table 17. A top burner of a conventional range was the second most frequently cited appliance used to prepare fish at home. Only 9% of all the respondents used a microwave oven to prepare fish, which represented only 20% of those who had microwave ovens in their homes. This percentage of those who used a microwave oven to cook fish was lower than that reported by Gast et al. (1980) who found that 35.7% of microwave owners surveyed had prepared fish in the microwave. However, the lower percentage found in the present study than that reported by Gast et al., reflected the nature of the question which was focused on the "most frequently" used appliance rather than "ever" used to prepare fish. Baking, broiling, and frying were the most frequently cited methods of cooking fish by that group (Table 18).

Table 17--Appliances most frequently used to prepare fish at home as reported by 32 respondents[a]

Appliance	% of respondents[b]
Conventional oven	65
Top burner of conventional range	38
Electric frying pan	12
Microwave oven	9
Other[c]	9

[a]Seven of the total number of respondents (39) did not prepare fish at home.

[b]Percentages add up to more than 100% because some respondents gave more than 1 response.

[c]Refers to barbecue grill.

Table 18--Methods of cooking most frequently used to prepare fish at home as reported by 32 respondents[a]

Cooking method	% of respondents who prepared fish at home[b]
Baking	69
Broiling	72
Frying	59
Steaming	9
Other[c]	16

[a]Seven of the total number of respondents (39) did not prepare fish at home.

[b]Percentages add up to more than 100% because some respondents gave more than 1 response.

[c]Refers to barbecue grill.

The percentages of respondents who prepared particular species of fish at home are presented in Table 19. Flounder and perch were cited most frequently by the respondents.

The primary reasons cited by all respondents not preparing fish more often at home are presented in Table 20. Lack of availability of the kind and/or form that they liked, cost, and not thinking to prepare it were the primary reasons given besides various responses written in by panelists. Taste and/or texture, and/or odor; and unfamiliarity with preparation methods were among the least frequently cited reasons for not preparing fish. This coincided with related survey results reported by Sanchez and Konopa (1974). They indicated that regular and irregular users of fish in Ohio liked the taste of fish and did not believe that fish was repugnant in appearance. The same respondents did not rate fish inferior to meat in taste, ease of cooking, preparation, and quality. They also were indifferent in their attitudes regarding cost of fish. In contrast, 41% of the respondents in the present study indicated cost as one of the primary reasons for not preparing fish more often. This finding coincides with a report that price of fish was found to be a significant factor influencing household expenditure on fish (Capps, 1982).

Respondents in the present study were asked to indicate their familiarity with, use, and like of certain species of fish. Some of the results of that inquiry are presented in Table 21. Seven of the species have not been commonly available to consumers: bluefish; butterfish; cusk; monkfish; orange roughy; sculpin; and turbot. Of all

Table 19--Fish species most commonly prepared at home by 32 respondents[a]

Fish species	% of respondents who prepared fish at home
Cod	28
Haddock	22
Perch	56
Flounder	66
Catfish	19
Salmon	59
Other[b]	56

[a]Seven of the total number of respondents (39) did not prepare fish at home.

[b]Refers to bass, bream, bluegill, butterfish, pike, red snapper, smelt, swordfish, sunfish, and trout.

Table 20--Primary reasons for not preparing fish more frequently at home as reported by 39 respondents

Reason	% of respondents[a]
Other[b]	59
Kind and/or form I like not readily available	54
Cost too much	41
Don't think of it	41
Unfamiliar with ways to prepare fish	28
Unfamiliar with fish, generally	23
Don't like its taste and/or texture and/or odor	18

[a]Percentages add up to more than 100% because some respondents gave more than 1 answer.

[b]Reason most frequently included in this category by respondents was that others living in the same household did not like fish and/or the method of preparation that respondents did.

Table 21--Frequency and percentage of respondents reporting familiarity with, use of, and like/dislike of 12 species of fish

Fish species	Heard of	Eaten	Prepared at home	Prepared in a restaurant	Like	Dislike
	--frequency of respondents-- (n = 39)		----------% of respondents who have eaten----------			
Bluefish	28	11	36	73	82	18
Butterfish	15	6	83	17	83	17
Cod	39	35	74[a]	49	89	11
Cusk	3	1	0	100	100	0
Flounder	39	37	78[b]	70[b]	97[a]	0[a]
Haddock	36	27	74[a]	56[a]	89[a]	7[a]
Halibut	37	22	68	68	91	9
Monkfish	16	5	60	20[a]	80[a]	20
Orange roughy	10	5	0	100	100	0
Salmon	39	38	82[a]	68[a]	95	5
Sculpin	2	1	0	100	100	0
Turbot	28	19	63	47	84	16

[a]One respondent did not respond when appropriate.

[b]Two respondents did not respond when appropriate.

39 respondents, only 2 and 3 people had heard of sculpin and cusk, respectively. Although higher numbers of respondents had heard of the other 5 underutilized species, few had eaten them. Cusk, orange roughy, and sculpin had not been prepared by any of the panelists, although they had eaten them in restaurants. More of the 39 respondents (38, 37, 35) reported having eaten salmon, flounder, and cod than they did other fish species listed in the questionnaire. A majority of respondents who had eaten any of the 12 species of fish, reported that they liked it. Of those fish species cited as not being liked by those who had eaten them, monkfish, bluefish, butterfish, and turbot were cited more frequently than the other species. However, all percentages calculated for "dislike" responses represent 20% or less of the respondents who had eaten the fish (Table 21).

Of the underutilized species of fish listed in the questionnaire, turbot was the most frequently heard of and eaten. In view of the indifference of the panel toward the turbot in the sensory evaluation, it is interesting to note that of those who reported that they had eaten turbot elsewhere, most (84%) liked it and most (63%) had prepared it at home.

It may be said of the consumer panelists, that, most liked the available species of fish that they had eaten, including some underutilized species; many ate fish in restaurants and even more prepared it at home, where they primarily baked or broiled it. These questionnaire findings and the hedonic scores from the sensory evaluation, indicated that heating in a microwave oven may be an acceptable method of cooking

turbot, or other species of fish, to consumers who like and usually prepare fish at home.

CHAPTER V

SUMMARY, LIMITATIONS, AND IMPLICATIONS

An investigation was undertaken to study the effects of microwave heating on the eating quality of an underutilized species of fish (Greenland turbot) and the energy requirements to cook it compared with that for cooking in a conventional oven. The quality of the cooked fish fillet sections was evaluated by using objective tests, a trained sensory panel, and a consumer sensory panel.

The energy comparison showed that the microwave oven cooked the fillet sections at a faster rate than did the conventional oven. The microwave oven had less cooking power and used less total energy to cook the turbot than did the conventional oven. The relative efficiency of the microwave oven was greater than that of the conventional oven. These findings indicate that the microwave oven is more time and energy efficient in cooking fish than is the conventional oven and should be considered as a choice by consumers who want to save time and energy in food preparation.

Evidence was found that determination of cooking times is tenuous for heating fish fillets in a microwave oven to a particular degree of doneness, indicated by a specific internal end-point temperature. This was evident from preliminary work as well as from observed ranges of internal temperatures of microwave-cooked turbot fillet sections of different sizes, weights, and thicknesses.

The time of the post-oven temperature rise of the fillet sections was monitored. A post-oven rise in temperature occurred in the fish heated in the microwave oven, but not in the conventionally heated fish. Although the observed time and rise in temperature were relatively little, it did indicate that some additional cooking of the fish was taking place after removal from the oven.

The moisture content of the cooked turbot fillet sections cooked by each method did not differ significantly, however, total cooking losses and solid-drip losses were greater for the fish cooked in the microwave than were those for fish heated conventionally. The evaporative loss was greater for fillet sections cooked conventionally than for those heated in the microwave oven. Kramer shear values for the microwave-heated fish were lower than those for the fish cooked conventionally, indicating that the microwave fish was softer.

The trained sensory panel evaluated 4 textural attributes of the turbot. They found no significant difference for flakiness and moistness of the samples but found that the microwave-heated fish was softer and less chewy than was the conventionally cooked fish.

There were replication differences for moistness, hardness, and chewiness scores. There were also differences in flakiness, moistness and chewiness due to panelist differences in scoring and differences due to the interaction of panelist x replication were found. The interaction of oven x panelist also was determined to be a source of variation for chewiness scores. The evidence of variation due to sources other than oven treatment indicated that the trained panelists may not have

had a clear understanding of the sensory parameters being evaluated and/or differences in fish were great enough to result in differences in scoring.

Analyses of scores for duplicate samples on each fillet section indicated that posterior and anterior samples did not differ, but that samples distal to the lateral line of the fillet were softer and more moist than those in the proximal location to the lateral line. This information was evidence that choice of location of sampling of fish fillets for sensory evaluation is important in interpreting results. Careful consideration should be given to the sampling plan and duplicate samples should be taken from the same location on fillets being compared by sensory panelists.

Analyses of objective, energy, and trained sensory panel data for right and left sides of fillets indicated that no differences were evident. These results imply that the different sides of a flatfish do not differ and use of different sides will not introduce undesirable variability into objective and sensory results. However, the differences found between and within fillet sections, previously mentioned, should be of concern in experimental design.

Significant direct relationships were found between trained panel scores for hardness and chewiness of cooked turbot samples; and between flakiness and fillet section thickness, raw weight, and raw moisture content, respectively. Hardness and chewiness, as measured by the trained panel, were each significantly related to Kramer shear values, solid-drip loss, and total cooking losses, respectively. The

corresponding correlations and that between hardness and chewiness support the fact that these parameters of fish can be successfully measured objectively, as well as by using a trained sensory panel. No significant relationships were found between pH and sensory attributes evaluated, which was a finding contrary to previously reported data.

The 39-member consumer panel did not indicate any difference in acceptability of turbot cooked by the different cooking methods. Using the hedonic test for acceptability, the panelists neither liked or disliked the turbot cooked by the 2 heating methods. Since the flaked samples were unseasoned and served at room temperature, scores may have been lower than if the fish had been served warm in a more familiar form with seasoning.

The results of the questionnaire indicated that most of the 39 respondents ate fish at least 2-3 times per month. They usually baked, broiled, or fried the fish they ate at home, in or on a conventional oven. Few of the respondents reported owning a microwave oven, and only 20% of those who did, used them most frequently as an appliance for cooking fish.

Slightly more respondents reported that they ate fish prepared at home more often than fish prepared in full- or fast-service restaurants. The primary reasons given for not preparing fish more often were: those related to other household members' dislike of fish and/or a particular method of preparing it; availability of the kind and/or form best liked; and the cost of fish.

When asked about familiarity with, use of, and like of 12 species of fish, cusk, monkfish, orange roughy, and sculpin were the least familiar to and most infrequently eaten by the respondents. Of all the 12 species eaten by the respondents, all were liked by a majority of the people who had eaten them. This was not unexpected, since all respondents were sensory panelists who were chosen to be on the consumer panel if they liked fish. Only 28% of the respondents had heard of turbot and fewer had eaten it. Of those who had eaten it, however, most (63%) prepared it at home, and most (84%) liked it.

It may be concluded that cooking turbot in a microwave oven is more energy and time efficient than in a conventional oven. However, in comparison with cooking turbot conventionally, greater total and solid-drip losses and less evaporative loss may be expected when using a microwave to cook the turbot. Turbot cooked in the microwave oven was softer and less chewy than conventionally heated turbot, but was judged to be equally as flaky and moist. According to the consumer panel results, consumers were indifferent toward the turbot cooked by the 2 heating methods, in terms of acceptability.

The results of this study suggest that if energy and time are important considerations for consumers in preparation of fish, microwave heating may be a suitable cooking method. However, until more research data is available, recommendations made to consumers may be limited regarding times for cooking fish in a microwave oven due to a variety of factors. The size, weight, thickness, and number of fillets influence the amount of time needed to cook the fillets in a microwave oven.

Differences among and within species also contribute to variation in fillets and influence the determination of cooking times, as well as the texture and eating quality of the cooked fish.

The present study was limited by the number of fillets and species that were tested. By using turbot as a representative underutilized fish species, conclusions and implications about other species of fish are limited. Further research on other fish species is needed as more underutilized, as well as common species of fish become more readily available to consumers.

The results from the sensory evaluation by the trained panel indicated that more training of the panelists was needed. The length of panelist training was apparently insufficient and limited the ability of panelists to evaluate the fish as precisely as was desired. Use of a standard for trained panelists during testing may have been warranted, also, to ensure the proper evaluation of fish attributes.

Recruitment of volunteers for the consumer panel was difficult and the resulting size and composition of the panel limited the generalizations that could be made to other consumer populations from the data results. The consumer questionnaire was given to only those who participated in the sensory evaluation and were people who liked fish. Because of this, comparison of responses to certain questions related to the frequency of eating fish were impossible to make.

Implications from the results of this study suggest that increased consumption of fish by consumers might result if more species and forms of fish, utilized and underutilized, were made more readily available to

them. In addition to greater availability, information is needed by consumers, regarding underutilized species of fish, as well as appropriate cooking methods for them. It was apparent that consumers in this study did like fish, in general, and if given the opportunity, prepare various species at home, including some underutilized species.

Consumers commonly seem to be concerned with health and diet. If consumers follow the Dietary Guidelines for Americans (USDA and USDHEW, 1980), they may increase their consumption of fish. As consumption of fish increases and changing lifestyles warrant time- and energy-saving methods of food preparation, such as microwave heating, then additional research on microwave cooking of fish and other seafood will be needed. In order to provide consumers with accurate, practical information and recommendations regarding microwave cooking of fish, applicable to most, if not all species of fish, specific areas of research must be explored further. Some areas that might be investigated further are: microwave cooking times of fish in relation to species, size, weight, thickness, and shape; sensory evaluation of various fish species, with special attention on definition of sensory attributes specific to fish; consumer attitudes about, knowledge of, and use of fish; and the need for consumer information about fish and its preparation and eating quality.

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APPENDICES

APPENDIX A

CALCULATIONS FOR COOKING LOSSES

COOKING LOSS DATA COLLECTION AND DETERMINATIONS

Oven _____

A. Before Cooking

1. weight of dish (and wrap),[a] g_____
2. weight of thawed fish, g_____
3. weight of dish, (wrap),[a] and fish, g_____

B. On Removal from Oven

1. weight of dish, (wrap),[a] fish, and solid/drip, g_____
2. weight of dish, (wrap),[a] and solid/drip, g_____

C. Losses

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

D. Losses as Percentage of Weight of Raw, thawed Prepared Fillet Section

1. due to evaporation, % (100 x C1/A2) _____
2. due to solid/drip loss, % (100 x C2/A2) _____
3. total loss, % (D1 + D2) _____

[a]Calculations for conventional oven does not include wrap.

APPENDIX B

ENERGY EXPENDITURE DETERMINATIONS FOR CONVENTIONAL AND MICROWAVE OVENS

I. Rotating Disc Method for Determination of Wattage of Conventional Oven (Luetzelschwab, 1980; Korschgen et al., 1980):

1. Attach watt-meter to oven.

2. Turn on oven. Time the revolution of the disc on the watt-meter. Use the black indicator mark on the disc for a signal to start and stop timing.

3. Determine oven wattage by multiplying Kh value (taken from meter) by 3,600 (number of seconds in an hour) and divide by the rotating time of the disc.

4. Time for one disc revolution = ____ seconds; wattage = 3,600 x ____ Kh value ÷ seconds for one disc revolution = ____ watts of bake element.

II. Determination of Cooking Power and Relative Efficiency of Conventional Oven:

1. Operate oven without a load and record watt hours and time.

2. Determine rate of energy consumption.

$$\frac{\text{watt hours}}{\text{minutes}} = \frac{\text{total watt hours consumed}}{\text{time of test}}$$

3. Calculate cooking power (energy for cooking).

$$\text{cooking power} = \text{watt hours to cook fish} - \left(\text{rate of energy consumption} \times \text{time to cook fish}\right)$$

4. Calculate relative efficiency without preheating.

$$\% \text{ RE} = \frac{\text{cooking power}}{\text{watt hours to cook fish}} \times 100$$

5. Calculate relative efficiency with preheating.

$$\% \text{ RE} = \frac{\text{cooking power}}{\text{watt hours to preheat + watt hours to cook fish}} \times 100$$

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

To determine the efficiency with a water load:

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

    $H = m \times c \times t$

    m = mass, g

    c = specific heat in calories/gram/°C

    t = rise in liquid in °C

11. Multiply H x 1.16222 x 10^{-6} to convert from small calories to kilowatt hours.

12. $$\text{Output} = \frac{\text{calculated or measured kilowatt hours}}{\text{time to cook}} \times 3600 \text{ sec} \times \frac{10^3 \text{ watt hours}}{\text{kilowatt hours}} = \text{watt hours}$$

IV. Determination of cooking power and relative efficiency of microwave oven for cooking fish fillet sections:

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

2. Determine rate of energy consumption.

$$\text{watt hours / minutes} = \frac{\text{total watt hours for water load} - \text{sensible heat (wh)}}{\text{time to cook water (min)}}$$

3. Calculate cooking power to cook fish.

$$\text{cooking power} = \text{watt hours to cook fish} - \left(\text{rate of energy consumption} \times \text{time to cook fish}\right)$$

4. Calculate relative efficiency.

$$\% \text{ RE} = \frac{\text{cooking power}}{\text{watt hours to cook fish}} \times 100$$

APPENDIX C

INSTRUCTIONS, SCORE CARD, TABLE OF RESULTS, AND NOTIFICATION LETTER FOR TRAINED SENSORY PANEL SCREENING

INSTRUCTIONS

Thank you for agreeing to participate in this screening for trained sensory panelists. PLEASE READ ALL INSTRUCTIONS BEFORE YOU BEGIN!

You will receive four sets of samples today. Each set will be presented separately.

When you are ready for your first set of samples, open the hatch. Rinse your mouth before you begin sampling, but do not eat crackers until you are instructed to do so on the score sheet.

After you finish each set, place the plate in the hatch and close it. Wait for your next set of samples. There will be a few minutes between sets to rest. After evaluating the fourth set of samples, you may leave. On your way out please feel free to take a piece of fruit from the bowl in Booth #1.

THANK YOU!

SCORE CARD

Date_____ Name_____

In front of you is a set of three samples of fish. Two of them are the same. Please taste all three samples from left to right and identify the odd one.

You should use the water to clear your mouth only before and after evaluating the entire set of samples and not between individual samples. You may eat one cracker AFTER you have finished evaluating the entire set of samples.

Identify the odd sample according to difference only. Circle the number below that corresponds to your choice.

_____ _____ _____

What was different about the sample that you chose? _____

_____

_____

KM/4/83

Table 22--Trained panel selection results

Potential panelist	Correct responses/ total responses made
1	11/16[a]
2	10/16[a]
3	9/16[a]
4	10/16[a]
5	8/16[b]
6	9/16[a]
7	5/12[b]
8	10/16[a]
9	12/16[a]
10	12/16[a]
11	2/8[b]
12	6/12[b]
13	9/16[a]
14	7/16[b]

[a]Acceptable on the basis of minimum 9/16 or 7/12 correct responses.

[b]Rejected on the basis of minimum 9/16 or 7/12 correct responses.

To: Sensory Screening Participants

From: Karen Madeira

Date: April 26,1983

Thank you for participating in the screening for trained sensory panelists. Your participation has contributed greatly to my research!

On the basis of the number of correct responses you made, you _____ been chosen as a member of the trained sensory fish panel.

The results of the screening were:

All samples on each plate were the same fish. Only the length of cooking time was varied, resulting in textural and moisture content differences. Frozen Freshore cod and perch portions ~~from Krogers~~ were used. You received two sets of cod and two sets of perch each day. All fish was baked at 375°F for 25 minutes. Then half of each lot of fish was heated in the microwave oven for 2,3, or 4 additional minutes (e.g. the fish was heated only two additional minutes on the first and last days). This was done to increase the difficulty in perceiving differences.

Considering your unfamiliarity with fish in sensory testing, everyone did well. However, only the top 9 people were chosen to continue in the research. Those who correctly identified the odd sample at least ____ out of ____ times were selected.

Your own results were:____ out of ____ correct.

If you were chosen to continue in the research as a trained panelist, I will contact you soon to schedule training session times.

Thank you again for your patience, concentration, and time!

APPENDIX D

ORIENTATION LETTER, DEFINITIONS AND INSTRUCTIONS, AND SCORE CARD FOR TRAINED SENSORY PANEL

Training for Fish Evaluation
May 6, 1983
Room 24

The trained panelist is an analytical "tool" or objective measure in sensory evaluation. The objectivity, precision and reproducibility that you exhibit will determine your effectiveness as a panel member. What you do here is important and your contribution is vital to this research. You have been chosen because you exhibited a potential inherent sensitivity to the characteristics being evaluated and have been able to reproduce duplicate judgements. As you train, you will be tested further for your ability to reproduce judgements specific to the research.

In order to make objective decisions you will be asked to disregard your personal preference and trained to become familiar with the testing material. It will be necessary that all panelists agree upon and know the exact connotation of each descriptive term used. Standards will be presented to you during training to help you become more stable in your judgements. The method of handling and testing of the samples will be discussed and a common procedure agreed upon. Therefore, your verbal input is essential.

We all will be learning from each other in the training sessions. However, general guidelines will be presented to you for the evaluation and you, as a group, will make most of the final decisions on the criteria for making the sensory judgements in the actual testing.

It generally is recommended that panelists refrain from smoking, chewing gum or tobacco, eating, or drinking for at least 30 minutes before testing. This also applies to the training sessions. At the end of each session refreshments will be provided.

Attendance at every training session is essential and sessions will be kept short. Tapes of the sessions will be made and will be available for review if you need them.

DEFINITIONS AND INSTRUCTIONS[a]

FLAKINESS . . . . The perceived ease of separation of sample into individual flakes and fibers when manipulated with a fork.

Prodedure: Anchor sample with fingers and with opposite hand hold fork with tines facing down. At a central location on the sample, pull with the fork up to four times. Evaluate overall ease of separation of flakes and fibers.

MOISTNESS . . . . The perceived degree of oil and/or water released from sample during chewing.

Procedure: Place a sample the size of one oyster cracker in mouth. After no more than two chews, evaluate moisture release.

HARDNESS . . . . The perceived force required to compress sample using molar teeth.

Procedure: Place a sample the size of one oyster cracker in mouth. Compress with one downward stroke of the upper jaw. Evaluate hardness.

CHEWINESS . . . . The total perceived effort required to prepare sample to a state ready for swallowing.

Procedure: Place a sample the size of one oyster cracker in mouth. Chew until sample is ready for swallowing. Evaluate the total perceived effort involved prior to swallowing.

---

[a]Adapted from Kapsalis and Maller (1982).

SCORE CARD

SAMPLE CODE NAME_____

Evaluate sample according to the definition and instructions for each characteristic. Record your score by making a vertical mark on the appropriate line below.

FLAKINESS



LOW FLAKINESS — HIGH FLAKINESS

MOISTURE



LOW MOISTURE RELEASE — HIGH MOISTURE RELEASE

HARDNESS



SOFT — HARD

CHEWINESS



LITTLE PREPARATION — MUCH PREPARATION

APPENDIX E

LETTER, NOTIFICATION FORM, INSTRUCTIONS, SCORE CARD, AND QUESTIONNAIRE FOR CONSUMER PANEL

NUTRITION
AND FOOD
SCIENCES

TO: College of Home Economics and Department of Food Technology and Science Faculty, Students, and Staff

FROM: Karen Madeira, Graduate Research Assistant, Nutrition and Food Sciences
Marjorie P. Penfield, Professor, Nutrition and Food Sciences

DATE: September 20, 1983

RE: Volunteers for Sensory Panel

We currently are conducting a research project on factors that affect the eating quality of fish. For that project we are looking for 30-50 volunteers to serve on a sensory evaluation panel.

On October 4 and 6 (Tuesday and Thursday) we will conduct sensory evaluation panels in the Sensory Laboratory (Room 17 of the Home Economics Building). Volunteers will be asked to come one time to complete a short questionnaire and to taste several fish samples. The session should take no longer than 15 minutes.

Your participation in this project would be greatly appreciated. If you are willing to participate, please return the attached form. Please indicate the times that you would not be available on those days. We will notify you of the time that you should come on one of the days, after all panelists are scheduled.

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

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

Please supply the information requested below and return to Karen Madeira, NFS Department, Room 229, HEB by September 28, 1983 (Wednesday).

Name _____

Campus Address _____

_____

Campus Phone _____

Please check ALL times that you are NOT available on BOTH days.

October 4, 1983 (Tuesday)

_____	10:15-10:30 a.m.	_____	1:45-2:00 p.m.
_____	10:30-10:45 a.m.	_____	2:00-2:15 p.m.
_____	10:45-11:00 a.m.	_____	2:15-2:30 p.m.
_____	11:00-11:15 a.m.	_____	2:30-2:45 p.m.
_____	11:15-11:30 a.m.	_____	2:45-3:00 p.m.
_____	11:30-11:45 a.m.	_____	3:00-3:15 p.m.

October 6, 1983 (Thursday)

_____	10:15-10:30 a.m.	_____	1:45-2:00 p.m.
_____	10:30-10:45 a.m.	_____	2:00-2:15 p.m.
_____	10:45-11:00 a.m.	_____	2:15-2:30 p.m.
_____	11:00-11:15 a.m.	_____	2:30-2:45 p.m.
_____	11:15-11:30 a.m.	_____	2:45-3:00 p.m.
_____	11:30-11:45 a.m.	_____	3:00-3:15 p.m.



NUTRITION
AND FOOD
SCIENCES

TO: _____

FROM: Karen Madeira, Graduate Student, NFS
Marjorie P. Penfield, Professor, NFS

DATE: September 30, 1983

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

Thank you for volunteering to participate in the sensory panel. Please come to Room 18 of the Home Economics Building on the day and time listed below. Please do not smoke or consume any food for 30 minutes prior to the session.

Day: _____ Time of Session: _____

If you find you cannot come on the day or at the time indicated, please leave a message for us with Nancy or Kim (5445 or 3491).

Thank you.

KM:MPP:kb

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

THANK YOU FOR AGREEING TO PARTICIPATE

IN THIS SENSORY EVALUATION STUDY.

You will receive four single samples of cooked fish to test today.* The samples will be followed by a short questionnaire. When you are ready for your first sample, open the hatch.

When you finish the first sample, place the souffle cup and scorecard in the hatch and keep the tray. Please wait. Your second sample then will be placed in the hatch for you. Repeat this process for the second and third samples.

When you finish the fourth sample, please place the tray with the souffle cup and scorecard in the hatch and close it. At that time you will be given a questionnaire to complete. When you have answered all the questions, please return the questionnaire before you leave.

Thank you!

* The fish has not been seasoned in order that you may better taste the fish itself.

KM/MPP/10-83

DEPARTMENT OF NUTRITION AND FOOD SCIENCES

Fish Evaluation Scorecard

Panelist number _____ Sample _____

On your tray is a sample of fish. Taste the sample and indicate your like/dislike by placing a check (✓) next to the response that best describes how you feel about the fish. Your comments are welcome.

After evaluating a sample and returning the souffle cup and scorecard in the hatch, please wait. There may be one or two minutes between samples. Please clear your mouth during this time by drinking some water and eating one oyster cracker between samples. If you need additional water, please let us know.

_____ Like Extremely

_____ Like Very Much

_____ Like Moderately

_____ Like Slightly

_____ Neither Like Nor Dislike

_____ Dislike Slightly

_____ Dislike Moderatley

_____ Dislike Very Much

_____ Dislike Extremely

Comments: _____

_____

KM/MPP/10-83

Panelist Number _____

QUESTIONNAIRE

1. Gender:

_____Female

_____Male

2. Age:

_____under 18 years

_____18-24 years

_____25-34 years

_____35-44 years

_____45 and over

3. Type of residence:

_____single family dwelling

_____multiple-family dwelling (duplex, apartment, townhouse)

_____mobile home

_____dormitory, sorority, fraternity

_____rented room

_____other, please specify _____

4. What is the main source of your meals? (please check only one)

_____cafeteria

_____home (prepared by yourself and/or someone else)

_____home of friends or relatives

_____fast-food restaurants or shops

_____full-service restaurants

_____other, please specify _____

5. Do you have a conventional gas and/or an electric oven in your home?

_____yes _____no

6. Do you have a microwave oven in your home?

_____yes

_____no

7. Do you have a convection oven in your home?

_____yes

_____no

8. Did you ever live near the coastline of a major body of water (Great Lakes, oceans) where a variety of fish was readily available?

_____yes Please specify area _____

_____no

9. Check the time period which best describes the frequency with which you eat fish. (please check only one)

_____one or more times per week

_____2-3 times per month

_____once per month

_____6-10 times per year

_____less than 6 times per year

_____never

10. If you eat fish, where is it most frequently prepared? (please check only one)

_____at home

_____home of a friend or relative

_____fast-food restaurant or cafeteria

_____full-service restaurant

_____other, please specify

11. Do you (or someone else) prepare fish (not shellfish) in your home?

_____yes _____no

IF THE ANSWER TO QUESTION 11 IS "YES", PLEASE ANSWER ALL OF THE FOLLOWING QUESTIONS. IF NOT, GO DIRECTLY TO QUESTION 16 AND CONTINUE.

12. In what form is fresh and/or frozen fish (not shellfish) most frequently prepared in your home? (Please check only one)

_____as whole fish

_____as fillets

_____preformed (fishsticks, croquettes, etc.)

_____other, please specify, _____

13. By what cooking method(s) is fish prepared in your home? (Please check all that apply)

_____baked

_____broiled

_____fried

_____steamed

_____other, please specify _____

14. What kinds of fresh and/or frozen fish are usually prepared in your home? (check all that apply)

_____cod

_____haddock

_____perch

_____flounder

_____catfish

_____salmon

_____other, please specify _____

15. What appliance is used most frequently to prepare fish in your home?

_____top burner of conventional (gas or electric) range

_____conventional (gas or electric) oven

_____convection oven

_____microwave oven

_____electric frying pan

_____other, please specify _____

16. From the list below, please choose the three most important reasons why fish is not prepared more frequently in your home. Place a 1 next to the most important reason, 2 next to the second most important reason, and 3 next to the third most important reason.

_____It costs too much.

_____The kind and/or form I like is not readily available.

_____I am unfamiliar with fish, generally.

_____I am unfamiliar with ways to prepare fish.

_____I don't like its taste and/or texture, and/or odor.

_____I don't think of it.

_____Other, please specify _____

17. Please check each column that applies for each fish (fresh and/or frozen) listed below.

	(a) have heard of	(b) have not heard of	(c) have eaten	(d) was prepared at home	(e) was prepared in restaurant	(f) I liked it	(g) I did not like it
bluefish	____	____	____	____	____	____	____
cod	____	____	____	____	____	____	____
butterfish	____	____	____	____	____	____	____
cusk	____	____	____	____	____	____	____
flounder	____	____	____	____	____	____	____
haddock	____	____	____	____	____	____	____
halibut	____	____	____	____	____	____	____
monk fish	____	____	____	____	____	____	____
orange roughy	____	____	____	____	____	____	____
salmon	____	____	____	____	____	____	____
sculpin	____	____	____	____	____	____	____
turbot	____	____	____	____	____	____	____

VITA

Karen Madeira was born in New Bedford, Massachusetts, on October 1, 1948. She is the daughter of Lydia Madeira and the late Joaquim Madeira. She attended Dunbar Elementary School and graduated from Fairhaven High School in Fairhaven, Massachusetts, in 1966. She attended Framingham State College in Framingham, Massachusetts, as a freshman in home economics and transferred to Southeastern Massachusetts University in Dartmouth, Massachusetts, where she earned her Bachelor of Arts degree in psychology in 1972. She was employed as a counselor in New Bedford after graduation.

In 1974 the author moved to Atlanta where she worked as an operating room technician. Later she attended Georgia State University as a graduate student and worked as a research assistant in anthropology. In 1977 the author moved to Knoxville, Tennessee, where she earned the Master of Science degree in consumer studies in 1979 at The University of Tennessee, Knoxville. After graduating, she worked for the Community Action Committee in Knoxville and organized a food-buying club for the elderly.

In 1980 the author entered the doctoral program in the Department of Nutrition and Food Sciences at The University of Tennessee, Knoxville, and worked as a research assistant, coordinating the Stokely Van Camp Symposium from 1980 to 1981. In 1981 she assumed the responsibilities of research assistant for the Agricultural Experiment Station. Under the direction of Dr. Marjorie P. Penfield, she completed her

graduate research in 1983 and received the Doctor of Philosophy degree in home economics in the food science option in 1984. After completing the doctoral program at The University of Tennessee, the author assumed the responsibilities of Assistant Professor at the University of Guelph in Ontario, Canada.