AN ABSTRACT OF THE DISSERTATION OF

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Title: Evaluating a Value-Added Product through Studies on Consumer Acceptability, Sensory Properties, and Their Correlations to Biochemical and Instrumental Texture Properties: The Case of Pacific whiting (*Merluccius productus*) Individually Quick Frozen (IQF) Fillets

Abstract approved: ______________________________
Michael T. Morrissey

Pacific whiting (*Merluccius productus*) is the most abundant groundfish species off the California, Oregon and Washington Coasts. The fish are mainly used as a raw material for the production of surimi. However, it is not economically wise to depend only on one product. There is a need to diversify the industry and develop a portfolio of product forms able to compete on the global marketplace.
This study examines the characteristics of Pacific whiting individually quick frozen (IQF) fillets through an evaluation of consumer acceptability and sensory analysis, as well as their correlations to biochemical and physical properties. Additionally, a comparison is made between Pacific whiting IQF fillets and characteristics from seven other fish species.

Sensory analysis by a trained panel showed Pacific whiting scoring highest in the flavor category of shellfish, medium in overall flavor intensity and fresh fish flavor, and high in moistness. Two different cooking methods: microwave (rapid) and conventional oven (slow) were studied with the results showing that the rapid method improved a number of texture attributes. Correlations between sensory texture attributes and instrumental texture results of Pacific whiting and the protease activity were found for both cooking methods but much higher in the slow one. All eight species were tested in a consumer test using a nine-point Hedonic scale. There were no significance differences ($p>0.05$) in flavor, texture, and overall acceptance of Pacific whiting with most of other commercial fish. However, the amount of variation in each group was high. No significant differences were found in firmness of Pacific whiting when compared to Dover sole. Five-point purchase intent scale showed no differences in consumers' willingness-to-buy when compared to species presently available in the marketplace. Pacific whiting IQF fillets, kept in frozen storage for 12 months, showed no differences in the flavor and texture attributes with fillets frozen for one month.

The following findings are based on the information gained from the focus group: (1) The most important factor affecting consumers' purchasing decision on fish is flavor, (2) Fish flavor must be fresh, mild, pleasant, and true to species, and (3) Fish texture is varied. Texture is not as important as such factors as flavor, odor, appearance, and thickness of fillets. Pacific whiting was found to be tasty and acceptable to the focus group participants. Qualitative and quantitative data collected from the focus group and the consumer tests, combined with its sensory characteristics' similarity to desirable commercial fish suggest a good potential of Pacific whiting in being utilized as IQF fillets.

Evaluating a Value-Added Product through Studies on Consumer Acceptability, Sensory Properties, and Their Correlations to Biochemical and Instrumental Texture Properties: The Case of Pacific whiting (*Merluccius productus*) Individually Quick Frozen (IQF) Fillets

by

Weeraporn Aksornsri

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Dean of Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Weeraporn Aksornsri, Author

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Dedicated to
my mother, father, grandmother
brother and sisters
with all my love, respect, and gratefulness.

Evaluating a Value-Added Product through Studies on Consumer Acceptability, Sensory Properties, and Their Correlations to Biochemical and Instrumental Texture Properties: The Case of Pacific whiting (*Merluccius productus*) Individually Quick Frozen (IQF) Fillets

CHAPTER 1. INTRODUCTION

1.1 Background

Pacific whiting, a gadoid species, is one of the most abundant commercially harvestable groundfish off the coasts of British Columbia, California, Oregon, and Washington (Alverson et al., 1964). Interest in the economics of Pacific whiting production and consumption is stimulated by expanding U.S. participation in the fishery, formerly dominated by foreign fishing and processing. The fish are now increasing in value, and are fully utilized by domestic processors, mainly as a raw material for the production of surimi. Although some researchers suggest that Pacific whiting IQF fillets could be successfully marketed, the Pacific whiting fillet remains poorly thought in the domestic fisheries because of flesh fragility and rapid decay. In addition, emphasis on marketing other products made from Pacific whiting has been minimal. Many food purveyors are reluctant to handle unfamiliar products for which quality and consumer acceptance data are not available.

Since there has been no systematic survey available concerning the sensory properties of Pacific whiting IQF fillets, this research study focuses on determining and describing consumers' perceptions of Pacific whiting compared with other commercially available whitings and whitefish through consumer testing and focus group discussions. The sensory property profiles of Pacific whiting IQF fillets were also evaluated through descriptive analysis using a sensory trained panel. Since Pacific whiting has a characteristic soft flesh due to protease activity, its texture characteristics were of interest. Protease activity of Pacific whiting IQF fillets were studied to determine whether or not there is relationship among sensory texture, instrumental texture, the amount of protease activity, and consumer acceptability.

This research is separated into three studies that explore sensory evaluation, consumer acceptability, and the biochemical and instrumental texture properties of Pacific whiting IQF fillets, as discussed in succession.

1.2 Statement of Purpose

1.2.1 Study 1: Sensory Characteristics of Pacific Whiting and Other Whitings and Whitefish

The first study evaluates the sensory properties of Pacific whiting IQF fillets with trained panelists. The results will be useful in recommending future product development and marketing design.

Objectives:

1. To develop appearance, aroma, flavor, and texture profiles for cooked Pacific whiting IQF fillets, compared to seven other whitings and whitefish species.

2. To investigate the differences in sensory properties of Pacific whiting IQF fillets cooked by two different methods: microwave oven (rapid cooking) and conventional oven (slow cooking).

1.2.2 Study 2: Consumer Acceptability of Pacific Whiting IQF Fillets: Consumer Testing and Focus Group Sessions

The second study evaluates consumers' acceptability of Pacific whiting IQF fillets. The methodology for this study was based on consumer testing of major sensory attributes and qualitative focus group discussions.

Objectives:

1. To explore consumers' acceptability and willingness to buy Pacific whiting IQF fillets.
2. To investigate whether sensory characteristics obtained from the trained panelists are consistent and meaningful with consumers' perceptions.
3. To gain insights into consumers' thoughts, reactions and purchasing behavior concerning fish that are affecting their buying decisions.

1.2.3 Study 3: Correlation of Sensory Texture Properties of Pacific Whiting IQF Fillets Resulting from a Descriptive Analysis with Biochemical and Instrumental Analyses

The third study is designed to discover how the textural properties of Pacific whiting IQF fillets, sensory and instrumental, correlate with the amount of protease activity, as well as with one another.

Objectives:

1. To determine the protease activity in the four whitings including Pacific, Argentinean, Chilean, and Peruvian whitings, through a biochemical analysis.
2. To determine the instrumental texture properties of the fish fillets from eight species, through the use of an instrumental texture profile analysis.
3. To understand the relationship between the sensory texture properties of Pacific whiting fillets and protease activity in the fish, through the use of a sensory descriptive analysis panel and a biochemical analysis.
4. To understand the relationship between the instrumental texture properties of Pacific whiting fillets and protease activity in the fish, through the use of an instrumental texture profile and a biochemical analyses.
5. To understand the relationship between the sensory and instrumental texture properties of Pacific whiting fillets, through the use of a sensory descriptive analysis panel and an instrumental texture profile analysis.

These results will assist in increasing marketing information of the abundant whiting resources along the California, Oregon, and Washington coasts. Additionally, the sensory profile and consumer acceptability results may be useful to processors, suppliers, and retailers for future design of value-added products.

CHAPTER 2. LITERATURE REVIEW

2.1 Pacific Whiting and Its Significance

The Pacific whiting fishery began off California before 1900 by the U.S. fishing industry with annual captures of less than 1,000 metric tons (mt) (Jow, 1973). Pacific whiting is most abundant in coastal waters during the summer when large feeding aggregations occur at depths of 30-300 fathoms (Dark, 1985). Four major Pacific whiting spawning stocks can be found off the coast of (1) California, Oregon, Washington, and British Columbia (i.e., the most abundant), (2) central Puget Sound, (3) the Strait of Georgia, and (4) the West Coast of southern Baja California (Stauffer, 1985). Pacific whiting flesh has a protein content ranging from 14% to 16%, with the oil content ranges from 0.5% to 3.8% depending on the season (Nelson et al., 1985).

Total annual landings of Pacific whiting over the last decade have averaged 200,000 mt (Radtke, 1995). Beginning in the mid-1960s, the Pacific whiting fishery was exploited in large volumes by foreign fishing fleets. The U.S. fish industry increased its participation in domestic exploitation of this species through joint ventures with foreign processors (Wilkins, 1992). In 1991 the fishery became completely domestic with the advent of at-sea U.S. catching/processing vessels entering the fishery. The shore-side whiting industry has increased its production from less than 10,000 mt in 1991 to over 70,000 mt in 1995 (Radtke, 1995). For 1995, Pacific whiting landings represent 60% of the total volume of all seafood landed in Oregon. Currently, most of the Pacific whiting harvest is used for surimi production given its high volume, bland taste, white color, and low price. However, processing Pacific whiting to IQF fillets result in a higher yield than the traditional surimi. The fillets could be an advantageous alternative product in the current market provided it is acceptable to consumers. The lack of domestic utilization of Pacific whiting as fillets can be attributed to several factors related to the fish properties: relative softening of the flesh, a fat layer associated with rancidity, the presence of myxosporidean parasites, and high levels of proteases in muscle tissue (Sylvia and Morrissey, 1992).

2.1.1 Proteolytic Enzymes and Their Roles

Proteases are a group of enzymes that can hydrolyze peptide bonds and a variety of proteins into shorter peptide chains. The enzyme can be categorized into exopeptidases or peptidases (cleave peptide bonds which are adjacent to either a free α-COOH group or a free -NH group) and endopeptidases or proteinases (cleave bonds of the polypeptide chain distant to its C-or N-terminal) (Barrett and McDonald, 1980; McDonald, 1985; McDonald and Barrett, 1980, McDonald and Barrett, 1986). Exopeptidases can be divided by subgroups on the basis of catalytic mechanisms, and by the reactions that they catalyze. Endopeptidases, on the other hand, cannot be classified by their substrate specificity, but by the nature of the catalytic group in the active site instead. Endopeptidases are divided into cysteine (thiol), serine, aspartic (acid or carboxyl), and metallo proteinases (Bird and Carter, 1980; IUB Committee on Enzyme Nomenclature, 1984).

All proteases in muscle cells are located inside muscle fiber, and degrade either sarcoplasmic and/or myofibrillar protein fractions. Protein degradation in muscle cells is intracellular. Its mechanisms can be explained through three different systems: multicatalytic proteases, calcium-dependent proteases, and lysosomal proteases (Bond and Butler, 1987). A multicatalytic proteinase can be classified as trypsin-like (arg-X), chymotrypsin-like (phe-X), and peptidyl-glutamyl (glu-X) peptide bond-hydrolyzing activity (Wilk and Orlowski, 1983).
The proteinases degrade some proteins including sarcoplasmic proteins at an optimum pH ranging between 7.0 and 9.0 (Dahlmann et al., 1985; Tanaka et al., 1986). A major group of enzymes in a calcium-dependent proteolytic system are calpains (calcium-dependent papain-like proteases) which require calcium ions for their activity (Pontremoli and Melloni, 1986). The system was found not only to be composed of two enzymes with different calcium sensitivity:- μ-calpain with low Ca^{+2} requirement (calpain I) and m-calpain with high Ca^{+2} requirement (calpain II) (Kishimoto et al., 1981), but also a different kind of calpain (Yoshihara et al., 1990). The enzymes in this system are active at pH 7.0-7.5 (Ouali, 1992). The lysosomal proteases are high in kidney, liver, and spleen and low in skeletal muscle (Bond and Butler, 1987).
These enzymes are involved in muscle protein degradation (Gerard et al., 1988) and in meat tenderization during postmortem of carcasses (Calkins et al., 1987). They are active at an acidic pH. The main lysosomal enzymes are cysteine proteinases: cathepsins B (EC 3.4.22.1), H (EC 3.4.22.16), and L (EC 3.4.22.15) and aspartic proteinase: cathepsins D (Barrett and Kirschke, 1981; Katunuma and Kominami, 1983). In rabbit muscle cathepsins L showed greater myosin digestion

than that of B and D. Cathepsin H appeared to have nondetectable action on myosin (Dufour et al., 1989).

2.1.2 Proteases in Pacific Whiting

Pacific whitings' major impediment for further commercial development is the soft texture of the individual fish flesh caused by a protease which is related to a microscopic parasite called Myxosporea. This parasitic infection results in high enzyme activity in the tissue. Infection rates vary significantly between fish and fish catches. Because the infected tissue is not always visually detectable, infected fish are not easy to cull out during processing (Morrissey et al., 1995).

Initial work with Pacific whiting related its abnormal, soft texture with the visual presence of hairlike cysts containing myxosporidian spores and the accompanying high level of proteolytic activity. Kabata and Whitaker (1985) found that the softening of fish tissue results from proteolytic activity during the heating process. Fish infected with myxosporidian parasites have a more intense hydrolysis activity.

The class Myxosporidia is the most common parasites found in fish (Lom, 1970). Almost 300 species are reported as being infected with these parasites. In fish, the protozoan invasion is far more dependent on ecological conditions (e.g., type and amount of food, temperature, stress conditions, etc.) than in terrestrial animals. This infectious condition is accepted as an intrinsic property of the Pacific whiting species. However, the parasite and the infection has little public health concern.

Offshore Pacific whiting contains two myxosporean parasites. One of these parasites has been identified as a new species, *Kudoa paniformis* (Kabata and Whitaker, 1981), and shown to be responsible for the rapid degradation of the Pacific whiting flesh (Tsuyuki et al., 1982). This parasite can induce a tissue response, resulting in the concentration of melanin, causing unsightly blotches in the flesh. Even though the parasite has little public health concern, it degrades flesh texture significantly and limits the utilization of this resource (Patashnik et al., 1982). The other parasite is *Kudoa thyrsitis.* Morado and Sparks (1986) found 51% of 178 Pacific whiting samples contained *K. paniformis,* while *K. thyrsitis* and mixed infections were observed in 7% and 17% of the Pacific whiting samples, respectively. The enumeration of white and black pseudocysts and identification of the Kudoa species was conducted by Kudo et al (1987). Results showed that white pseudocysts were more closely correlated with cooked texture quality than were black pseudocysts. *K. paniformis* and mixed infections correlated well with sensory texture, while *K. thyrsitis* infections correlated poorly. Pacific whiting from southern fishing areas had higher white pseudocyst counts of *K. paniformis*, and more soft abnormal texture than Pacific whiting from northern fishing areas.

Similar flesh softening problems due to proteases have also been observed in other fish, for example, Threadfin bream (*Nemipterus virgatus*), Arrowtooth flounder (*Atheresthes stomias*), and Menhaden (*Brevoorti tyrannus*). The proteases in those fish which caused thermal degradation of texture, have been reported to be serine proteinase, cysteine proteases, and alkaline protease, respectively (Boye and Lanier, 1988, Kinoshita et al., 1991, Wasson et al., 1992, and An et al., 1994a).

The problems of parasitism and flesh fragility of Pacific whiting may limit penetration into the quality-conscious segment of the fish market. Given these problems, Pacific whiting would be competitively disadvantaged in the retail store market sector. However, if consumers could be persuaded to adopt the cooking method required to avoid enzymatic softening of the flesh, the potential exists for Pacific whiting to be marketed toward retail stores. Yet, consumers may resist changing their cooking habits because of unfamiliarity with this species.

2.1.3 Research on Pacific Whiting

There have been numerous works on Pacific whiting, especially at Oregon State University. Some of them are included. For example, the work of Hsu et al (1993) on protein denaturation in Pacific whiting fillets. They found no changes in quality of fillets stored at -8°C were significantly greater than those stored at lower temperatures.
Fillets stored at -34 and -50°C showed no significant advantage over those stored at -20°C as measured by salt-soluble protein extractability and Ca^{+2} ATPase activity. Morrissey et al (1993) investigated the effects of protease inhibitors at different concentrations on Pacific whiting mince and surimi. When measured by autolysis, gel electrophoresis, and torsion, beef plasma protein (BPP) showed the strongest inhibition of proteolytic effect in surimi, followed by egg white and potato extract. However, all three compounds showed strong inhibition in fish mince when measured by autolysis. Piyachomkwan and Penner (1995) studied the effect of whey protein concentrate (WPC), BPP, and bovine serum albumin (BSA) on the autolysis of Pacific whiting surimi. They found that the extent of inhibition by WPC correlated with their protein contents. No proteolytic activity could be detected in surimi samples

supplemented at 1% level with BPP, while surimi with up to 4% BSA supplementation had no demonstrable effect on autolysis.

An et al (1994a) compared existing assay systems for pacific whiting protease, optimized conditions for measuring proteolytic activity, and characterized proteases which hydrolyze myofibrilar proteins in Pacific whiting. The result showed that the assay based on detection of trichloroacetic acid-soluble product, using azocasein as substrate, showed highest sensitivity. Using that assay, optimal pH of the protease was 5.5 and optimal temperature was 55°C. An et al (1994b) continued their research and found that in Pacific whiting fillets cathepsin B was the most active cysteine protease, while cathepsin L was predominant in surimi. Peak activity of the cysteine protease cathepsin B was the highest (observed at 20°C), followed by cathepsin L (at 55°C) and H (at 20°C). However, the total cumulative activity of all three cathepsins was the highest at 55°C. Because only cathepsin L showed the maximum temperature at 55°C, this enzyme may be the principal protease contributing to the textural degradation of Pacific whiting fillets during conventional slow cooking. They also found that the degradation pattern of myofibrils by the protease was the same as the autolytic pattern of surimi. Purification of Pacific whiting proteases by Seymour et al (1994) showed that the proteolytic activity is mainly due to cathepsin L as characterized by its chemical inhibition, activity against specific substrates, temperature, and pH profiles. The purification has shown two activity peaks (P-I and P-II) representing two forms of the proteases when assayed by hydrolysis of azocasein. P-I and P-II showed pH optimum at 5.5 and 6.0 and temperature optimum at 55° and 60°C, respectively. An acidification to dissociate cathepsin L-inhibitor complex

from Pacific whiting (An et al, 1995a) suggested that P-I and P-II may be the same enzyme with different forms. P-I is complex-formed with an inhibitor, while P-II is the free form of the enzyme. An et al (1995b) applied a protease activity staining method for Pacific whiting protease and compared and quantified proteolytic activities in the fish.
They found that the activity was more pronounced for ocean-caught Pacific whiting than Puget Sound Pacific whiting or ocean-caught arrowtooth flounder. They used sodium dodecyl sulfate (SDS)-substrate gel in their activity staining method, which provided valuable information on molecular characteristics of protease in the complex muscle system.
Park et al (1994) studied gelation behavior of Pacific whiting surimi.
The result showed that the strongest gels were formed at 25°C setting followed by 90°C heating. The bonds that strongly influenced gel formation were found to be hydrogen and hydrophobic. Despite a number of works done on Pacific whiting, there has not been much sensory research performed on the fish.

2.2 Role of Sensory Evaluation and Its Technique

As a scientific discipline, sensory evaluation is a relatively new field of specialization that has the advantage of utilizing existing information from mature and related sciences e.g., physiology, psychology, and mathematics (Sidel et al., 1981). Sensory evaluation involves measuring human responses to products and ingredients through development and the use of principles and methods. A common element in these tasks is the use of humans as evaluators, suggesting sensory evaluation's proximity to the behavioral and social sciences. Sensory evaluation is the measurement of a product's quality based on information received from the five senses: sight, smell, taste, touch, and hearing. The signal generated at the nerve endings of the senses are transmitted via the central nervous system to the brain where they are integrated with past experience, expectations, and other conceptual factors before the opinion of the response is summarized (Amerine et al., 1965; Larmond, 1970). Sensory texture measurement is perceived primary by touch (the tactile sense), although the eyes and ears can provide information on some important components of the total product texture profile (Bourne, 1982).

Sensory analysis has increased its recognition and use by government, university, and industrial laboratories in the U.S. and abroad. In the fishery industry sensory evaluation plays an important role in the quality determination of raw materials and its products. Sensory tests determine quality variations by observing changes in the odor, taste, color, and the texture of the product. These changes are unique for each species, with important implications for handling, preservation, processing and storage of that particular product (Barral et al., 1989). It is the quantification of human responses that joins sensory evaluators, whether they are in marketing, product formulation, quality assessment, sensory-instrumental analyses, or fundamental research (Pangborn, 1980). Additionally, sensory evaluation is an important aspect of product development. It is a good method to evaluate the quality of new foods in the early stages of development, and provide a basis where instrumental methods could be designed for use as quality measurement and production control.

2.2.1 Sensory Methods

In order to measure products' perceived characteristics, quality, acceptability, and differences between products, a variety of test procedures in sensory evaluation are available:

2.2.1.1 Descriptive Analysis

Descriptive analysis methods involve the detection, discrimination, and description of both qualitative and quantitative product sensory aspects by trained panels (Meilgaard et al., 1991). Descriptive analysis is a unique and highly specialized form of sensory analysis. It can include all sensory parameters or be limited to certain aspects (e.g., flavor or texture profiling). In these descriptive methods, qualitative aspects combine to define a product and differentiate it from others, while quantitative (e.g., intensity) aspects define to what degree each qualitative characteristic is present in that sample. There are several standard techniques available (Cairncross and Sjostrom, 1950; Caul, 1957; Amerine et al., 1965; Stone et al., 1974; Meilgaard et al, 1991). These techniques use a system whereby particular sensory characteristics of a food product are identified and defined, using physical standard stimuli for trained panelists. A vocabulary/language is created to communicate sensory characteristics of the food product. Various scaling techniques are used to measure the strengths of these characteristics. The sensory descriptive panel can be considered a reliable method to judge flavor and texture profile of a product (Hegenbart, 1989).

Four commonly used descriptive analysis are (1) *Flavor Profile Method*: the method involves the analysis of perceived aroma and flavor product characteristics, their intensities, order of appearance, and aftertaste (Meilgaard et al., 1991; Einstein, 1991). The method, developed by Arthur D. Little, Inc. in the late 1940s (Cairncross and Sjostrom, 1950), is "based on the concept that flavor consists of identifiable taste, odor, and chemical feeling factors plus an underlying complex of sensory impressions not separately identifiable" (ASTM, 1990); (2) *Texture Profile Method*: the Texture Profile method was developed partly because textural attributes were not included in flavor profiling. The method was developed by General Foods Corporation in the early 1960s (Brandt et al.,1963; Szczesniak et al., 1963; Szczesniak, 1963; and Aguilera and Stanley, 1990). With this method, the entire texture of the food product is described with initial impressions through mastication and swallowing; (3) *Quantitative Descriptive Analysis* (QDA): resulted from the need to precisely quantify and statistically analyze certain applications of profile data (Stone et al., 1974; Stone et al., 1980; Stone and Sidel, 1985; ASTM, 1990). The elements of QDA include: development of a list of perceptible sensory attributes with panel agreement, the order of attribute occurrence, and relative attribute intensity measurement. This is followed by statistical analyses of the responses. Test results are often graphically presented using the spider plot. The plot provides a visual presentation of product similarities and differences (Einstein, 1991; Meilgaard et al., 1991); and (4) *Spectrum Descriptive Analysis*: the method is based on characterization of a product's sensory categories (ASTM, 1990). This characterization includes perceptible sensory attribute identification, along with attribute intensity measurements (Einstein, 1991; Meilgaard et al., 1991).

Some studies have implemented descriptive analysis in fish. For example, Chambers and Robel (1993) employed sensory flavor and texture profile analysis to selected cooked freshwater fish in retail distribution. The highly trained panel in this study provided the first sensory property examination of a variety of freshwater fish available to the consumer.

2.2.1.2 Qualitative Research

Qualitative research provides detailed information about people's attitudes, opinions, perceptions, behaviors, habits, and practices (Zikmund, 1991). Qualitative research concentrates on vocabulary or meanings, not intensities or frequencies. This type of research answers the questions "what and why" but not "how much or how often". It is concerned with describing and understanding products and ideas rather than measuring them (Chambers and Smith, 1991). Qualitative research methods are applicable to sensory studies, but are not considered substitutes for quantitative research (Zikmund, 1991). When used together, quantitative and qualitative studies may provide more comprehensive information than would be gained by either alone. The common types of qualitative research are (1) *in-depth or one-on-one interviews*: the interviewer conducts successive interviews with up to 50 consumers, using a similar format with each, but probing for additional elaboration in response to each consumer's answers (Meilgaard et al., 1991; Zikmund, 1991) and (2) *focus groups*.

A focus group session is a qualitative information-gathering technique which is guided by a trained moderator through a specific topic discussion with 8-10 participants (Krueger, 1988; Wu, 1989). The moderator (1) directs the flow of the discussion; (2) recognizes important points and motivates the group to explore and elaborate on them; (3) observes the nonverbal communication; (4) creates an atmosphere allowing respondents to relax; (5) synthesizes the information regarding the objectives; and (6) tests ideas generated by the information (Gordon, 1988). A focus groups is an unstructured, free-flowing interview with a flexible format discussion among participants (Zikmund, 1991). Focus groups are the most widely used qualitative research methods. They are used in market research to help evaluate consumer promotions, new products, advertising campaigns, and brand images for a particular product or service. The method allows consumers to express their underlying perceptions and opinions or attitudes about a product. Each participant is encouraged to express his or her views and to react to the views of others (Solomon, 1992). A session usually lasts about one to two hours. Outcomes cannot be quantified, but they do provide important qualitative information, as well as insights into consumer behavior. Often efforts are made to randomize sample selection, but results cannot be considered representative because responses to all issues are not solicited or received from every participant. Focus groups have both advantages and disadvantages.

Advantages are: (1) the techniques are relatively fast and easy to execute, (2) the group setting allows participants to respond to other participant comments and are more likely to express their own opinions and feelings, (3) the security of being in a group encourages more candor,

(4) groups representing specific, desired characteristics can be assembled, and (5) researchers can obtain feedback and responses from multiple segments of consumers (Solomon, 1992; Zikmund, 1991).

Disadvantages are: (1) focus groups are not often based in natural settings, thus increasing an uncertainty about the response accuracy, (2) group decision-making processes are not always the same as individual. Group judgments tend to be polarized (more extreme) than individual judgment (Solomon, 1992). The use of trained moderators to conduct focus groups is recommended to ease the discussion.
Chosen participants should be representative of the target consumers (Greenbaum, 1992). Focus groups can assist marketers in explaining how consumers feel about current food choices, and what they want for future choices. In a focus group discussion (Thayer, 1994), five shoppers discussed the pros and cons of frozen foods. A housewife said she buys lots of frozen vegetables and juice, but feels that sometimes the frozen vegetables are soft. An administrative assistant suggested that grocery stores should place frozen foods close to the cash registers so those items can be the last food selection before exiting the store.

Other general questions focus groups can address include the level of appeal for a particular idea, the ease with which a promotional concept is understood, the degree of difference between one concept and a competitor's, and whether a proposed program is consistent with the image of the product or service that it will support.

2.2.2 Product Quality Testing

Quality is an elusive term, meaning different things to different people. Any statement about the quality of a product is a statement about someone's perception and opinions (Fishken, 1990). A useful definition of quality is: "Quality is the composite of those characteristics significant in determining degree of acceptability (Kramer and Twigg, 1962)" and "Sensory quality is a complex set of sensory characteristics, including appearance, aroma, taste, and texture, that is maximally acceptable to a specific audience of consumers, those who are regular users of the product category, or those who, by some clear definition, comprise the target market (Fishken, 1990)." Thus, the criterion of quality is consumer appreciation.

Food quality factors are those which the consumer value toward that product (Aguilera and Stanley, 1990). All the attributes perceived by the consumer become part of his/her perception of quality. These are dependent on sight (i.e., size and shape, color, and visible defects), firmness and touch (i.e., mouthfeel), smell (odor), and taste (Kramer and Twigg, 1962). To accurately reflect market activity, product testing procedures must be based on a clear understanding of consumer behavior. Behavioral research in perception, learning, cognition, psychophysics, and psychometrics provide the basis for the principles and methods sensory scientists use today (Sidel et al., 1981).

Consumer behavior is the study of the processes involved when individuals or a group select, purchase, use, or dispose of products, services, ideas, or experiences to satisfy needs and desires (Solomon, 1992). It is an ongoing process, not merely what happens at the moment a consumer purchases a product or a service. Understanding the determinants of food choices and intake has major implications for both food producers and consumers. During product tests a large amount of information bypasses respondents' sensory receptors (de Chernatony and Knox, 1990), and due to limited cognitive capabilities, the perceptual system allocates processing capacity by filtering out information regarded as having low informational value.

Olson (1972) assumed that consumers' cue utilization depended upon whether the cues originated from the physical product (e.g., price, level of advertising) or from extrinsic cues (i.e., generalized quality indicators across products). Cox's research (1967) revealed that consumers base their decisions on a limited number of available cues (e.g., color, texture, feel). These cues were believed to be indicative of the value of certain characteristics with dominant effect on cue utilization.

2.2.3 Sensory Measurements

There are four types of scales used in sensory data quantification (Cardello and Maller, 1987; Meilgaard et al., 1991; Zikmund, 1991; and O'Shaughnessy, 1992): *nominal scaling*: it merely identifies or names different objects or classes of objects. Any categorical data can be assigned numbers, which are counted and placed in a frequency distribution; *Ordinal scaling*: this provides information about the rank order of objects from "most" to "least." Ordinal scaling, however, does not say anything about the degree of distance/interval; *Interval scaling*: it provides information about the sensory distances/intervals among stimuli. The most widely used interval scaling is the nine-point hedonic category scale; and *Ratio scaling* which has a zero quality amount. Ratio scales have absolute rather than relative quantities. The absolute represents a point on the scale where there is an absence of the given attribute (Zikmund, 1991; Moskowitz, 1974; Moskowitz and Fishken, 1979; Moskowitz, 1977).

There were a number of researchers who employed a 7-point category scale (Wesson et al., 1979; Sawyer et al., 1981; Cardello et al., 1982; Sawyer et al., 1984; Prell and Sawyer, 1988), a 9-point scale (Madeira and Penfield, 1985; Sawyer et al., 1988), and a 5-point scale (Hamilton and Bennett, 1983; Rainey, 1986) in their quantitative sensory research. Rounds et al (1992) performed in-home comparative taste tests on rainbow trout and brown trout to determine consumer reaction. By using a nine-point hedonic scale, color of flesh, odor, flavor, texture, and overall acceptability of the fish were evaluated. In food sensory analysis, the hedonic scale is generally used the most to measure consumers favorability for specified sensory characteristics of different foods, given its understandability by even the least experienced respondents.

2.2.4 Type of Evaluators in Sensory Analysis

2.2.4.1 A Consumer Panel

A consumer panel is usually employed when a food manufacturer wants to know if a new or improved product is acceptable to the public; and if degree of acceptability is high enough to ensure sufficient sales volume. The questions asked are of hedonic nature (i.e., how much is this sample liked/disliked?). In a consumer panel product samples are provided to typical consumers for evaluation. Success in this type of work is dependent upon both a representative demographic sample, and the development of an appropriate questionnaire (Aguilera and Stanley, 1990). Several consumer tests were developed on the sensory evaluation of fish. In general, consumers had personal preferences for certain types of fish, even though there are few obvious differences between types when they are filleted. Hamilton (1980) compared the various whitefish species whose sensory properties were identifiable and distinguishable from one another. They found that appearance, texture, and flavor all contributed to determining the relative acceptability of fish species, and these small differences in properties led to definite preferences for certain types of fish among the consumers.

In 1984, Hamilton and Bennett continued investigating consumer preferences for nine fresh white fish species with sensory evaluation panels. Most consumers found all species acceptable, and were advised to base their choice on species price rather than species identification. They concluded that a large number of species can be satisfactorily interchanged without causing adverse consumer reaction. However, it seemed that most consumers tended to pay more attention to familiar, more expensive species rather than experiment with less expensive, less known varieties. Consumer evaluation of sensory properties of 18 Atlantic fish species was performed by Sawyer et al (1988), using written surveys and consumer tests. Terms used to describe the cooked fish were generated, and consumer acceptance of those species was concluded.

2.2.4.2 An Expert Panel

An analytical expert panel is quantitative in its mission, and objective in its application (Aguilera and Stanley, 1990). It attempts to measure intensity differences in samples attributes. Questions such as "How tough/tender is this meat sample?" or "How chewy is this cookie?" are asked. The objective is not only to receive qualitative characteristics of a sample, but also numerical data for statistical analysis. Thus a well-trained, dedicated panel of judges is required to meet the objectives.

Trained expert panels differ from consumer panels principally in their number of participants. A panel, smaller by an order of magnitude, can offer precision when the members possess a collective background of experience and agreement. A disadvantage with the expert panel is the experts may project their subjectivity, resulting in inaccurate market forecasting. Civille and Szczesniak (1973) summarized the requirements for trained panelists as (1) be able to work cooperatively and harmoniously with a group and develop a feeling of team identity with the group, (2) be able to spare the time for training (2-3 hours a day for several weeks), and the regular operation of the panel for an indefinite period, (3) should be interested in their work, and dedicated to developing a team that will provide results with the precision and reproducibility of a scientific instrument, (4) having common sense and reasonable intelligence, (5) be able to discuss the test and reach a consensus with the other members of the panel, (6) be able to portray a professional attitude and take pride in their work, (7) it is recommended that trained panelist not have dentures as they restrict the perception of some texture attributes, (8) it is desirable to have gender represented on the panel, although the panel can be comprised predominantly of one gender, and (9) it is also recommended that those individuals involved in product development not to be asked to be on a panel given the possibility of exhibiting preconceived ideas of the textural quality of the products to be examined.

In training a sensory expert panel, reference standards are useful tools because they help panelists develop terminology to properly describe products, help determine intensities and anchor end points, and shorten training time. Orienting the panel by using reference standards can increase researchers' confidence. The researcher may feel that changes in product testing are more likely to have occurred because of changes in the product themselves, rather than in the panelists' perceptions of the products (Rainey, 1986). A standardized sensory methodology for evaluating the texture and appearance of cooked fish (Cardello et al., 1981) was applied to an evaluation of 17 North Atlantic fish species (Cardello et al., 1982). The sensory evaluation using a trained panel provided a data base for grouping fish species, according to similarities and dissimilarities in their sensory characteristics.

2.2.5 Sensory Research on Fish

Several studies have used sensory evaluation as a tool in designing a product development or quality control. De Koning and Mol (1992) found a highly significant correlation between dimethylamine (DMA) content in frozen South African hake (*Merluccius capensis* and *Merluccius paradoxus*) fillets and sensory texture. They were able to predict the quality of hake texture from its DMA content. Tissue sensory evaluation of six marine fish was studied to explore the relationship between free amino acid (FAA) content, and the sensory quality (Umar and Qadri, 1988). They found no significant accumulation of individual FAA during ice storage, and no distinct change was observed except with ammonia content. Nashimoto et al (1987) found the K-value (a ratio of inosine + hypoxanthine/inosine monophosphate + inosine + hypoxanthine) of tiger prawn (*Paneus japonicus*) corresponding with the excellent score on the sensory evaluation. Freshness sensory scores of Sockeye salmon and Pacific herring also correlated well with K-values (Luong et al., 1991). Perez-Villarreal and Pozo (1990) found the sensory assessment and k-values to provide the highest correlation with storage time in albacore tuna.

Bennett and Hamilton (1986) studied the effect of thawing and freezing of two white fish species (cod and whiting). They concluded that samples which had been frozen and thawed were no less acceptable than the fresh samples. The effect of iced storage and freezing and thawing on cod (Connell and Howgate, 1968) and on haddock (Connell and Howgate, 1969) were investigated using small expert panels. The results showed that storage at -30°C for 6 months did not further affect quality.
Silva et al (1994) used sensory evaluation to evaluate irradiated bluejack mackerel at different pasteurizing doses. Sensory differences were found between non-irradiated control and irradiated samples. The shelf-life of irradiated samples were two to three times longer. A cod fillet shelf-life study was performed by Einarsson (1994) to predict spoilage and bacterial growth. The fillets were stored in air and modified atmosphere at constant and varying temperature. The result showed that the models for predicting changes in sensory scores were more accurate than those predicting changes in bacterial numbers.

There were also sensory studies on dry-salted fish (Srikar et al., 1993), canned fish (Sims et al., 1992), fish sauce (Sanceda et al., 1992), and other fish products. An excellent reviews discussing sensory assessment of quality in fish and other seafood was published (York and Sereda, 1994). Although several studies have evaluated sensory properties of fish, limited published research is available concerning sensory properties and consumer reactions toward Pacific whiting.

2.3 Food Texture and Its Role

2.3.1 Definition of Texture

In general, the textural properties of a food are the group of physical characteristics that arise from the structural elements of the food; are sensed by touching; are related to the deformation, disintegration, and flow of the food under a force; and are measured objectively by function of mass, time, and distance (Bourne, 1982). Some of the definitions of texture are as follows:

"Texture is the composite of the structural elements of food and the manner in which it registers with the physiological senses (Szczesniak, 1963; Sherman, 1970)."

"By texture we mean those qualities of food that we can feel either with the fingers, the tongue, the palate, or the teeth (Potter, 1968)."

"Texture is one of the three primary sensory properties of foods (i.e., appearance, flavor, and texture) that relates entirely to the sense of touch or feel and is, therefore, potentially capable of precise measurement objectively by mechanical means in fundamental units of mass or force (Kramer, 1973)."

"Texture is the attribute of a substance resulting from a combination of physical properties and perceived by the senses of touch (including kinesthesis and mouthfeel), sight, and hearing. Physical properties may include size, shape, number, nature, and conformation of constituent structural elements (Jowitt, 1974)."

One may conclude that textural properties of foods have the following characteristics (Bourne, 1982): (1) it is a group of physical properties that are derived from the structure of the food; (2) it belongs under the mechanical or rheological subheading of physical properties; (3) it consists of a group of properties, not a single property; (4) it is sensed by touching, usually in the mouth, but other parts of the body may be involved (frequently hands); (5) it is not related to the chemical senses of taste or odor; and (6) objective measurement is by means of functions of mass, distance, and time only.

Examining a food textural properties almost always includes the development of a method of evaluation (sensory, instrumental or both), as well as an explanation of textural influence on natural variation and processing effects. This is an empirical approach as it does not evaluate the fundamental properties of the food that dictate its response (Stanley and Voisey, 1979).

Several studies have evaluated fish textures. For example, Reid and Durance (1992) assessed canned salmon texture with nine trained sensory judges, and by instrumental texture profile analysis.
Both methods revealed significant differences between maturity grades of canned salmon, with the sensory method being more sensitive.
The relationships between instrumental measurements and sensory evaluations of textural qualities of fish paste products were investigated by Shindo et al (1993). They found both hardness and viscousness

corresponded to jelly strength. Fillets from Pacific whiting between San Francisco Bay and Vancouver island, infected with myxosporean pseudocysts, were cooked and assessed for texture (Kudo et al., 1987). Average sensory texture ratings declined exponentially with white pseudocyst (*K. paniformis*) number/gram of tissue. Black pseudocysts (*K. thyrsitis*) did not correlate with sensory texture.

2.3.2 Properties of Muscle Foods

A number of food processing operations depend heavily on rheological (physical) properties of the product because of its profound effect on the quality of the finished product (Bourne, 1982). Rheology is the study of the deformation and flow of matter. The science of rheology has many applications in the field of food acceptability, food processing, and handling. In food acceptability, rheology is important to food technologists regarding the sense of touch (textural properties), which is one of the principle quality factors. For example, the flesh of fresh fish recovers quickly after squeezing, while stale fish does not. During the process of mastication (i.e., to chew up) a number of rheological properties (e.g., deformation of the first bite, flow properties of the mass of chewed food with saliva) are sensed in the mouth.

The response of food materials when subjected to various forces is of the greatest importance. Mechanical properties of foods form the basis of textural properties, and influence the handling and processing of foods. The three common action of force types applied on materials are: compressive (application of uniaxial parallel force to cause flattening), tensile (application of uniaxial parallel force to cause extension), and shearing (application of uniaxial tangential force to cause separation or cutting) (Aguilera and Stanley, 1990). When a material is subjected to one or more of these forces, its dimensions will change by some amount, meaning a deformation will occur. Three ways a material may deform are: elastic, plastic, and viscous. Either force-deformation or stress-strain results can be obtained.

2.3.3 Instrumental Texture Analysis

Instrumental analysis can be used to measure some fundamental mechanical property of the food, to evaluate a nonmechanical physical property that is highly correlated to texture, or to imitate the human masticatory process. Rheological quality control measurements are used to characterize texture as one of the sensory attributes involved in consumer-determined quality. In general, consumer-determined quality is described by various aspects of sensory acceptability: texture, appearance, color, flavor, and two physiological factors: wholesomeness and nutritive value (Escher, 1983).

A number of different instruments and many measuring principles are proposed for food texture instrumental characterization (Sherman, 1970; Sone, 1972; Kramer and Szczesniak, 1973). All of them are based on the prerequisite that some valid relationship can be established between sensory and rheological data. In principle, the material rheological property measurement consists of force and deformation as functions of time (Prins and Bloksma, 1983). Food texture instrumental analysis generally involves equipment consisting of a drive system imparting controlled linear or circular motion to a probe which makes contact with a test cell sample. The force required to achieve a certain deformation is recorded. The test cell is the component varied from machine to machine (Aguilera and Stanley, 1990).

There are usually three types of *direct* objective tests measuring real textural properties of materials (Bourne, 1982): (1) *fundamental tests*: these tests measure well-defined rheological properties. However, they may be less useful measuring senses in the mouth when food is masticated. A commonly used test is Young's modulus of elasticity, shear modulus, Bulk modulus, and Poisson' s ratio. The tests are advantageous in knowing exactly what is measured and disadvantageous in poor correlation with sensory methods, incomplete specification of texture, and in speed; (2) *empirical tests*: these instrumental tests measure parameters that are poorly defined, but in practical experience are found to be related to textural quality. The tests are successful in measuring foods' textural properties, thus they are widely used in the food industry; and (3) *imitative test*: these tests imitate the conditions to which the food material is subjected to in reality. Examples are the General Foods Texturometer which imitates the teeths chewing action. Botta (1991) developed a portable instrument to rapidly and objectively determine raw Atlantic cod fillets texture, hardness and resilience, without destruction. This instrument was dependable compared to the trained and experienced fish inspectors.

2.3.4 Research on Fish Muscle Texture

There has been numerous research on instrumental texture analysis. Some of those include a punch test that was used to measure instrumental texture of snapper and rockfish (Sawyer et al., 1984). The results showed good correlations between both sensory hardness and chewiness and the instrumental parameter of maximum shear stress. Greene and Babbitt (1990) performed Instron puncture tests on raw, baked, steamed, deep-fat fried and microwaved samples of arrowtooth to investigate how cooking methods affected proteases. They found that rapid inactivation of the proteases by microwave cooking significantly improved textural properties. Penetrometer tests (Izquierdo et al., 1991) in cooked sturgeon meat revealed the cooked meat to be firmer, prior to ATP (adenosine triphosphate) depletion and the onset of rigor, than in the postrigor state. Compression tests showed texture of cooked meat was firmest when the muscle was in rigor, as well as cooked meat from struggled fish was softer than that from anesthetized fish. Morrissey et al. (1993) used a torsion test to investigate the effectiveness of different inhibitors. Pacific whiting surimi gel made with 1% beef plasma protein improved gel strength, observed by the increased shear stress and shear strain. Chung et al. (1994) also employed a torsion test to study the effects of high hydrostatic pressure (HHP) on gel strength of Pacific whiting and Alaska pollock surimi, compared to heat-set controls. HHP + 1% BPP whiting and pollock gels showed a great increase in strain values at all pressure/temperature combinations.

Nute et al (1987) related the sensory characteristics of ham to their mechanical properties (shear and tensile strength). Trained panel's mean scores revealed that firmness increased with shear strength, while cohesiveness and rubberiness increased with tensile strength and total water content. Beilken et al (1990) studied profiled sensory on frankfurters. Consensus results were obtained by the trained panel.

They used various compression and punch tests, and found the compression tests to relate better to the sensory data. Chung and Merritt (1991) developed a texture instrumental measurement method for scallop meat after frozen storage, replacing the sensory method. They found a significant correlation not only between sensory evaluation and compressive force (compression method), but also shear peak force (shear method) and sensory result. Progress has been made in quantifying instrumental and sensory texture assessment. However, limitations are still prevalent when only using instrumental tests to predict textural quality of food.

2.4 Statistical Analysis of Sensory Data

2.4.1 Analysis of Variance

Analysis of Variance (ANOVA) is a hypothesis testing technique to determine if statistically significant differences on means occur between two or more groups or populations. ANOVA involves the investigation of the effects of one treatment variable on an interval-scaled dependent variable. It is a form of dependence analysis where measures on a single dependent variable Y are collected under a variety of experimental conditions (O'Shaughnessy, 1992). It compares variances to make inferences about the means (Zikmund, 1991). The ANOVA analyzes variability in the entire data set to see how much can be attributed to differences between means, and how much is due to variability in the individual populations (Devore and Peck, 1986).

2.4.2 Principal Component Analysis

Principal component analysis (PCA) is a statistical technique applied to a single set of variables where the researcher is interested in discovering which variables in the set form coherent subsets that are relatively independent of one another. In PCA, all the variances in the observed variables are analyzed. The specific goals of PCA are to summarize patterns of correlations among observed variables, to reduce a large number of observed variables to a smaller number of components by finding linear combinations of those variables that explain most of the variability (Statgraphics Statistical Graphics System, 1988), to provide an operational definition for an underlying process by using observed variables, or to test a theory about the nature of underlying processes (Tabachnick and Fidell, 1989).

2.4.3 Correlation Analysis

Correlation Analysis is a bivariate statistical technique used to measure associations of one variable to another. The procedure generates a matrix of correlation coefficients for a set of observed values. The correlation coefficient (r) is a descriptive measure of the closeness of a linear relationship between two variables (Snedecor and Cochran, 1989). The correlation coefficients provide a normalized and scale-free measure of the association between two variables. It indicates the strength of the association (how strongly the sample X and Y values are linearly related) and the direction of that association. The coefficient values fall between -1 and +1. A positive correlation indicates that the variables vary in the same direction, while a negative correlation indicates that the variables vary in the opposite direction.

Statistically independent variables have an expected correlation of zero (Statgraphics Statistical Graphics System, 1988). Correlation analysis is useful because researchers can compare two correlations, without regard for the amount of variance exhibited by each variable separately. Methods from correlation analysis are used when the objective is to assess the strength of any relationship between two variables (Devore and Peck, 1986). Correlation does not prove causation, as variables other than those being measured may be involved. The coefficient of determination (r^2) measures the total variance in the dependent variable accounted for by knowing the value of the independent variable (Zikmund, 1991).

CHAPTER 3. MATERIALS AND METHODS

3.1 Fish Supplies for Overall Studies

Three studies were undertaken: (1) characterizations of sensory properties of Pacific whiting IQF fillets and other commercial whitings and whitefish, (2) consumer acceptability of Pacific whiting IQF fillets using consumer testing and focus group discussions, and (3) correlation of sensory texture properties of Pacific whiting IQF fillets resulting from descriptive, biochemical, and instrumental texture analyses.

Eight species of fish were used in this research studies. Pacific whiting (*Merluccius productus*) was supplied by the Pacific Coast Seafood Co., Astoria, OR. This PAC was referred to as frozen PAC stored for one month (PAC) sample. The frozen PAC stored for one year (PAC^y) was also the Pacific whiting supplied by the Pacific Coast Seafood Co., Astoria, OR, but previously packed with double sealed bags, and kept frozen for one year prior to the study. Argentinean whiting (*Merluccius hubbsi*) (ARG) and Peruvian whiting (*Merluccius gayi peruanus*) (PER) were obtained from Shore Trading Co., Boston, MA. Chilean whiting (*Merluccius gayi*) (CHI) was supplied by the Food Engineering Institute at Catholic University, Valparaiso, Chile. Dover sole (*Microstomus pacificus*) (DOV), lingcod (*Ophiodon elongatus*) (LIN), Alaskan pollock (*Theragra chalcogramma*) (POL), and rockfish (*Sebastes melanops*) (ROC) were supplied by the Portland Fish and Oyster Co., Astoria, OR. All frozen fish were obtained as IQF fillets. Samples were packed and shipped in dry ice to the Department of Food Science and Technology at Oregon State University (OSU). They were kept frozen at -37°C upon arrival.

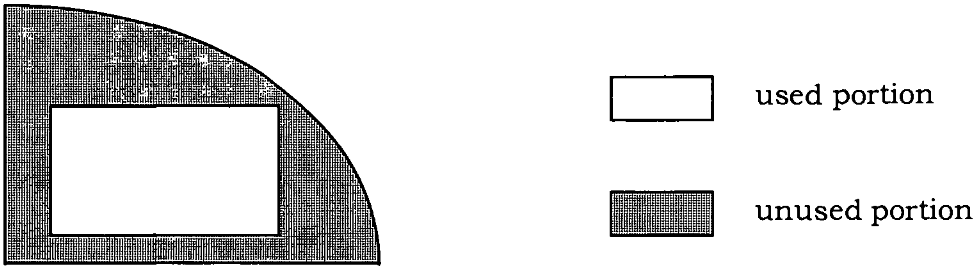
3.2 Fish Samples for Overall Studies

For all three studies, head and tail parts (≈3.8 cm or 1.5 in) and outer edges of PAC IQF fillets and the seven other species previously identified were removed and discarded. Only the middle section of the fillets were used in the studies. Two types of PAC IQF fillet samples were used throughout the investigation: (1) uncoded samples, and (2) coded (identified) samples. Ninety PAC fillets were coded for tracking purposes. "Coded" means the samples were taken from "numbered" fillets. Each of the 90 fillets were divided into three sections (Figure 3.2.1). Each of the three sections were used for the three different studies. The reason this was done was to compare PAC's performance over the entire investigation. The other seven fish species samples were uncoded. Table 3.2.1 summarized the types of PAC IQF fillets samples used in each study. The frozen PAC^y, PAC previously kept frozen for one year, was uncoded. Head and tail parts (≈3.8 cm or 1.5 in) and outer edges of the PAC^y IQF fillets were also removed and discarded as described above.

3.3 Study 1: Sensory Characteristics of Pacific Whiting and Other Whitings and Whitefish

3.3.1 Fish Samples and Preparation

Test 1: Sensory profiles for PAC and other commercial whitefish and whiting IQF fillets (DOV, LIN, POL, ROC, ARG, CHI, and PER) were performed. The sample tested by the trained panelists was randomly selected from several IQF fillets from each species, cut from the middle



Fillet #1, ..., #90

A middle portion of a fillet was divided into three main sections, for the three studies:

- Section 1: Trained panelists → Study 1: Sensory descriptive analysis
  - • 1.3 X 1.3 cm piece
  - - cooked in a microwave oven
  - - cooked in a conventional oven

- Section 2: Consumers → Study 2: Consumer testing
  - • 3.8 X 3.8 cm piece
  - - cooked in a microwave oven

- Section 3: Analysis → Study 3: Correlation analysis
  - • 6.0 grams for biochemical analysis of protease activity
  - • 1.3 X 1.3 cm piece for instrumental analysis
  - - cooked in a microwave oven
  - - cooked in a conventional oven

Figure 3.2.1 Division of coded Pacific whiting IQF fillets used in the entire study.

Table 3.2.1 Eight fish species sample types used in the entire study.

	Pacific whiting		Argentinean	Peruvian	Chilean	Dover sole	Ling cod	Pollock	Rockfish
	Microwave	Conventional							
Study 1: Sensory Descriptive Analysis									
Test 1	Uncoded (U)	-	U	U	U	U	U	U	U
Test 2	Coded*(C)	C	U	U	U	-	-	-	-
Study 2: Sensory Affective Test-Quantitative and Qualitative									
Consumer tests	U and C**	-	U	U	U	U	U	U	U
Focus group	*** ****	***	****	****	****	***	-	-	****
Study 3: Correlation Analysis									
Biochem	C	C	U	U	U	-	-	-	-
Instrument	C	C	U	U	U	U	U	U	U

Note:
- * Sensory texture ratings of Pacific whiting IQF fillet from both cooking methods were used in correlation analysis in Study 3
- ** Consumer perception ratings were used in correlation analysis with sensory descriptive and biochemical analysis
- *** Home use fillets by focus group participants
- **** Hand-on fillets used in focus group discussions

section of the fish into 1.3 X 1.3 cm (0.5 X 0.5 in) pieces, stored, cooked, and served to the trained panelists individually. The samples were cooked using a microwave oven (GoldStar MA-1172MW: MultiWave, 1.1 Cu. Ft. 1,000 Watts Turntable, GoldStar Co., Ltd. Seoul, Korea) for 35 sec per 12 pieces (including 15 sec defrosting) until internal temperature reached 73°C (minimum temperature requirement of Marion County Health Department, Salem, OR to ensure safety of product). Four replications were done for each sample.

Test 2: Sensory profiles and comparison of PAC fillets cooked by two different methods, and comparison of PAC and three whitings (ARG, CHI, and PER). Coded PAC fillet were used in this test. One out of the three sections (section 1) of each coded fillet were cut into 1.3 X 1.3 cm pieces and tasted by the trained panelists (Figure 3.2.1). The PAC samples were cooked using two cooking methods: slow (a conventional oven) and rapid (a microwave oven). These PAC samples, for both cooking methods, came from the same fillet. One sample was cooked in a microwave oven for 30 sec per nine pieces (including 15 sec defrosting) and another was cooked in a conventional oven at 350°F (177°C) for 15 min or until the internal temperature reached 73°C. The other three whitings (i.e., ARG, CHI, and PER) were cooked only in a microwave oven. Ten replications were done for each sample.

3.3.2 Sensory Procedures

3.3.2.1 Training the Panelists

Nine students and staff (6 females and 3 males) from Oregon State University Departments of Food Science and Technology, Food Nutrition, Crop Science, and Entomology participated in training sessions, and subsequent evaluation of fish samples. The participants were selected based on interest, availability, and sensory detection ability. They were trained in 20 one-hour training sessions with five sessions per week. The training was conducted in the Sensory Science Laboratory at OSU and followed standards procedures used by American Society for Testing and Materials (1990). The two initial sessions stressed the training objectives and the importance of a trained panel. The vocabulary and definitions of appearance, aroma, flavor, and texture were also introduced to the panelists (Table 3.3.1, 3.3.2, 3.3.3, and 3.3.4). The reference standards were used in training and testing appearance, aroma, flavor, and texture profiles of fish (Meilgaard et al., 1991).

The trained panel evaluated the fish samples for appearance, aroma, flavor, and texture. Descriptors were developed by the trained panel, as well as from the reference standards. A trained panel consensus determined the final base attributes. Throughout this study, trained panelists received reference materials to assist in the standardization of appearance, aroma, flavor, and texture descriptors, to train and assist panelists in evaluation, and to reduce variability among panelists.

3.3.2.2 Testing

Test 1: To test sensory profiles for PAC and other commercial whitings and whitefish (DOV, LIN, POL, ROC, ARG, CHI, and PER) IQF fillets. Testing by the trained panelists was conducted in individual booths at the Sensory Science Laboratory at Oregon State University, Corvallis, OR. Twelve 1.3 X 1.3 cm. pieces of each species sample were

Table 3.3.1 Appearance characteristic definitions and standards used in the sensory descriptive analysis.

Appearance Characteristic	Definition	Standard			
		Low	Low-medium	Medium-high	High
Color intensity	The intensity or strength of the color from light to dark.	White paper No: W-25 (25% cotton acid free) (Lightest)	Index paper No: I-1	Resume paper No: R-2 (soft white linen text)	Art Pad white drawing paper No: 4003 (Dutton-LeBus Paper, Inc., CA) (Darkest)
Flake size	The size of flakes which can be seen on the surface and inside of the product using a fork to separate.	1.5-2.0 mm	4.0-5.0 mm	-	7.0-8.0 mm

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

Table 3.3.2 Aroma characteristic definitions and standards used in the sensory descriptive analysis.

Aroma Characteristic	Definition	Standard
Fresh fish	An aroma associated with cooked fresh fish that distinctively characterizes it as *fresh* fish.	-
Fishy	The aroma associated with *undesirably* strong fish smell.	Figaro cat food: tuna Bumble Bee Seafoods, Inc., San Diego, California
Ocean	The aroma of *fresh ocean water.*	Pacific ocean water from Newport, Oregon
Nutty	The aroma associated with *chopped nuts,* such as pecans.	Ground Walnut pieces PLANTERS® Gold Measure: Baking & Cooking Nuts
Buttery	The aroma associated with *warm melted butter.*	Darigold butter, Grade AA

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

Table 3.3.3 Flavor characteristic definitions and standards used in the sensory descriptive analysis.

Flavor Characteristic	Definition	Standard Low	Standard High
Overall flavor intensity	The initial *total* impact of fish flavor, a *positive* or *negative* perception.	A 1.3 X 1.3 cm (0.5 x 0.5 inch) piece of pollock	A 1.3 X 1.3 cm piece of Peruvian whiting
Fresh fish	The flavor associated with *cooked fresh fish* that distinctively characterizes it as *fresh* fish.	-	-
Fishy	The flavor associated with an *undesirable* strong fish taste.	A 1.3 X 1.3 cm piece of dover sole	Brunswick® Canadian Sardines in spring water
Shellfish	The flavor associated with *cooked shellfish* such as lobster, clam, or scallop.	-	Cooked scallop
Nutty	The flavor associated with *chopped nuts* such as pecans, walnuts, etc.	-	Ground walnut pieces Planters® Gold Measure: Baking & cooking nuts

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

Table 3.3.3, continued Flavor characteristic definitions and standards used in the sensory descriptive analysis.

Flavor Characteristic	Definition	Standard Low	Standard High
Buttery	The flavor associated with *warm melted butter.*	-	Darigold butter, Grade AA
Sweet	The taste stimulated by *sucrose, other sugars,* and by other sweet substances.	2% sucrose solution in distilled water	9% sucrose solution in distilled water
Salty	The taste of sodium chloride and other salts found in ocean water.	0.2% salt solution in distilled water	0.5% salt solution in distilled water
Bitter	The taste stimulated by substances such as quinine, caffeine, and hop bitters.	0.05% of Alum Schilling® solution in distilled water	0.1% of Alum Schilling® solution in distilled water

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

Table 3.3.4 Texture characteristic definitions and standards used in the sensory descriptive analysis.

Texture Characteristic	Definition	Technique	Standard		
			Low	Medium	High
Flakiness	The perceived ease of separation of the sample into individual flakes.	Put the sample in your mouth, manipulate sample with the tongue against the palate.	A 1.3 X 1.3 cm (0.5 x 0.5 inch) piece of white sturgeon *(Acipenser transmontanus)*	A 1.3 X 1.3 cm piece of dover sole	A 1.3 X 1.3 cm piece of pollock
Size of flake in mouth	The size of individual flake perceived after separation from the sample.	From the above method, perceive the size of the flake with tongue and palate.	-	-	-

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

Table 3.3.4, continued Texture characteristic definitions and standards used in the sensory descriptive analysis.

Texture Characteristic	Definition	Technique	Standard		
			Low	Medium	High
Hardness	Force required to bite through the sample.	Bite through a 1.3 X 1.3 cm (0.5 x 0.5 inch) sample with molars.	A 1.3 X 1.3 cm piece of dover sole	A 1.3 X 1.3 cm piece of snapper *(Lutjanus peru)*	A 1.3 X 1.3 cm piece of white sturgeon *(Acipenser transmontanus)*
Mushiness	The degree of fish flesh softness perceived as "mush".	Put the sample in your mouth, manipulate sample with the tongue against the palate.	A 1.3 X 1.3 cm piece of Peruvian whiting	-	An ounce of mashed potato
Moistness	The amount of wetness in sample when mixed with saliva.	Chew 1.3 X 1.3 cm sample with molars for seven times.	A 1.3 X 1.3 cm piece of White Sturgeon *(Acipenser transmontanus)*	A 1.3 X 1.3 cm piece of Snapper *(Lutjanus peru)*	A 1.3 X 1.3 cm piece of Dover sole

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

Table 3.3.4, continued Texture characteristic definitions and standards used in the sensory descriptive analysis.

Texture Characteristic	Definition	Technique	Standard Low	Standard Medium	Standard High
Toothstickiness	The amount of particles that stick on teeth during chewing.	Chew 1.3 X 1.3 cm sample with molars for ten times.	A 1.3 X 1.3 cm (0.5 x 0.5 inch) piece of carrot	-	A 1.3 X 1.3 cm piece of Doodles™ Cheese flavored baked corn puffs. Borden, Inc., Columbus, Ohio.
Chewiness	Count the number of times it takes to chew in order to disintegrate the sample to a state ready for swallowing and score.	Chew 1.3 X 1.3 cm sample with molars until it is ready to swallow, expectorate the sample instead.	A 1.3 X 1.3 cm piece of dover sole	A 1.3 X 1.3 cm piece of snapper *(Lutjanus peru)*	A 1.3 X 1.3 cm piece of cusk

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

Table 3.3.4, continued Texture characteristic definitions and standards used in the sensory descriptive analysis.

Texture Characteristic	Definition	Technique	Standard		
			Low	Medium	High
Mouthcoating	The amount of particles left in mouth, on roof, or on tongue.	Chew 1.3 X 1.3 cm sample with molars until it is ready to swallow. Instead of swallowing, expectorate sample. Evaluate residues in mouth.	A 1.3 X 1.3 cm (0.5 x 0.5 inch) piece of dover sole	A 1.3 X 1.3 cm piece of snapper *(Lutjanus peru)*	A 1.3 X 1.3 cm piece of white sturgeon *(Acipenser transmontanus)*

Note: The standards listed above were determined based on the author's preliminary work with two OSU sensory science laboratory staff.

served each time, and trained panelists tested four species at one time and one set per day. Individual panelists performed four replications for each species over a two week testing period. All samples were cooked using a microwave oven. Serving temperature was approximately 43±2°C. Samples were presented to the trained panel in a 57 gm (2 oz.) plastic cup coded with a 3-digit, random number. The ballot, standards, and the species samples were presented on a serving tray to each panelist.

Test 2: To test sensory profiles and compare PAC fillets cooked by two different methods, and compare PAC with three whitings (ARG, CHI, and PER).

Only coded PAC samples were used in this study. Two cooking methods were employed for PAC: microwave oven (rapid) and conventional oven (slow). The other three whitings were cooked only by a microwave oven. The trained panelists tested five samples (i.e., 2 PAC, ARG, CHI, and PER) at one time. The test was replicated ten times over a two week testing period.

The trained panelists evaluated the following descriptors: *appearance*- color intensity and flake size; *aroma*- fresh fish, fishy, ocean, nutty, and buttery descriptors; *flavor*- overall flavor intensity, fresh fish, fishy, shell fish, nutty, buttery, sweet, salty, and bitter; and *texture*- flakiness, size of flake, hardness, mushiness, moistness, toothstickiness, chewiness, and mouthcoating. Because of time constraints, the author and trained panelists agreed to reduce the previous working descriptors to only the main characteristics of each attribute for Test 2.

Each characteristic descriptor for both Test 1 and Test 2 was rated using a nine-point intensity scale. A score of "1" represented the lightest, none, and the smallest (the least) for color intensity, flavor, and texture descriptors, respectively; a score of "5" represented medium or moderate; and a score of "9" represented the darkest, extreme, or the greatest.

3.3.3 Experimental Design and Statistical Analysis

A randomized complete block design was used in Test 1 and Test 2. Test 1 evaluated four replications over eight treatments (i.e., eight fish species cooked in a microwave oven) and Test 2 provided ten replications over five treatments (i.e., four whiting species, including two cooking methods for PAC). The block corresponded to each of the nine panelists in each replication (Figure 3.3.1). An assumption of this design was that the trained panelist would maintain constant sensory perceptions when evaluating the samples. Replication serves a number of purposes in this experiment. Firstly, it provides an estimate of experimental error (because it provides several observations on experimental units receiving the same treatment). Secondly, it increases precision by reducing standard errors which is equal to square root of a product of sample variance divided by number of observations (replications). Finally, it broadens the base for making inference (as replication is increased a wider variety of units can be brought into the experiment) (Petersen, 1985). Evaluations by trained panelists were analyzed per each descriptor through three-way analysis of variance with panelist (P), replication (R), and treatment (T) as factors. Interaction effects were also tested. The descriptors treatment means were compared using Fisher's least significance difference test ($p<0.05$). The data were also analyzed

TEST 1:

Panelists (P): #1, #2, #3, #4, #5, #6, #7, #8, and #9

Treatments (T): PAC, ARG, CHI, PER, DOV, LIN, POL, and ROC (all were cooked in a microwave oven)
(fish species)

Replications (R): 4

TEST 2:

Panelists: #1, #2, #3, #4, #5, #6, #7, #8, and #9

Treatments : PAC 1 (cooked in a microwave oven), PAC 2 (cooked in a convection oven),
(fish species) ARG, CHI, and PER (cooked in a microwave oven)

Replications: 10

An example:
Block #1
(Panelist #1)

Replication

	I	II	III	IV	V	VI	VII	VIII	IX	X
Treatment	PAC 1	PER	CHI	ARG	PAC 2	PAC 1	PER	CHI	ARG	PAC 2
	PAC 2	PAC 1	PER	CHI	ARG	PAC 2	PAC 1	PER	CHI	ARG
	ARG	PAC 2	PAC 1	PER	CHI	ARG	PAC 2	PAC 1	PER	CHI
	CHI	ARG	PAC 2	PAC 1	PER	CHI	ARG	PAC 2	PAC 1	PER
	PER	CHI	ARG	PAC 2	PAC 1	PER	CHI	ARG	PAC 2	PAC 1

Figure 3.3.1 A randomized complete block design used in the sensory descriptive analysis.

through principal component analysis (PCA) using SAS statistical package version 6.03 (SAS Institute, Inc., Cary, NC, 1987).

3.4 Study 2: Consumer Acceptability of Pacific Whiting IQF Fillets: Consumer Testing and Focus Group Sessions

3.4.1 Consumer Testing

3.4.1.1 Fish Samples and Preparation

Both "coded" and "uncoded" PAC samples were used in this study. One section of each fillet (section 2) from the ninety coded PAC fillets were used in the consumer testing (Figure 3.2.1). The section was cut into a 3.8 X 3.8 cm (1.5 x 1.5 in) piece, kept frozen at -37°C in a 7.6 X 10.2 cm (3 x 4 in) polyethylene bag.

The eight uncoded fillet species included ARG, CHI, PER, DOV, LIN, POL, ROC, and PAC were also cut into a 3.8 X 3.8 cm piece, and kept frozen at -37°C in a 7.6 X 10.2 cm polyethylene bag until the day of the consumer testing. A separate sample of frozen PAC^y, kept frozen for a year, was also cut and handled as explained above. On those days, the fish were transfered into styrofoam boxes, packed with frozen packs of ice gel, and transported to the testing areas in Salem, OR. The fish pieces were taken off the plastic bags, placed on a plate, and cooked using a microwave oven (GoldStar MA-1172MW: MultiWave, 1.1 Cu. Ft. 1,000 Watts Turntable, GoldStar Co., Ltd. Seoul, Korea) until the internal temperature reached 73°C (i.e., approximately 3 min per nine pieces including 40 sec of defrosting). Serving temperature was approximately 43±2°C. A sample of PAC was served to each consumer along with three other fish samples, so that consumers could indicate responses toward PAC relative to the other species they were testing.

3.4.1.2 Sensory Evaluation Techniques

The consumer testing was designed according to an affective test (i.e., how well a product is liked by consumers). Three measurement methods were employed: (1) a nine-point Hedonic scale, (2) a five-point Just-Right scale, and (3) a five-point Purchase Intent scale.

The consumer testing took place at the Oregon State Fair, Salem, OR in the Summer of 1994 for four consecutive days. The specific testing was at a seafood testing corner inside the exhibit building. The participants were chosen based on their interest and availability. They were asked to fill out a questionnaire on their perceptions and feelings toward the samples they were tasting, and were asked demographic questions. Seven hundred and thirty one consumers were randomly served four samples of fish at one time. Each 3.8 X 3.8 cm whitefish sample were served in a 57 gm plastic cup, coded with a 3-digit random number. In reducing consumer distraction, two portable dividers served as individual booths. Drinking water was provided so the consumers could rinse their mouths between samples.

3.4.1.3 Statistical Method

An incomplete block design was used in the consumer testing. Each participant was treated as a block, without replications. Each consumer was not testing all fish samples. The data received from the consumer testing were analyzed using analysis of variance (ANOVA) and t- test (mean comparisons, using LSD: Least Significant Different as a criteria). Correlation analysis was also employed when investigating the relationships between sensory perception from trained (study 1) and untrained (i.e., consumer) panels (study 2).

3.4.2 Focus Group

3.4.2.1 Procedures and Content of the Sessions

The focus group sessions were conducted for the purpose of qualitative information-gathering. The moderator (i.e., author) guided the nine participants through a discussion of fish and related foods (Krueger, 1988). Three focus group sessions were conducted with the nine participants at the Sensory Science Laboratory, on the OSU campus. Each focus group session lasted about one and a half hours. The session was designed and pilot-tested informally to clarify the discussion probes, sequence of presentation, appropriateness of the support materials, and time needed to conduct the session.

Each participant was paid $15 at the end, for attending the sessions. Pacific whiting IQF fillets were provided to the participants to take home after each session. The participants tested the product at home under normal situations, and used their experiences as a basis for subsequent discussion on related topics during the focus group sessions.

Each session was tape recorded and video recorded for later review and analysis (Goldman and McDonald, 1987). The result of the focus group discussion was summarized and organized from the author's notes during each session, and video/tape transcription.

A number of issues were discussed in each session. However, some were brought up and discussed in other sessions as well, as the discussion progressed and when the topic was related.

The topics discussed were those relevant to consumers' fish consumption and purchasing decisions. Table 3.4.1 lists the content of each focus group session.

3.4.2.2 Participants

All nine participants were female. They were randomly contacted by telephone, and were all residents of the Corvallis, OR area.
The participants were screened for whether they were 25 years of age or older, the primary food shopper for their household, and whether they purchased fish on a regular basis. Table 3.4.2 summarizes the demographic characteristics for the nine participants.

All participants' autobiography was summarized in Appendix A, with their assumed names (i.e., Pam, Kim, Sue, Joy, Pat, Jane, Rose, Claire, and Gail). Group dynamics were excellent and participants were cooperative and very enthusiastic.

3.4.2.3 Hand-on Samples for Discussion

Samples of IQF fish fillets were brought to the focus group during the discussions, and were for participants to prepare and test at home (Table 3.2.1). Meat and scallops were also presented for comparison purposes. Short surveys, asking about their perceptions, were filled out during the take-home product testing, and brought back to discuss in the group sessions. Cooked fish fillets were also provided when issues on flavor, texture, and other characteristics of fish were discussed.

Table 3.4.1 Content and design of the focus group discussions.

Issue	Activity
Session 1: Introduction Consumers' feelings toward fish and other foods	The author talked about the purposes of focus group discussions and what would be expected out of the participants. Participants introduced themselves. The author brought Pacific, Argentinean, Peruvian, and Chilean whitings for discussion initiation. Participants described perceptions on: - frozen IQF fish fillet - fresh IQF fish fillet The author brought raw beef and other seafood (i.e., scallop). Participants discussed and compared fish with beef, and scallops. Participants evaluated Pacific whiting fillets in their homes, prepared and tasted by cooking with a microwave, and by their preferred methods.

Table 3.4.1, continued Content and design of the focus group discussions.

Issue	Activity
Session 2: Characteristics considered desirable and undesirable to consumers regarding fish and Pacific whiting	Demonstration of raw and cooked Pacific and Argentinean whitings. Participants discussed and described desirable and undesirable characteristics of fish. Participants discussed each sensory property of fish (obtained from the trained panel). Participants discussed desirable and undesirable characteristics of Pacific whiting, after tasting it. Participants evaluated Pacific whiting and dover sole fillets in their homes, prepared and tasted by their preferred method, and discussed their perceptions.

Table 3.4.1, continued Content and design of the focus group discussions.

Issue	Activity
Session 3:	
Desirable and undesirable characteristics of fish and Pacific whiting (continued)	Participants continued to discuss desirable/ undesirable characteristics of Pacific whiting and fish in general
Factors affecting consumers' purchasing decision toward fish, and their willingness to try new species of fish	Participants discussed factors affecting their purchasing decisions toward fish, and toward one particular fish over another.
	Participants discussed from their perspectives, their buying behavior and ways to introduce new fish into the market.

Table 3.4.2 Demographic characteristics of the nine focus group participants.

Demographic characteristic		Number of participants
Gender	Female	All 9 persons
Age	25-39	5
	40-54	4
Household size	1	1
	2	2
	3	2
	4	2
	5	2
Family income before taxes	\$20,000- \$40,000	5
	\$40,001- \$60,000	2
	\$60,001- \$80,000	2
Type of seafood normally purchase*	fresh	7
	frozen	5
	canned	3
Frequency of seafood consumption	once/week	4
	twice/month	4
	once/month	1
Frequency of whitefish consumption	twice/month	4
	once/month	4
	less than once/month	1
Seafood purchasing location*	market (seafood, grocery)	7
	fast-food	1
	restaurant	2

Note: * The focus group participants were able to respond to all choices.

Table 3.4.2, continued Demographic characteristics of the nine focus group participants.

Demographic characteristic		Number of participants
Type of whitefish usually purchased*	Halibut	5
	Cod	4
	Rockfish	4
	Pollock	3
	Sole	2
	Red snapper	1
	Orange Roughy	1
Maximum price they will pay for whitefish	Less than $ 2.50 /lb	1
	$ 2.50-2.75 /lb	3
	$ 4.00 /lb	4
	$ 7.00 /lb	1
Range of price they usually pay for whitefish	$2.00-3.00 /lb	8
	$4.00-5.00 /lb	1

Note: * The focus group participants were able to respond to all choices.

3.5 Study 3: Correlation of Sensory Texture Properties of Pacific Whiting IQF Fillets Resulting from a Descriptive Analysis with Biochemical and Instrumental Analyses

3.5.1 Samples and Preparation

The last section (section 3) of the 90 coded PAC fillet samples (Figure 3.2.1) were used for the following studies: (1) biochemical analysis of protease activity and (2) texture instrumental analysis. Ninety uncoded ARG, CHI, and PER fillets were also used in the biochemical analysis. For texture instrumental analysis, seven other fish species were selected at random and analyzed (n=12). Two replicates were performed for each fish fillet. All of these samples were stored in individually labelled polyethylene bags (7.6 X 10.2 cm (3 x 4 in), 2 mil), and kept frozen at -37°C until tested.

3.5.2 Protease Biochemical Assay

Protease activity was quantified using an autolysis assay (Makinodan et al.,1985 and Wasson et al., 1992). A sample of three grams was incubated at 55°C in a waterbath (Polytherm Science/ Electronics, Inc., Dayton, OH) for 30 minutes to induce autolysis. Three grams of the control were not incubated, but kept on ice in a cold room (4°C) at all times. Enzymatic reaction was stopped by adding 27 ml of cold 5% trichloroacetic acid (TCA) solution (Baker Analyzed®, J.T. Baker Inc., Philipsburg, NJ). After blending with a homogenizer (Polytron®, Brinkmann Instruments, Westbury, NY), unhydrolyzed proteins were allowed to precipitate for 15-20 minutes at 4°C and centrifuged (Sorvall®, RC-5B refrigerated superspeed centrifuge, Du Pont Instruments Co., Newtown, CT) at 8,300 xg for 15 minutes. The TCA-precipitated proteins were recovered in the supernatant. The hydrolyzed oligopeptide content in the supernatant was determined by the Lowry assay at 750 nm (DU Spectrophotometer Series 600, Beckman Instruments, Inc., Redmond, WA), under visible light (Lowry, 1957). The activity of the protease was expressed as millimoles (per 30 minutes) of tyrosine released from proteins in three-gram samples.

3.5.3 Texture Instrumental Analysis

Four 1.3 X 1.3 cm (0.5 x 0.5 in) pieces were needed from each coded PAC fillet (two pieces for a microwave oven and two pieces for a conventional oven). In this analysis, compression force was used to mainly determine sample's instrumental hardness, and was chosen to imitate the way the trained panel evaluated sensory hardness of fish, in the previous study. PAC samples, cooked with rapid (microwave oven) and slow (conventional oven) methods, were tested for hardness1, hardness2, chewiness, and cohesiveness using double-cycle compression of 80% compressive force (travel distance was 8/10 of the original thickness). The height of the force peak on the first compression cycle (first bite) was hardness1 while the second compression cycle (second bite) hardness2. The ratio of the positive force areas under the first and second compressions (A_2/A_1) was cohesiveness (Figure 3.5.1). The other parameter, chewiness, was the product of hardness X cohesiveness X springiness (the distance that the food recovered its height during the

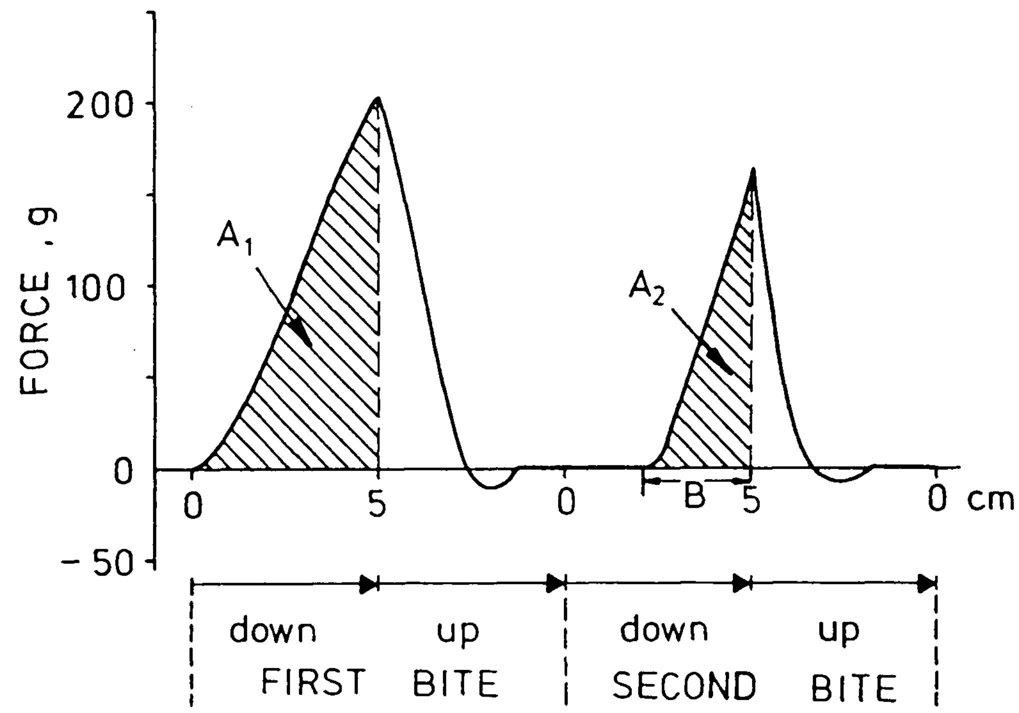


Figure 3.5.1 Texture profile analysis. A_1/A_2 = cohesiveness (dimensionless), B = springiness (cm) (Bourne, 1982).

time that elapsed between the end of the first bite and the start of the second bite). The resulting force-time curve was analyzed using Instrumental Texture Profile Analysis (TPA) attributes of Hardness1, Area1, Hardness2, Area2, and springiness (Bourne, 1982). Based on a preliminary study, a compressive force at 80% provided the greatest distance, and the least destruction to the fish flesh. The main characteristic of interest was the instrumental hardness values (cycle1 and 2). Testing speed of the load cell (100 lb) was 10 cm/min.
The testing was performed using a MTS Sintech machine (SINTECH 1/G, MTS Sintech, Inc., Research Triangle Park, NC) based on the Test Works: Advanced Software for Materials Testing, version 2.1 (MTS Sintech, Inc., Research Triangle Park, NC). The seven other fish were analyzed using the same conditions above.

3.5.4 Statistical Analysis

A completely randomized design, with multivariate observations in one fillet, was used in this study. All ninety coded PAC fillets were evaluated and data were collected on their sensory texture (study 1), instrumental texture (study 3), amount of protease activity (study 3), and consumer perceptions (study 2). The ANOVA was performed on a biochemical analysis of the four whitings (PAC, ARG, CHI, and PER) and an instrumental texture analysis of all eight fish species, along with the PCA using SAS statistical package version 6.03 (SAS Institute, Inc., Cary, NC, 1987). Data correlations were analyzed between the amount of protease activity in PAC and (1) sensory textural attribute scores obtained from the trained panel and (2) instrumental texture values

obtained from the Sintech machine. Correlations between sensory texture scores and instrumental texture values of PAC were also investigated. The correlation coefficient is a measure of the closeness of the relationship between two variables, and always falls between -1 and +1. A positive correlation indicates that the variables vary in the same direction, while a negative correlation indicates that the variables vary in the opposite direction. Stepwise regression under "Regression Models" in Statgraphic version 7.0 was used to obtain the best fitted model for both sensory/instrumental texture characteristics and the amount of protease activity. The stepwise variable selection procedure adds variables to a model (forward selection) one at a time. The selected models were chosen with the largest adjusted R^2.
These correlations and regressions were determined using Statgraphic version 7.0 (Statgraphics Statistical Graphics System, 1988).
The statistical analysis was performed for the overall trained panel.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Study 1: Sensory Characteristics of Pacific Whiting and Other Commercial Whitings and Whitefish

4.1.1 Sensory Profiles of Pacific Whiting Compared with Other Fish

The analysis of variance on each appearance and aroma characteristic showed significant differences across the species of fish (Table 4.1.1). Replication effects were not significant for any characteristics which indicated that the panelists were well trained and were reproducible in their results (Table 4.1.1). The panelist effect was significant for all characteristics except flake size. This was not unusual, as it reflects the differences in panelists' usage of a range of the intensity scale (Power, 1988).

4.1.1.1 Appearance

Table 4.1.2 shows means and standard deviations of appearance and aroma descriptive analysis result. The color intensity of PAC was rated medium to medium dark (6.0), similar to CHI (6.3) and ROC (6.1). PER scored the darkest in color intensity (7.8), while DOV scored the lightest (2.3). Flake size of each species was compared to the measured standards: Flake size of PAC was similar to CHI, DOV, and POL.
The results showed ROC as having the largest flake size (5.2).
Among all fish studied (i.e., DOV, ROC, POL, LIN, PER, CHI, ARG, and PAC), PAC had a medium flake size (3.4) and PER had the smallest flake size (2.8).

Table 4.1.1 ANOVA Table and significance level for appearance and aroma characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Sources of Variation	Appearance		Aroma				
	Color intensity	Size of flakes	Fresh fish	Fishy	Ocean	Nutty	Buttery
Treatment (Trt)	***	***	*	***	***	***	***
Panelist (Pan)	**	ns	*	**	***	*	**
Replication (Rep)	ns	ns	ns	ns	ns	ns	ns
Pan * trt	***	ns	***	***	***	***	***
Trt * rep	ns	ns	ns	ns	ns	ns	ns
Pan * rep	**	ns	ns	ns	ns	ns	ns

Note : "ns" refers to not significant.
: *, **, *** refer to significance at $p \leq 0.05$, 0.01, and 0.001, respectively.

Table 4.1.2 Means and SD (standard deviations) for appearance and aroma characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Appearance		Aroma				
	Color	Flake Size	Fresh Fish	Fishy	Ocean	Nutty	Buttery
Pacific (PAC)	6.0^{d} (1.7)	3.4^{bc} (1.6)	4.3^{abc} (1.8)	3.9^{bc} (2.2)	3.8^{bc} (1.8)	2.7^{bcd} (1.6)	2.6^{bc} (1.5)
Peruvian (PER)	7.8^{e} (1.5)	2.8^{a} (0.9)	4.0^{ab} (2.2)	5.7^{d} (2.1)	4.6^{c} (1.8)	3.1^{cde} (2.1)	1.1^{a} (0.2)
Argentinean (ARG)	7.1^{e} (1.7)	4.2^{d} (1.5)	4.2^{abc} (2.0)	4.3^{c} (2.2)	3.8^{bc} (2.2)	3.7^{e} (2.2)	3.5^{d} (2.2)
Chilean (CHI)	6.3^{d} (1.9)	3.8^{cd} (1.5)	4.8^{bc} (1.8)	3.5^{abc} (2.2)	3.3^{b} (1.7)	2.0^{ab} (1.3)	2.0^{b} (1.7)
Dover sole (DOV)	2.3^{a} (1.2)	2.9^{ab} (1.3)	4.9^{bc} (2.5)	2.6^{a} (1.8)	2.4^{a} (1.3)	3.2^{de} (2.1)	3.8^{d} (2.3)
Ling cod (LIN)	3.4^{b} (1.6)	4.3^{d} (1.7)	5.1^{c} (2.3)	3.0^{ab} (2.2)	3.6^{b} (2.3)	2.3^{bc} (1.9)	3.1^{cd} (1.8)
Pollock (POL)	5.0^{c} (1.7)	3.8^{cd} (1.4)	4.1^{ab} (2.1)	3.2^{ab} (1.9)	3.0^{ab} (1.9)	1.3^{a} (0.8)	2.2^{b} (1.6)
Rockfish (ROC)	6.1^{d} (1.6)	5.2^{e} (1.4)	3.6^{a} (2.0)	4.5^{c} (2.4)	3.1^{ab} (1.8)	2.2^{b} (1.6)	2.4^{bc} (1.5)
Significance Level	***	***	*	***	***	***	***
LSD	0.76	0.67	0.98	0.99	0.87	0.81	0.79

Note : Means with different letters within a column denote a statistically significant difference ($p \leq 0.05$)
: Significance level, * and ***, refer to significance at $p \leq 0.05$ and 0.001, respectively.
: LSD refers to "Least Significant Difference", a criterion serving as a mean separator for a multiple comparison (Petersen, 1985).
: Intensity scale values range from one to nine, where one equals to the lightest, the least, the smallest and nine equals to the darkest, biggest, or greatest.

4.1.1.2 Aroma

PAC fresh fish aroma was moderate (4.3), similar to the other fish species. Yet, a slight to moderate level (3.9) of fishy aroma was detected in PAC by the trained panelists. The species with the slightest fishy aroma was DOV (2.6), while the greatest was PER (5.7). The ocean, nutty, and buttery aromas of PAC were not significantly different ($p > 0.05$) from most of the commercial species.

The appearance and aroma profiles of PAC, as compared with other whitings and whitefish, are shown (Fig. 4.1.1a and 4.1.1b) using a spider web plot (Stone et al., 1974). This spider web plot visually portrays species with their appearance and aroma characteristics: Each axis represents an individual characteristic. The center of the graph represents no perceived intensity, while the distance away from the center represents an increase in intensity.

The Principal Component Analysis (PCA) model for aroma characteristics (Table 4.1.3) suggested that only the first two principal components (PC), PC1 and PC2, were significant and explained 47.6% and 27.3% of the total variation, respectively. It is reasonable to select attributes that have weightings (loading coefficients) greater than 0.30 or less than -0.30 (Thompson and McEwan, 1988). The loadings provide a weighting for each attribute on a principal axis and are useful in deciding which attributes are important in differentiating the samples.

The aroma loadings for PC1 indicated that the buttery and fresh fish aromas were negatively correlated with fishy, ocean, and nutty aroma characteristics. In PC2, nutty and buttery were positively correlated and there were no negatively correlated characteristics. Figure 4.1.2 shows the principal plot resulting from the PCA.

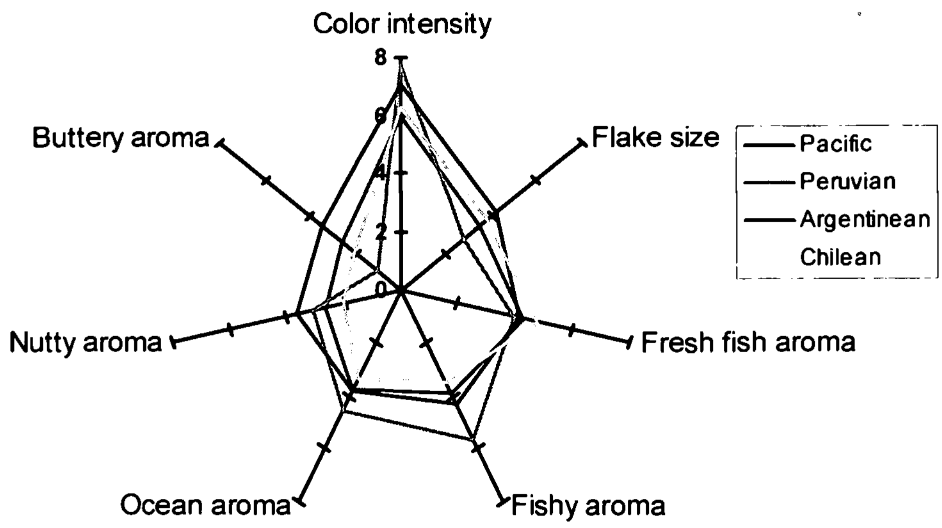


Figure 4.1.1a Appearance and aroma characteristics of Pacific whiting and three other whitings.

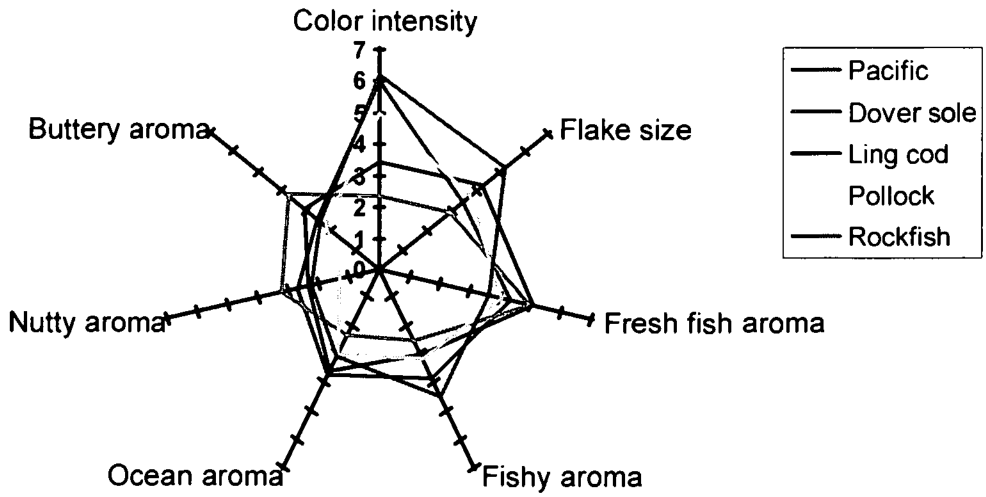


Figure 4.1.1b Appearance and aroma characteristics of Pacific whiting and four other whitefish.

Table 4.1.3 Principal component analysis for each aroma characteristic of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Aroma characteristic	Eigenvector	
	Principal Component 1	Principal Component 2
Fresh fish	-0.389	0.179
Fishy	0.601	0.112
Ocean	0.512	0.231
Nutty	0.152	0.791
Buttery	-0.450	0.525
Eigenvalue	2.38	1.37
Proportion (%)	47.64	27.30
Cumulative (%)	47.64	74.94
Characterizing attribute(s)		
Loading (+)	Fishy and ocean	Nutty and buttery
Loading (-)	Buttery and fresh fish	

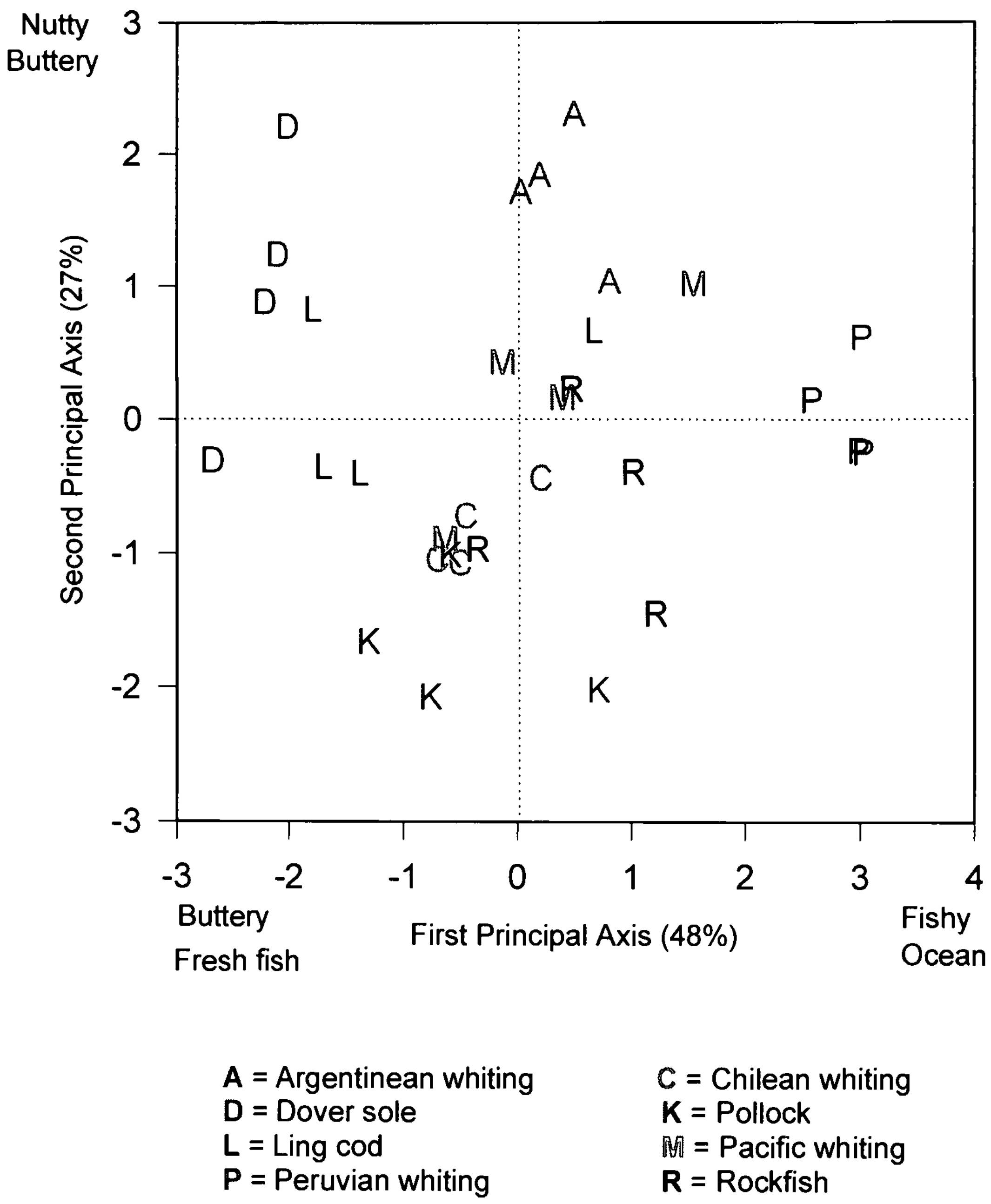


Figure 4.1.2 Principal component analysis: principal axes 1 vs 2 of aroma characteristics of eight fish species. Four points of a letter represent four replications across nine trained panelists. The data analyzed are from the sensory trained panel (Test1).

Table 4.1.4 presents means of PC1 and PC2 for aroma characteristics. On PC1, PER was separated significantly high ($p \leq 0.05$) from the other fish based on fishy and ocean aroma (Fig. 4.1.2), whereas DOV mean was located on the negative end of PC1 indicating that DOV was rated significantly higher ($p \leq 0.05$) in buttery and fresh fish aroma.
Both PER and DOV were clearly separated from the rest. For PC1, PAC was on the positive axis but not significantly different from POL, CHI, ARG, and ROC. POL and ARG were the sole member of the first and third group of PC2, respectively, while the six other species were the mixtures of the second group.

4.1.1.3 Flavor

The univariate analysis of variance for each flavor characteristic (Table 4.1.5) showed significant differences among the fish species. The experiment had a favorable reproducibility, as indicated by the non-significant replication effect. The overall flavor intensity of PAC (4.8) was significantly ($p \leq 0.05$) less intense than PER, ARG, LIN, and ROC (Table 4.1.6). However, the flavor intensity of PAC was not significantly different from CHI, DOV, and POL. PAC's fresh fish flavor was moderate (4.5), and similar to most commercial fish (mean range = 3.0-5.8).
PER had the lowest level of fresh fish flavor (3.0), but highest (5.4) in fishy flavor as shown in Fig. 4.1.3a. Contrary to the PER results, DOV had the highest level of fresh fish flavor and the lowest in fishy flavor (Fig. 4.1.3b). The sweetness, saltiness, nutty, and buttery flavors of PAC were not different from the majority of fish. Bitterness of PER was rated significantly higher ($p \leq 0.05$) than the other fish. Shellfish flavor of PAC

Table 4.1.4 Principal component (PC) axis 1 and 2: mean values for aroma characteristics of Pacific whiting and seven other whitings and whitefish.

Species	PC1 Means	Species	PC2 Means
Dover sole	- 2.261 ^{a}	Pollock	- 1.692 ^{a}
Lingcod	- 1.049 ^{b}	Chilean whiting	- 0.818 ^{ab}
Pollock	- 0.491 ^{bc}	Rockfish	- 0.649 ^{bc}
Chilean whiting	- 0.365 ^{bcd}	Peruvian whiting	0.068 ^{bcd}
Pacific whiting	0.295 ^{cd}	Pacific whiting	0.178 ^{cd}
Argentinean whiting	0.386 ^{cd}	Lingcod	0.186 ^{cd}
Rockfish	0.586 ^{d}	Dover sole	1.004 ^{de}
Peruvian whiting	2.898 ^{e}	Argentinean whiting	1.723 ^{e}
LSD	1.014		0.957
Significance Level	0.000		0.000

Table 4.1.5 ANOVA Table and significance level for flavor characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Sources of Variation	Flavor								
	Overall	Fresh fish	Fishy	Shellfish	Nutty	Buttery	Sweet	Salty	Bitter
Treatment (Trt)	***	***	***	**	***	***	***	***	***
Panelist (Pan)	***	ns	**	***	ns	***	**	***	ns
Replication (Rep)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Pan * trt	**	**	**	***	***	***	***	***	***
Trt * rep	*	ns	ns	ns	ns	ns	ns	ns	ns
Pan * rep	ns	ns	ns	ns	ns	**	*	ns	*

Note : "ns" refers to not significant.
: *, **, *** refer to significance at $p \leq 0.05$, 0.01, and 0.001, respectively.

Table 4.1.6 Means and SD (standard deviations) for flavor characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Overall	Fresh Fish	Fishy	Shellfish
Pacific (PAC)	4.8^{ab} (1.9)	4.5^{bc} (1.7)	3.3^{bc} (2.1)	3.4^{c} (2.1)
Peruvian (PER)	6.4^{c} (2.2)	3.0^{a} (1.5)	5.4^{d} (1.9)	2.9^{abc} (1.9)
Argentinean (ARG)	5.9^{c} (1.7)	4.7^{bc} (1.7)	3.3^{bc} (1.9)	3.3^{bc} (2.2)
Chilean (CHI)	5.0^{b} (1.7)	5.1^{cd} (2.1)	2.8^{b} (2.5)	2.6^{abc} (1.9)
Dover sole (DOV)	4.7^{ab} (2.3)	5.8^{d} (1.8)	1.8^{a} (0.9)	2.6^{abc} (1.7)
Ling cod (LIN)	6.1^{c} (1.6)	4.6^{bc} (1.9)	2.9^{b} (1.8)	2.3^{a} (1.5)
Pollock (POL)	4.1^{a} (1.4)	3.6^{ab} (2.3)	2.6^{ab} (1.6)	2.3^{a} (2.1)
Rockfish (ROC)	6.1^{c} (1.7)	3.9^{ab} (2.1)	4.0^{c} (2.3)	2.5^{ab} (1.4)
Significant Level	***	***	***	*
LSD	0.86	1.10	0.89	0.84

Note : Means with different letters within a column denote a statistically significant difference ($p \le 0.05$)
: Significance level, * and ***, refer to significance at $p \le 0.05$ and 0.001, respectively.
: LSD refers to "Least Significant Difference", a criterion serving as a mean separator for a multiple comparison (Petersen, 1985).
: Intensity scale values range from one to nine, where one equals to the least or the smallest and nine equals to the biggest or greatest.

Table 4.1.6, continued Means and (standard deviations) for flavor characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Nutty	Buttery	Sweet	Salty	Bitter
Pacific (PAC)	3.1^{bc} (1.9)	3.2^{cd} (2.0)	3.1^{bc} (1.7)	2.6^{ab} (1.4)	1.9^{abc} (1.0)
Peruvian (PER)	3.4^{c} (1.8)	1.0^{a} (0.0)	1.9^{a} (1.5)	3.3^{b} (1.8)	3.3^{d} (1.9)
Argentinean (ARG)	3.9^{c} (2.1)	3.9^{de} (2.0)	3.2^{c} (1.8)	2.8^{ab} (1.5)	2.1^{bc} (1.2)
Chilean (CHI)	1.9^{a} (1.2)	1.9^{b} (1.4)	2.9^{bc} (1.4)	2.6^{ab} (1.6)	1.4^{a} (0.8)
Dover sole (DOV)	3.6^{c} (2.5)	4.3^{e} (2.7)	3.2^{c} (1.8)	2.1^{a} (1.1)	1.8^{abc} (0.9)
Ling cod (LIN)	2.4^{ab} (2.0)	2.8^{bc} (2.0)	2.3^{ab} (1.5)	3.3^{b} (1.9)	2.3^{c} (1.3)
Pollock (POL)	1.6^{a} (1.1)	1.9^{b} (1.7)	2.5^{abc} (1.7)	2.4^{a} (1.9)	1.6^{ab} (1.0)
Rockfish (ROC)	2.4^{ab} (2.1)	3.1^{cd} (2.1)	2.9^{bc} (1.8)	2.3^{a} (1.5)	1.6^{ab} (1.1)
Significant Level	***	***	***	*	***
LSD	0.88	0.88	0.77	0.75	0.55

Note : Means with different letters within a column denote a statistically significant difference ($p \leq 0.05$)
: Significance level, * and ***, refer to significance at $p \leq 0.05$ and 0.001, respectively.
: LSD refers to "Least Significant Difference", a criterion serving as a mean separator for a multiple comparison (Petersen, 1985).
: Intensity scale values range from one to nine, where one equals to the least or the smallest and nine equals to the biggest or greatest.

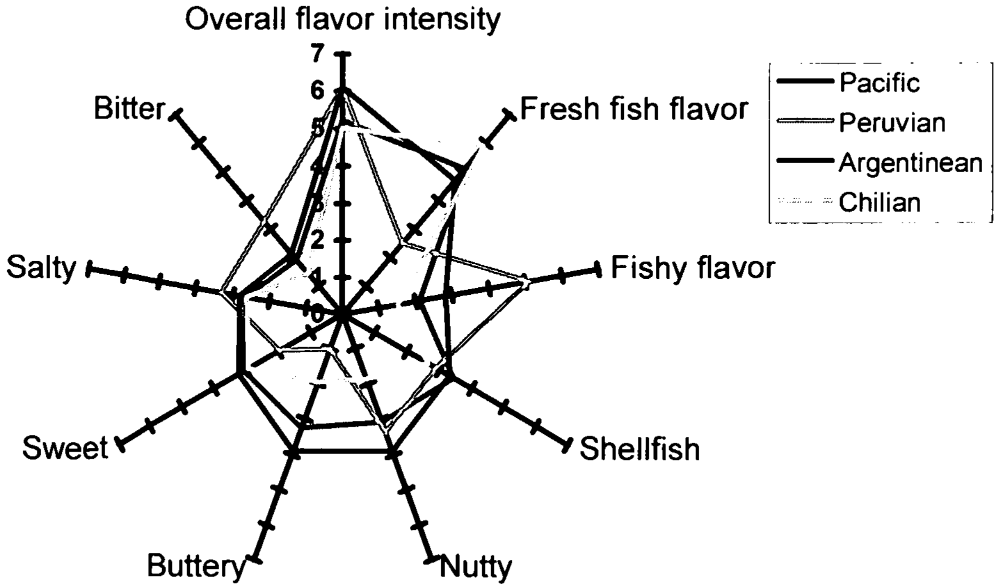


Figure 4.1.3a Flavor characteristics of Pacific whiting and three other whitings.

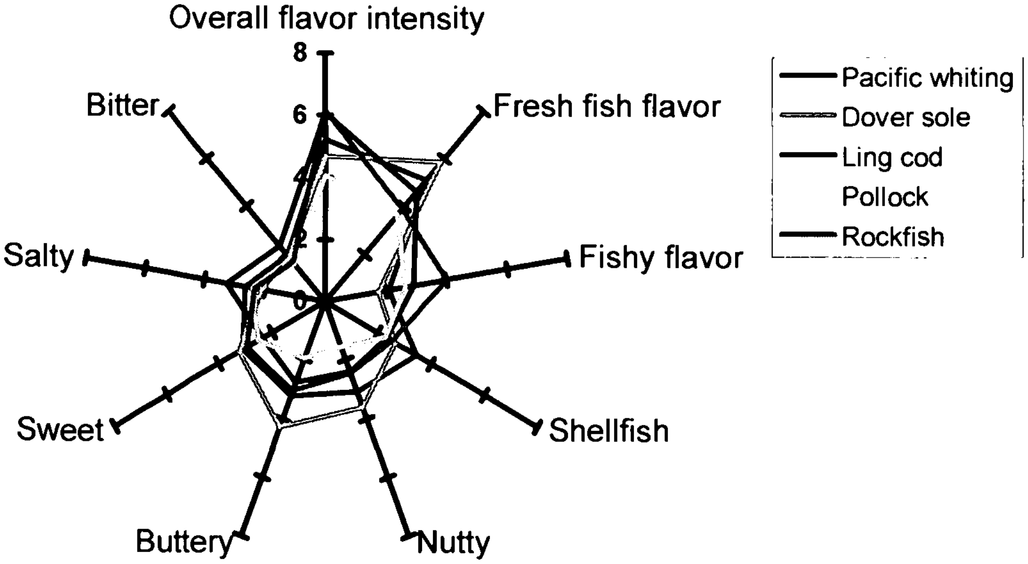


Figure 4.1.3b Flavor characteristics of Pacific whiting and four other whitefish.

scored the highest (3.4) but was not significantly different from other species.

The PCA model for flavor characteristics is presented in Table 4.1.7. Only the first two principal components (PC1 and PC2) were significant and explained 40.4% and 22.2% of the variance, respectively. The descriptor combinations that characterize flavor for the first two principal axes are provided (Table 4.1.7). For example, the first principal axis has positive loadings for fishy flavor, bitterness, saltiness, and overall flavor intensity. PC2 was weighted in nutty, shellfish, buttery flavors, and bitterness on positive axis. Figure 4.1.4 presents the PCA plot, while Table 4.1.8 shows the means of PC1 and PC2 for flavor characteristics of all eight fish species. There were basically three major groupings of fish on PC1, with DOV as the sole member of the first group, then PAC, CHI, ARG, POL, ROC (leaning toward both negative and positive axis) and LIN as the second group. PER was clearly separated from the rest as the third group having high fishy flavor, bitter and salty tastes, and overall flavor intensity. In PC2, POL was clearly separated from the rest even though this fish was not significantly different from CHI. ARG was located on the positive axis having high nutty and shellfish flavor, but this fish was not significantly different from PAC and PER.

4.1.1.4 Texture

The analysis of variance on texture characteristics showed significant differences among species of fish (Table 4.1.9). Replication effects were not significant for most characteristics, except for hardness and mouthcoating, indicating a favorable reproducibility. The oral

Table 4.1.7 Principal component analysis for each flavor characteristic of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Flavor characteristic	Eigenvector	
	Principal Component 1	Principal Component 2
Overall flavor intensity	0.334	0.204
Fresh fish	-0.404	0.039
Fishy	0.417	0.212
Shellfish	-0.051	0.434
Nutty	-0.029	0.614
Buttery	-0.386	0.354
Sweet	-0.361	0.261
Salty	0.365	0.034
Bitter	0.368	0.327
Eigenvalue	3.64	1.99
Proportion (%)	40.39	22.15
Cumulative (%)	40.39	62.54
Characterizing attribute(s)		
Loading (+)	Fishy flavor, bitterness, saltiness, and overall flavor intensity	Nutty flavor, shellfish flavor, buttery flavor, and bitterness
Loading (-)	Fresh fish flavor, buttery flavor, and sweetness	

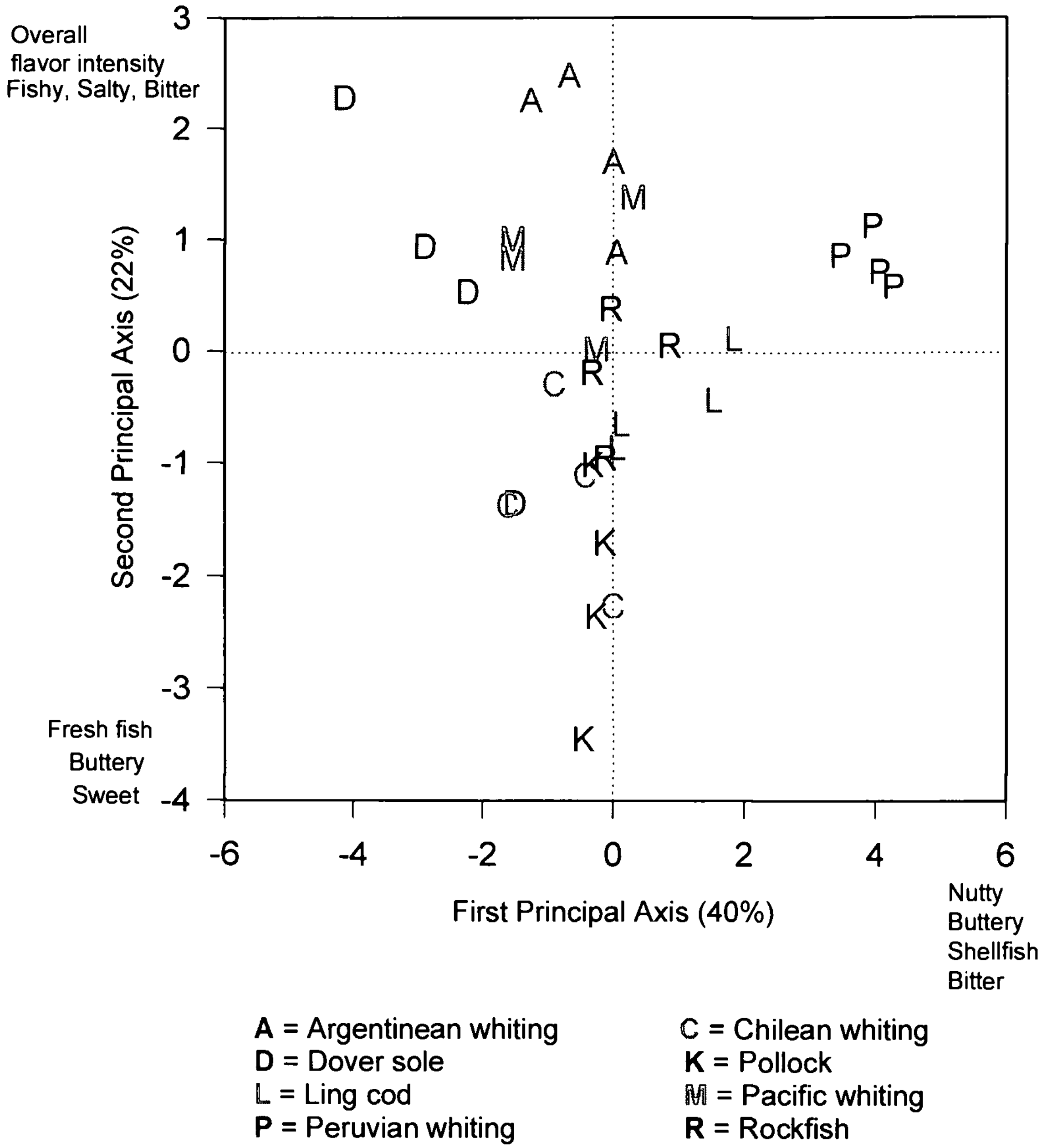


Figure 4.1.4 Principal component analysis: principal axes 1 vs 2 of flavor characteristics of eight fish species. Four points of a letter represent four replications across nine trained panelists. The data analyzed are from the sensory trained panel (Test1).

Table 4.1.8 Principal component (PC) axis 1 and 2: mean values for flavor characteristics of Pacific whiting and seven other whitings and whitefish.

Species	PC1 Means	Species	PC2 Means
Dover sole	- 2.692 [a]	Pollock	- 2.135 [a]
Pacific whiting	- 0.748 [b]	Chilean whiting	- 1.264 [ab]
Chilean whiting	- 0.736 [b]	Lingcod	- 0.463 [bc]
Argentinean whiting	- 0.459 [b]	Rockfish	- 0.181 [bcd]
Pollock	- 0.296 [b]	Dover sole	0.597 [cd]
Rockfish	0.100 [bc]	Pacific whiting	0.806 [de]
Lingcod	0.890 [c]	Peruvian whiting	0.812 [de]
Peruvian whiting	3.941 [d]	Argentinean whiting	1.828 [e]
LSD	1.065		1.198
Significance Level	0.000		0.000

Table 4.1.9 ANOVA Table and significance level for texture characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Sources of Variation	Texture							
	Flakiness	Size of flakes	Hardness	Mushiness	Moistness	Toothstickiness	Chewiness	Mouth coating
Treatment (Trt)	***	*	***	***	**	**	***	***
Panelist (Pan)	**	*	***	*	ns	*	**	ns
Replication (Rep)	ns	ns	**	ns	ns	ns	ns	*
Pan * trt	ns	ns	*	***	*	**	**	**
Trt * rep	ns	ns	*	*	ns	ns	ns	ns
Pan * rep	ns	ns	*	*	ns	ns	ns	ns

Note : "ns" refers to not significant.
: *, **, *** refer to significance at $p \leq 0.05$, 0.01, and 0.001, respectively.

texture rating for PAC flake size was the smallest and significantly different from the other fish (Table 4.1.10). Similar results for flakiness were found in PAC, LIN, DOV, and PER, while CHI and ARG were rated first and second, respectively. Hardness of PAC was not significantly different from CHI. PAC's mushiness and moistness scores were rated the highest of all species with DOV having the second highest. PAC was also rated high in toothstickiness and mouthcoating, possibly due to its high mushiness. Yet, PAC's toothstickiness and mouthcoating scores were not significantly different from most of the other fish studied. PAC had the lowest chewiness, similar to CHI and DOV. The spider web plot for the texture profile is shown in Fig. 4.1.5a and 4.1.5b.

The PCA model of texture characteristics (Table 4.1.11) showed that only PC1 and PC2 were significant, explaining 42.7% and 27.9% of total variation, respectively. The loading of texture characteristics for PC1 indicated that hardness, chewiness, size of flakes in mouth, and flakiness were negatively correlated with mushiness, moistness, toothstickiness, and mouthcoating characteristics. In PC2, flakiness, moistness, and size of flakes in mouth were negatively correlated with mouthcoating, toothstickiness, chewiness, hardness, and mushiness. Characterizing descriptors in PC1 were hardness, chewiness, and size of flakes in mouth (positive loading), and mushiness and moistness (negative loading). Table 4.1.12 and Figure 4.1.6 show the PCA means and plot from PCA analysis, respectively. For PC1, three major groupings were formed: PAC was a sole member of the first group, being high in mushiness and moistness, while DOV, CHI, POL, LIN, ARG, and PER comprised the second group. ROC (the third group) was harder and more chewy than the rest but not significantly different from PER and

Table 4.1.10 Means and SD (standard deviations) for texture characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Flakiness	Size of flakes in mouth	Hardness	Mushiness
Pacific (PAC)	4.3^{a} (2.1)	2.9^{a} (1.9)	3.0^{a} (1.5)	5.1^{c} (2.7)
Peruvian (PER)	4.9^{ab} (2.6)	4.4^{e} (1.9)	6.1^{d} (2.1)	2.8^{b} (2.3)
Argentinean (ARG)	6.2^{c} (2.0)	5.6^{g} (2.2)	5.1^{c} (1.7)	2.9^{b} (1.9)
Chilean (CHI)	6.8^{c} (1.8)	4.3^{de} (1.7)	3.7^{ab} (1.7)	3.1^{b} (2.2)
Dover sole (DOV)	4.9^{ab} (2.3)	4.1^{d} (2.0)	3.9^{b} (2.5)	4.2^{c} (2.6)
Ling cod (LIN)	4.6^{a} (2.6)	3.4^{b} (2.1)	5.0^{c} (2.1)	3.0^{b} (2.3)
Pollock (POL)	5.8^{bc} (2.0)	3.7^{c} (2.1)	4.0^{b} (1.9)	2.5^{ab} (1.7)
Rockfish (ROC)	5.8^{bc} (2.0)	4.7^{f} (2.2)	6.7^{d} (1.4)	1.7^{a} (1.3)
Significant Level	***	***	***	***
LSD	1.01	0.21	0.87	1.00

Note : Means with different letters within a column denote a statistically significant difference ($p \leq 0.05$)
: Significance level, * and ***, refer to significance at $p \leq 0.05$ and 0.001, respectively.
: LSD refers to "Least Significant Difference", a criterion serving as a mean separator for a multiple comparison (Petersen, 1985).
: Intensity scale values range from one to nine, where one equals to the least or the smallest and nine equals to the biggest or greatest.

Table 4.1.10, continued Means and SD (standard deviations) for texture characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Moistness		Toothstickiness		Chewiness		Mouthcoating	
Pacific (PAC)	6.1^{d}	(2.4)	4.6^{c}	(2.38)	3.6^{a}	(1.6)	5.6^{d}	(2.2)
Peruvian (PER)	4.7^{ab}	(1.6)	3.5^{ab}	(1.30)	6.7^{c}	(1.8)	4.8^{bcd}	(1.6)
Argentinean (ARG)	5.5^{bcd}	(1.3)	3.4^{ab}	(1.18)	4.7^{b}	(1.5)	4.0^{ab}	(1.8)
Chilean (CHI)	5.9^{cd}	(1.4)	2.9^{a}	(1.37)	4.2^{ab}	(1.8)	3.7^{a}	(1.7)
Dover sole (DOV)	6.1^{d}	(2.3)	4.7^{c}	(1.83)	4.3^{ab}	(2.3)	5.2^{cd}	(2.1)
Ling cod (LIN)	4.9^{abc}	(2.1)	4.4^{bc}	(1.93)	5.9^{c}	(2.2)	4.8^{bcd}	(2.1)
Pollock (POL)	5.4^{abcd}	(2.3)	4.3^{bc}	(1.98)	4.8^{b}	(1.9)	4.5^{abc}	(1.7)
Rockfish (ROC)	4.3^{a}	(1.3)	4.1^{bc}	(1.76)	6.0^{c}	(1.6)	5.1^{cd}	(1.5)
Significant Level	***		***		***		***	
LSD	1.17		1.06		0.87		0.86	

Note : Means with different letters within a column denote a statistically significant difference ($p \le 0.05$)
: Significance level, * and ***, refer to significance at $p \le 0.05$ and 0.001, respectively.
: LSD refers to "Least Significant Difference", a criterion serving as a mean separator for a multiple comparison (Petersen, 1985).
: Intensity scale values range from one to nine, where one equals to the least or the smallest and nine equals to the biggest or greatest.

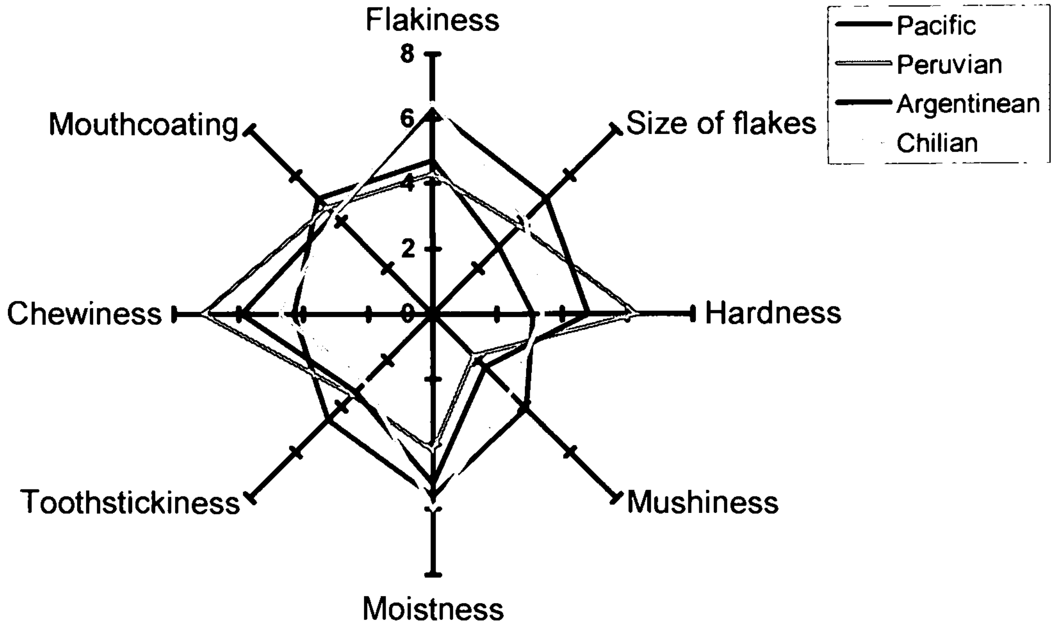


Figure 4.1.5a Texture characteristics of Pacific whiting and three other whitings.

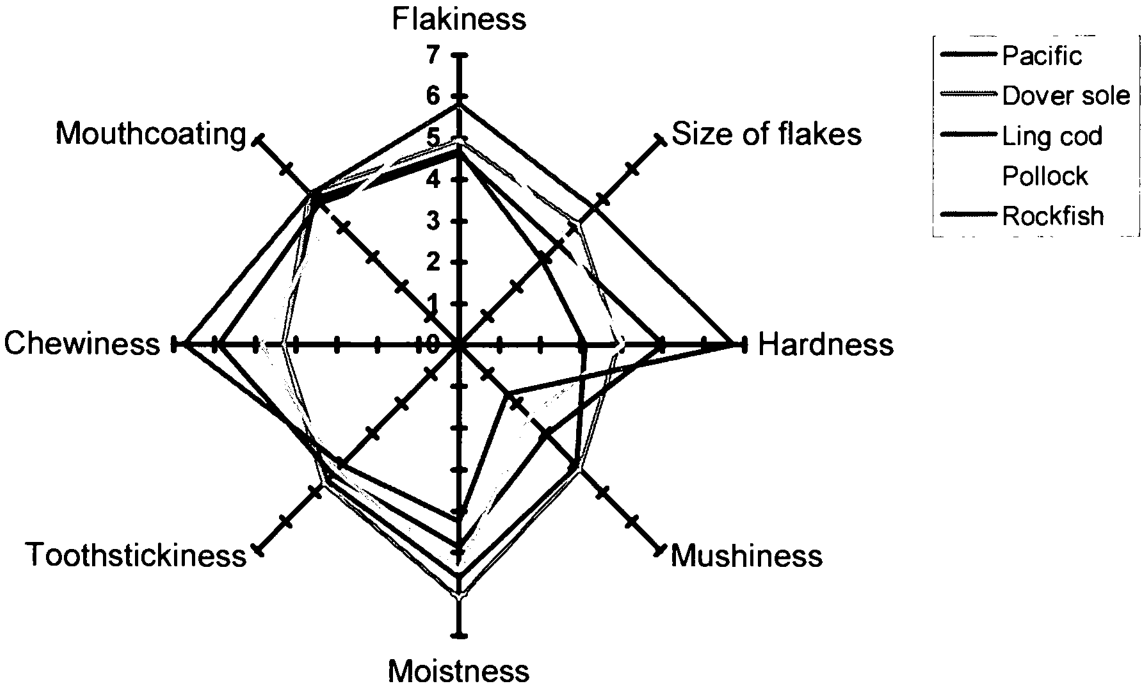


Figure 4.1.5b Texture characteristics of Pacific whiting and four other whitefish.

Table 4.1.11 Principal component analysis for each texture characteristic of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Sensory Texture characteristic	Eigenvector	
	Principal Component 1	Principal Component 2
Flakiness	0.137	-0.551
Size of flakes	0.353	-0.081
Hardness	0.482	0.164
Mushiness	-0.461	0.094
Moistness	-0.400	-0.273
Toothstickiness	-0.170	0.490
Chewiness	0.456	0.238
Mouthcoating	-0.123	0.532
Eigenvalue	3.41	2.23
Proportion (%)	42.68	27.87
Cumulative (%)	42.68	70.55
Characterizing attribute(s)		
Loading (+)	Hardness, chewiness, and size of flakes in mouth	Mouthcoating and toothstickiness
Loading (-)	Mushiness and moistness	Flakiness

Table 4.1.12 Principal component (PC) axis 1 and 2: mean values for texture characteristics of Pacific whiting and seven other whitings and whitefish.

Species	PC1 Means	Species	PC2 Means
Pacific whiting	- 3.030 ^{a}	Chilean whiting	- 2.515 ^{a}
Dover sole	- 1.462 ^{b}	Argentinean whiting	- 1.443 ^{ab}
Chilean whiting	- 0.304 ^{bc}	Pollock	- 0.342 ^{bc}
Pollock	- 0.236 ^{bc}	Peruvian whiting	0.683 ^{cd}
Lingcod	0.219 ^{cd}	Rockfish	0.712 ^{cd}
Argentinean whiting	0.885 ^{cde}	Dover sole	0.747 ^{cd}
Peruvian whiting	1.656 ^{de}	Pacific whiting	0.977 ^{d}
Rockfish	2.273 ^{e}	Lingcod	1.181 ^{d}
LSD	1.490		1.316
Significance Level	0.000		0.000

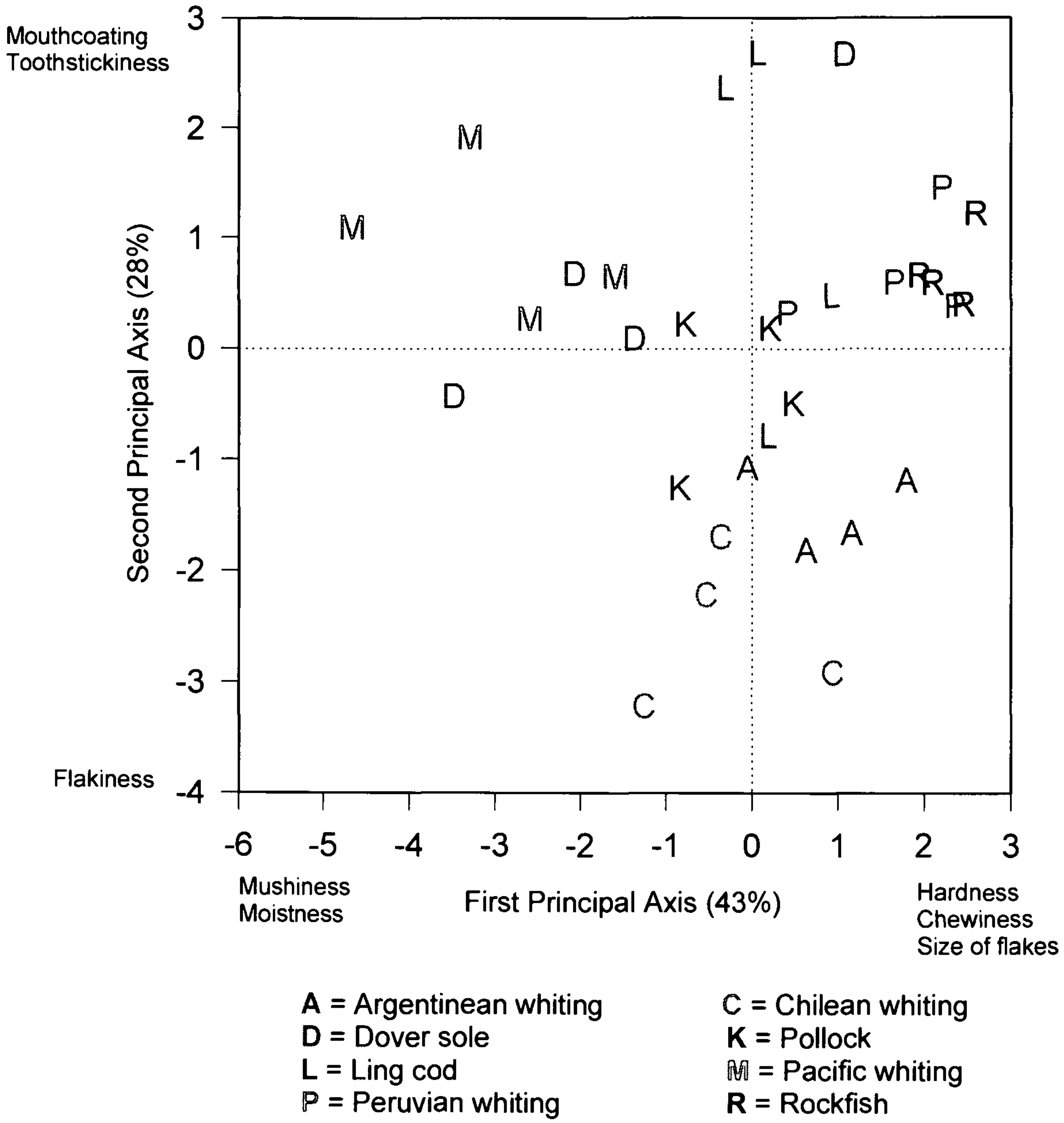


Figure 4.1.6 Principal component analysis: principal axes 1 vs 2 of sensory texture characteristics of eight fish species. Four points of a letter represent four replications across nine trained panelists. The data analyzed are from the trained panel (Test1).

ARG. PC2 did not separate the fish as well as PC1. The PC2 positive axis was described by mouthcoating and toothstickiness, and negative axis by flakiness. The fish that had negative means values were CHI, ARG, and POL, while PER, ROC, DOV, PAC, and LIN had positive means.

4.1.1.5 Sensory profile summary

In summary, color intensity, flake size, aroma, and most flavor characteristics of PAC were closest to CHI (which was the most accepted fish based on study 2: consumer testings). However, some of PAC's texture characteristics were different from CHI (e.g., lower in flakiness and size of flake and higher in mushiness, toothstickiness, and mouthcoating). The overall flavor intensity of PAC was similar to CHI, DOV, and POL. PAC's shellfish flavor was rated the highest. In general, PAC was rated mild to medium level in most attributes. Dellenbarger et al. (1993) evaluated catfish, hybrid striped bass, and red snapper using an eight-member sensory panel. Catfish was considered a mild flavoured fish relative to the other finfish. The panel preferred the mild catfish, giving it higher ratings for texture, juiciness, and overall acceptability.

4.1.2 Sensory Profile of Pacific Whiting Cooked by Two Different Methods

The analysis of variance on each sensory descriptor (Table 4.1.13) showed significant differences among the four whitings: PAC cooked with two different methods and ARG, CHI, and PER cooked in a microwave oven. That is, the trained panelists detected differences among the four whitings for each sensory characteristic. Replication effects were not

Table 4.1.13 ANOVA Table and significance level for aroma, flavor, and texture characteristics of individually quick frozen (IQF) fillets of Pacific whiting cooked in microwave/conventional ovens and three other whitings.

Sources of Variation	Aroma		Flavor		
	Fresh fish	Fishy	Overall flavor intensity	Fresh fish	Fishy
Treatment (Trt)	***	***	***	***	***
Panelist (Pan)	***	***	***	***	***
Replication (Rep)	ns	ns	ns	*	**
Pan * trt	***	***	***	***	***
Trt * rep	ns	ns	ns	ns	ns
Pan * rep	***	ns	**	ns	ns

Note : "ns" refers to not significant.
: *, **, *** refer to significance at $p \leq 0.05$, 0.01, and 0.001, respectively.

Table 4.1.13, continued ANOVA Table and significance level for aroma, flavor, and texture characteristics of individually quick frozen (IQF) fillets of Pacific whiting cooked in microwave/conventional ovens and three other whitings.

Sources of	Texture						
Variation	Flakiness	Size of flakes	Hardness	Mushiness	Moistness	Chewiness	Mouth-coating
Treatment (Trt)	***	***	***	***	***	***	***
Panelist (Pan)	***	***	***	***	***	***	***
Replication (Rep)	ns	ns	ns	ns	ns	ns	ns
Pan * trt	***	***	***	***	***	***	***
Trt * rep	ns	ns	ns	ns	ns	**	ns
Pan * rep	***	ns	ns	**	*	ns	ns

Note : "ns" refers to not significant.
: *, **, *** refer to significance at $p \leq 0.05$, 0.01, and 0.001, respectively.

significant for most characteristics, except for fresh fish and fishy flavor. The trained panel evaluated the difference in PAC between two cooking methods: microwave and conventional ovens. There were no significant differences detected between the two cooking methods (Table 4.1.14) concerning aroma (fresh fish and fishy) and flavor (overall intensity, fresh fish, and fishy). Brady et al. (1985) evaluated sensory quality and thiamin content of flounder and haddock fillets heated in a conventional and microwave ovens. A sensory panel did not detect differences due to heat treatment in the flavor, appearance, or overall of either species, but found microwave-heated flounder fillets significantly more crumbly than those heated conventionally. In this study, cooking PAC with two different methods resulted in significant ($p \leq 0.05$) differences of texture characteristics. Rapid cooking in a microwave oven resulted in significantly greater ratings for PAC flakiness, size of flakes in mouth, hardness, and chewiness, with lower rating for mushiness and mouthcoating. Cooking PAC with different methods affected the activity level of proteases in the fish. The microwave cooking resulted in a rapid increase of temperature inside the fish. Cooking fish in this way increases the temperature pass the zone of 50-65°C quickly, thus the enzyme had less time to be activated, causing fewer softening problems. In contrast, the slow method (i.e., a conventional oven) takes longer for the fish temperature to pass that danger zone. The enzyme was activated during that longer time period causing softening problems. An et al., 1994b found that Cathepsin B was the most active cysteine protease in PAC fillets. However, Cathepsin L showed the highest activity at 55°C when cooked the fillets in a conventional oven, indicating its function in myosin degradation during conventional heating of

Table 4.1.14 Means and SD (standard deviation) for the main sensory textural characteristics of Pacific whiting IQF fillet cooked by two different methods: (1) a microwave and (2) a conventional oven from the trained panel descriptive analysis.

Attribute	Microwave oven	Conventional oven	p-value
Aroma:			
Fresh fish aroma	4.87 (2.07)	4.98 (2.36)	0.58 ns
Fishy aroma	2.71 (2.11)	2.59 (2.03)	0.62 ns
Flavor:			
Overall flavor intensity	5.17 (1.97)	5.27 (2.05)	0.48 ns
Fresh fish flavor	5.08 (2.16)	5.07 (2.24)	0.95 ns
Fishy flavor	2.11 (1.34)	2.09 (1.42)	0.90 ns
Texture:			
Flakiness	4.67 (2.25)	3.24 (2.56)	***
Size of flakes in mouth	2.94 (1.62)	1.81 (1.33)	***
Hardness	3.11 (1.49)	2.49 (1.29)	***
Mushiness	4.07 (2.30)	5.94 (2.34)	***
Moistness	5.60 (1.90)	5.38 (2.04)	0.24ns
Chewiness	4.33 (1.44)	3.25 (1.54)	***
Mouthcoating	4.98 (1.49)	6.72 (1.62)	***

Note : Number of observations= 90 and Level of Significance = 0.05.
: *** denotes significant difference at $p \leq 0.001$.
: ns denotes not significant difference.
: Intensity scale values are from one to nine.

PAC fillets. Greene and Babbitt (1990) observed the sharp drop in protease autolytic activity in arrowtooth flounder at above 60°C. This suggested that rapid cooking would minimize tissue damage by denaturing the enzymes before widespread proteolysis could occur. They found that slow oven cooking caused a severe drop in resistance to force when using Instron punch tests, compared to the raw fillet. Microwave cooking the fish caused a 2.8-fold increase in force at the initial point of failure compared to baking, and a 1.6-fold increased over steam cooking. Thus, microwave cooking maintains muscle integrity in the whole fish fillet. Focus group participants (study 2) also reported similar results. Most of the focus group participants stated that cooking PAC in an oven made the fish mushier than cooking it in a microwave, or a quick (3-4 minutes) pan-frying. However, neither the rapid nor slow cooking methods changed the aroma or flavor characteristics of PAC. There were also other factors affecting the sensory quality perception of the fish. Johansson et al (1992) found that a different level of final internal temperatures (55°, 65°, and 75°C) had a greater effect on the eating quality of rainbow trout and cod, baked in both conventional and microwave ovens, than the heating method. An increase in temperature resulted in a decrease in tenderness, juiciness, flavor, and in surface moistness. The spider web plot for Pacific whiting IQF fillets sensory profile is shown for the two cooking methods (Fig. 4.1.7a and 4.1.7b).

The PCA model of sensory characteristics (Table 4.1.15) showed that only PC1 and PC2 were significant, explaining 60.6% and 24.9% of total variation, respectively. Characterizing sensory descriptors in PC1 were hardness, chewiness, fishy aroma, and fishy flavor (positive loading) and mushiness, fresh fish flavor, and fresh fish aroma (negative loading).

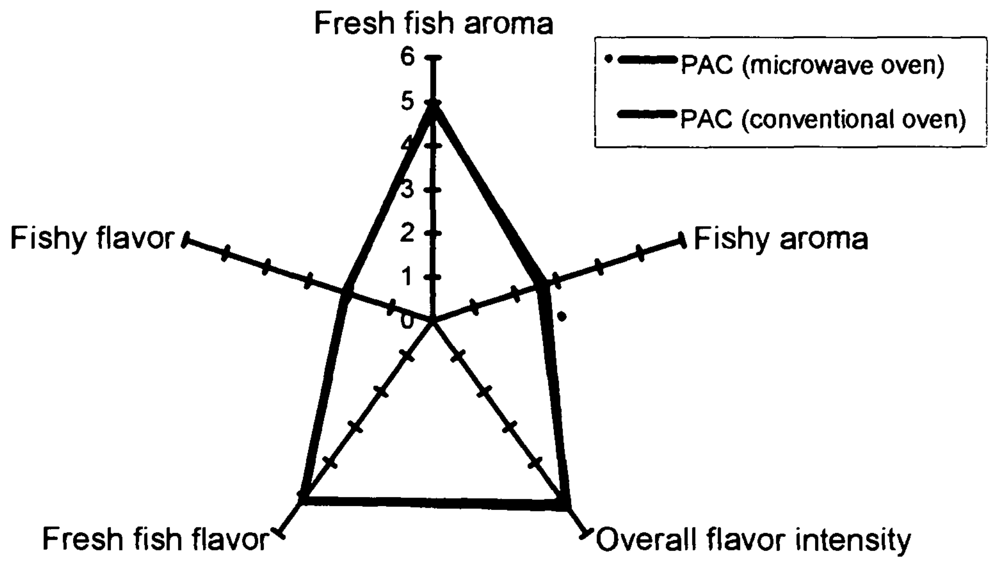


Figure 4.1.7a Aroma and flavor characteristics of Pacific whiting fillets cooked in microwave and conventional ovens.

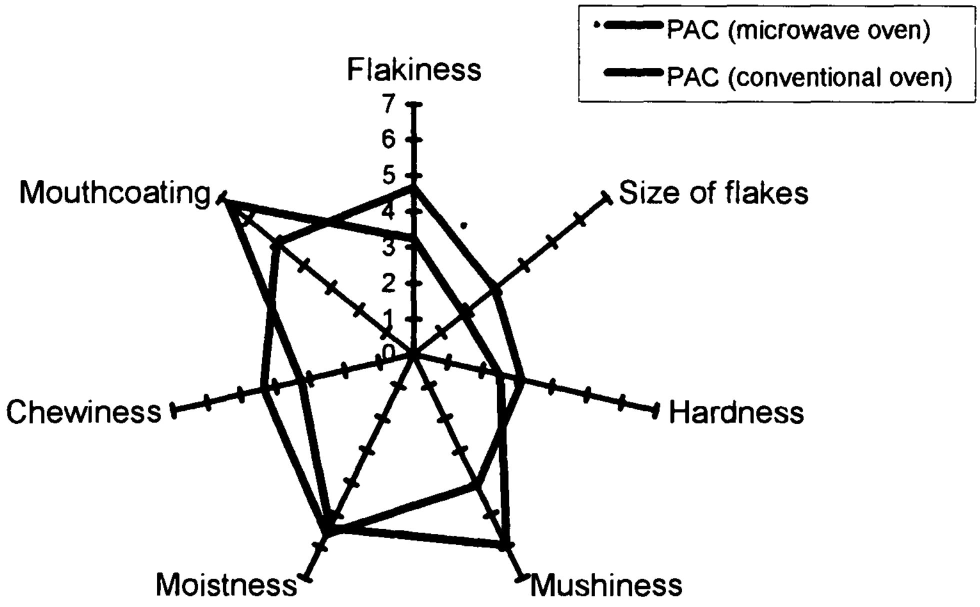


Figure 4.1.7b Texture characteristics of Pacific whiting fillets cooked in microwave and conventional ovens.

Table 4.1.15 Principal component analysis for each aroma, flavor, and texture characteristic of Pacific whiting IQF fillets cooked by two different methods and three other whiting.

Descriptor	Eigenvector	
	Principal Component 1	Principal Component 2
Fresh fish aroma	-0.307	0.190
Fishy aroma	0.342	-0.129
Overall flavor intensity	0.293	-0.023
Fresh fish flavor	-0.309	0.264
Fishy flavor	0.330	-0.208
Flakiness	0.042	0.531
Size of flakes	0.191	0.457
Hardness	0.360	0.041
Mushiness	-0.310	-0.279
Moistness	-0.287	0.251
Chewiness	0.347	0.129
Mouthcoating	-0.177	-0.428
Eigenvalue	7.27	2.98
Proportion (%)	60.56	24.86
Cumulative (%)	60.56	85.42
Characterizing attribute(s)		
Loading (+)	Hardness, chewiness, fishy aroma, and fishy flavor	Flakiness and size of flakes in mouth
Loading (-)	Mushiness, fresh fish flavor, and fresh fish aroma	Mouthcoating

In PC2, flakiness and size of flakes in mouth were positive loadings, where mouthcoating was a negative loading. Figure 4.1.8 shows five major groupings of the fish. Characteristics on the positive PC1 axis (Table 4.1.16) described PER, ARG, and CHI. Microwaved PAC and PAC cooked in a conventional oven oriented toward the negative axis which was weighted in mushy texture, fresh fish aroma, and flavor. For PC2, PER and PAC (oven cooked) had negative means scores indicating they were high in mouthcoating. PAC (microwave cooked) and ARG were on the positive axis. CHI was the last group being more flaky than other fish.

4.2 Study 2: Consumer Acceptability of Pacific Whiting IQF Fillets: Consumer Testing and Focus Group Sessions

In this study, the focus group discussions and the consumer testing were used to measure consumer perceptions about the PAC IQF fillets. Focus groups are for evaluating consumer satisfaction with PAC fillet product, while a consumer test measures consumers independently and quantitatively in a larger study, with a representative sampling (Grinchunas et al., 1993). In addition, the questionnaires used in the consumer test are a productive means of finding information, and they allow researchers to get a response from every individual they wish to sample (McKenna-Harmon and Harmon, 1992). Results from the consumer tests also allowed for more precise analysis of competitive fish species.

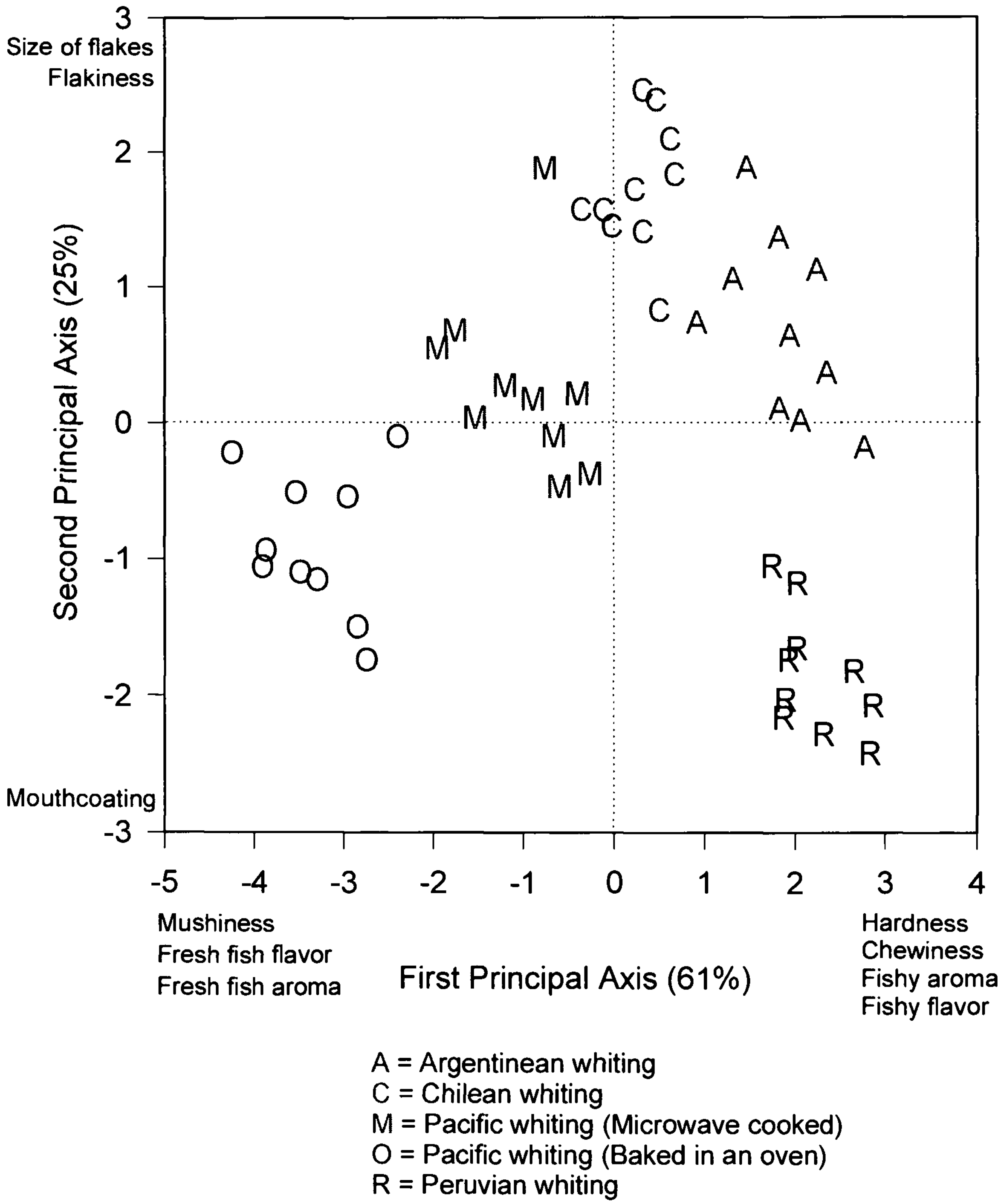


Figure 4.1.8 Principal component analysis: principal axes 1 vs 2 of sensory characteristics of four whiting species. Ten points of a letter represent ten replications across nine trained panelists. The data analyzed are from the sensory trained panel (Test2).

Table 4.1.16 Principal component (PC) axis 1 and 2: mean values for sensory characteristics of Pacific whiting cooked by two different methods (conventional and microwave ovens) and three other whitings.

Species	PC1 Means	Species	PC2 Means
Pacific whiting (oven)	- 3.332 [a]	Peruvian whiting	- 1.844 [a]
Pacific whiting (microwave)	- 1.007 [b]	Pacific whiting (oven)	- 0.888 [b]
Chilean whiting	0.259 [c]	Pacific whiting (microwave)	0.286 [c]
Argentinean whiting	1.868 [d]	Argentinean whiting	0.713 [c]
Peruvian whiting	2.211 [d]	Chilean whiting	1.733 [d]
LSD	0.454		0.510
Significance Level	0.000		0.000

4.2.1 Consumer Testing of Pacific Whiting IQF Fillets and Seven Other Fish

Seven hundred thirty-one consumers tested Pacific whiting and seven other whitings and whitefish IQF fillets at the Oregon State fair. PAC, PER, ARG, and CHI comprised the four whiting samples tested by the consumers. While, DOV, LIN, POL, and ROC were the commercial whitefish evaluated against the four whitings.

4.2.1.1 Demographic characteristics of the consumers participating in the consumer test

Just over half of respondents (≈53%) in the consumer testing were male and 70% were between the ages of 30-59 years old (Fig. 4.2.1 and 4.2.2). Household income ranged mostly (≈64%) between $20,000-40,000 and $40,001-60,000 (Fig. 4.2.3). Two-thirds of the consumers consumed seafood once a week (37%) and twice a month (27%) (Fig. 4.2.4). When asked to rate importance of four criteria (appearance, flavor, texture, and price), the majority of the consumers (83%) found flavor to be the most important characteristic when purchasing seafood (Fig. 4.2.5), followed by appearance (48%) and then by texture (44%). Consumers rated price as the least important characteristic.

Flavor was found to be the most important characteristics of PAC not only for the consumers from the consumer testings, but also for the focus group participants (study 2). In 1983, Hamilton and Bennett summarized that flavor was the most significant positive determinant of acceptability. Additionally, they found that most fresh whitefish could be satisfactorily interchanged with one another without causing adverse consumer reaction.

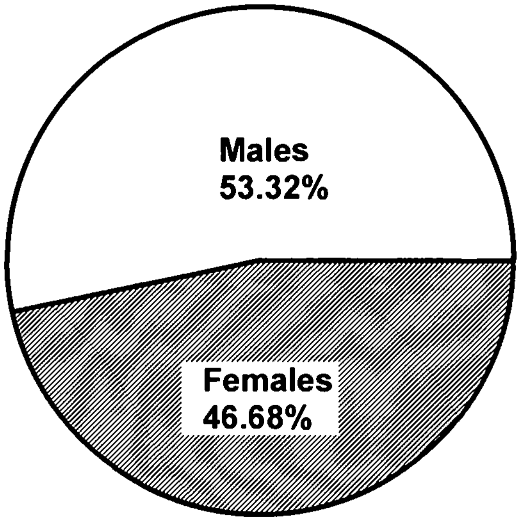


Figure 4.2.1 Gender of consumers participating in the consumer test.

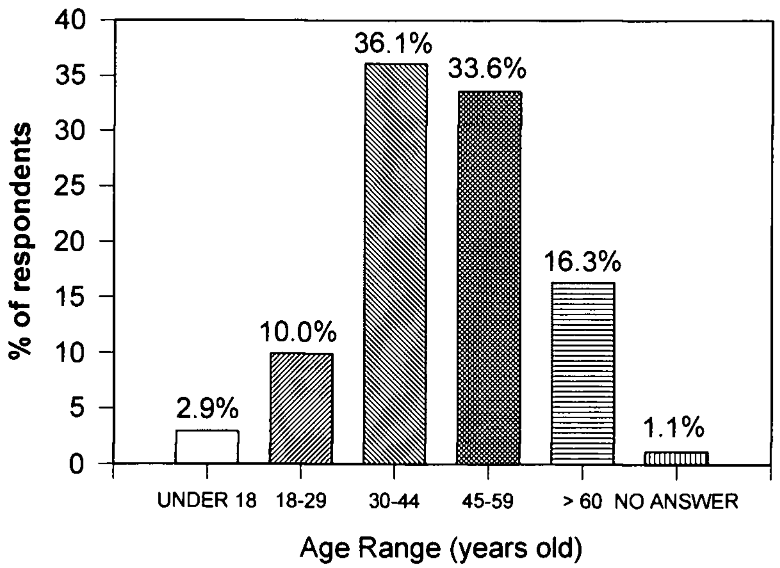


Figure 4.2.2 Age range of consumers participating in the consumer test.

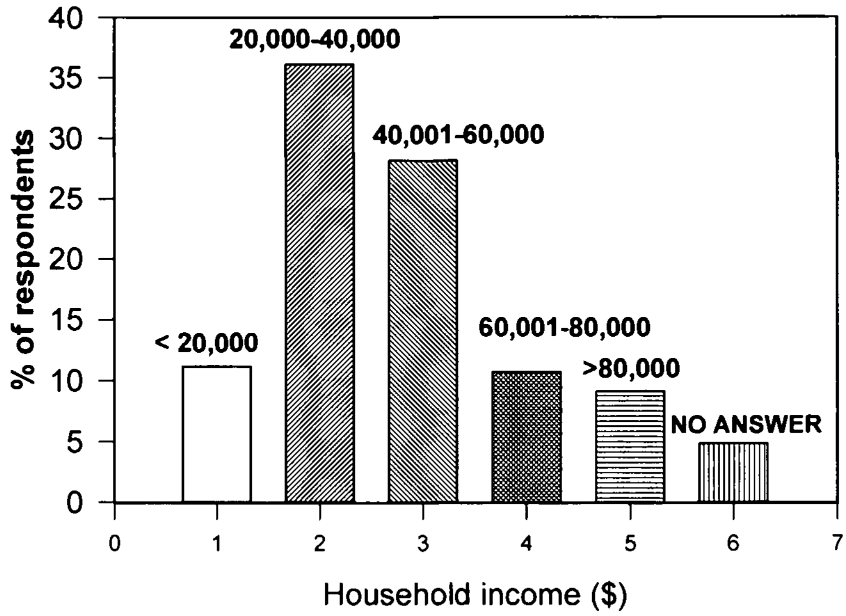


Figure 4.2.3 Household income before taxes for consumers who participated in the consumer test.

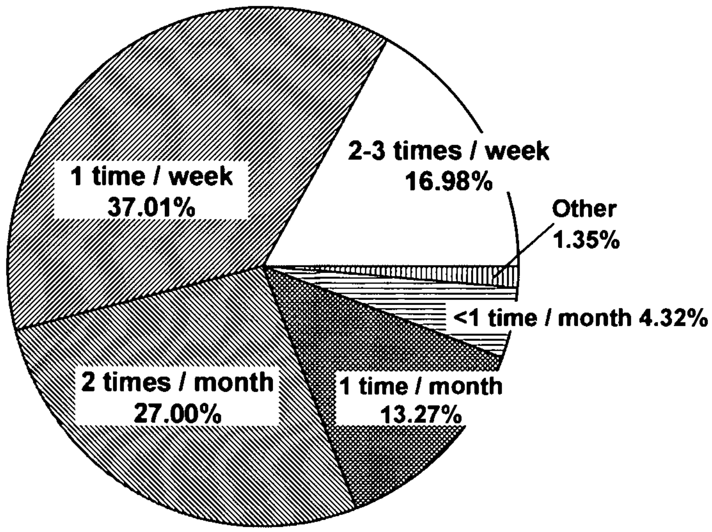


Figure 4.2.4 Seafood consumption of those consumers who participated in the consumer test.

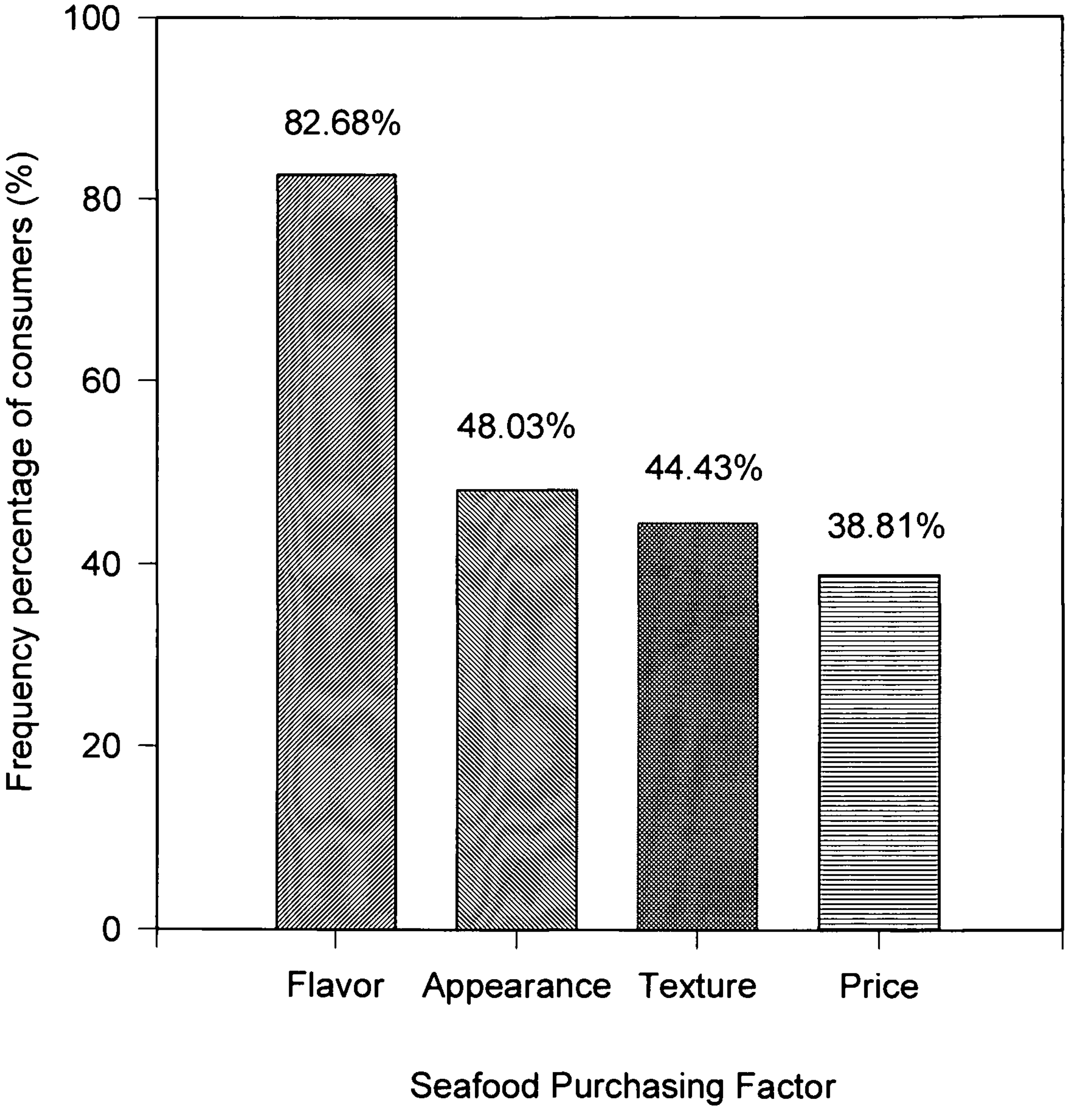


Figure 4.2.5 Respondents of the consumer test who rated flavor, appearance, texture, and price as their most important consideration when purchasing seafood.

4.2.1.2 Consumer perception

Table 4.2.1 summarizes the consumer results. There were three scales (i.e., nine-point Hedonic, five-point Just-Right, and five-point Purchase Intent) used within the survey design. For the questions using the five-point Just-Right scale, the responses indicated as *just-right* (a rating of "3") are shown in Table 4.2.1 and the distribution of all just-right ratings on four attributes (i.e., thickness of fillet, color, fish flavor intensity, and firmness) are presented in Fig. 4.2.6.

1). Appearance

Based on the nine-point Hedonic scale, consumers rated the appearance of DOV the highest (6.6), and LIN the second highest (5.7). The appearance rating of PAC (5.5) was not significantly different from LIN, CHI, ARG, or POL. PER received the lowest rating for appearance. Approximately 48% of consumers rated PAC's fillet thickness as just-right (Table 4.2.1). With the exception of LIN and ROC, this just-right percentage was similar to the other commercial fish. The thickness distribution curve was slightly skewed to the left (Fig. 4.2.6a) as 34% of consumers rated PAC as too thin. Two-thirds of consumers (≈65%) scored DOV's color as just right (Table 4.2.1). More than 54% of participants felt PAC's color was just right. Its color was not perceived significantly different from that of DOV. However, 27.5% of consumers rated its color as too dark, making the distribution curve slightly skewed to the left (Fig. 4.2.6b). Consumers did not perceive ROC and PER as having the right color, as only approximately 31% and 34% said their color was just right. Hamilton and Bennett (1983) summarized that

Table 4.2.1 Means and SD (standard deviations) for appearance, flavor, texture, and overall characteristics resulting from consumer testing of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Appearance[1] Liking	Thickness[2] Just-Right	Color[2] Just-Right	Overall[1] Liking
Pacific (PAC)	5.5^{c} (2.1)	48.4%^{c}	54.6%^{f}	6.0^{bc} (2.2)
Chilean (CHI)	5.6^{c} (1.9)	60.1%^{c}	55.2%^{cd}	6.3^{c} (2.1)
Peruvian (PER)	4.5^{a} (2.1)	44.7%^{c}	34.2%^{a}	3.8^{a} (2.3)
Argentinean (ARG)	5.5^{c} (2.0)	54.5%^{c}	53.8%^{de}	6.1^{bc} (2.2)
Dover sole (DOV)	6.6^{d} (1.8)	62.1%^{c}	65.1%^{f}	5.7^{b} (2.2)
Ling cod (LIN)	5.7^{c} (2.2)	67.9%^{ab}	58.5%^{ef}	5.9^{bc} (2.2)
Pollock (POL)	5.5^{c} (2.0)	58.9%^{bc}	50.6%^{bc}	5.9^{bc} (2.1)
Rockfish (ROC)	5.0^{b} (2.1)	45.8%^{a}	31.3%^{b}	5.9^{bc} (2.1)
Significance Level	***	***	***	***
LSD	0.23			0.41

Note [1]The average ratings are from a 9-point hedonic scale.
[2]The frequency of just-right rating (3) from a 5-point scale.
: The analysis was performed at confidence level of 95%.
: Significant level, ***, refers to significant at $p \leq 0.001$
: Means with different letters within a column denote a statistically significant difference

Table 4.2.1, continued Means and SD (standard deviations) for appearance, flavor, texture, and overall characteristics resulting from consumer testing of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Flavor[1] Liking	Flavor Intensity[2] Just-Right	Texture[1] Liking	Firmness[2] Just-Right	Purchase Intent[3]
Pacific (PAC)	6.0[bc] (2.2)	48.1%[bc]	5.7[b] (2.2)	55.4%[a]	49.3%[bc]
Chilean (CHI)	6.1[c] (2.0)	46.2%[ab]	6.2[c] (1.9)	62.8%[b]	53.7%[cd]
Peruvian (PER)	3.8[a] (2.3)	17.1%[e]	4.1[a] (2.3)	26.8%[d]	17.3%[a]
Argentinean (ARG)	6.1[c] (2.2)	55.8%[d]	5.9[bc] (2.1)	62.5%[c]	52.3%[bcd]
Dover sole (DOV)	5.6[bc] (2.2)	34.5%[a]	6.1[bc] (2.8)	51.8%[a]	44.5%[b]
Ling cod (LIN)	5.6[b] (2.1)	42.0%[bc]	6.0[bc] (2.1)	68.1%[d]	46.7%[bc]
Pollock (POL)	5.8[bc] (2.1)	38.0%[a]	5.8[b] (2.0)	53.4%[b]	51.9%[bcd]
Rockfish (ROC)	5.8[bc] (2.1)	40.2%[bcd]	6.2[bc] (1.8)	60.2%[c]	50.0%[bcd]
Sig. Level	***	***	***	***	***
LSD	0.49		0.43		

Note [1]The average ratings are from a 9-point hedonic scale.
[2]The frequency of just-right rating (3) from a 5-point scale.
[3]The frequency of Probably- and Definitely-Would-Buy score (4 and 5) from a 5-point purchase intent scale.
: The analysis was performed at confidence level of 95%.
: Significant level, ***, refers to significant at $p \leq 0.001$
: Means with different letters within a column denote a statistically significant difference

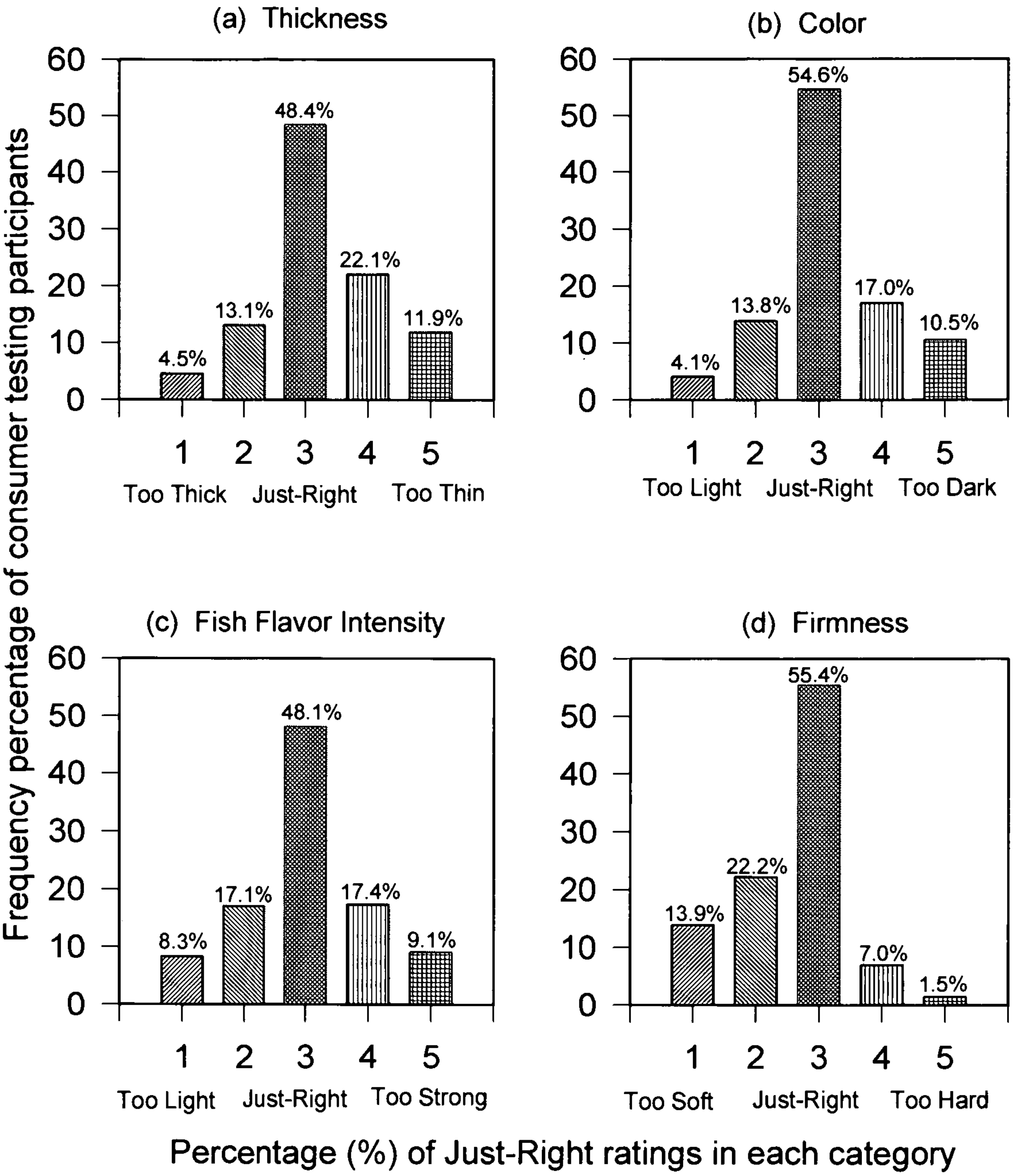


Figure 4.2.6 Distribution of Just-Right ratings of consumer testing participants on (a) thickness, (b) color, (c) fish flavor intensity, and (d) firmness of Pacific whiting IQF fillets.

appearance of fish was either a neutral or negative determinant of consumer acceptability.

2). Flavor

Consumers' mean flavor ratings for PAC was 6.0 out of 9.0 (i.e., like to like moderately), and not significantly different from the other commercial fish (Table 4.2.1). PER was rated the lowest for flavor liking (3.8). ARG's flavor intensity received the highest percentage of just-right responses from consumers (≈56%), and PAC received the second highest percentage of responses (≈48%). Its distribution curve (Fig. 4.2.6c) was normal as approximately the same amount of consumers said PAC flavor intensity was either too light or too strong. PER received the lowest percentage of just-right responses (≈17%).

The flavor liking of PAC was rated as high as the highest rated species (i.e., CHI and ARG). However, according to focus group participants (study 2), the flavor of PAC fillet itself was mild. The focus group participants suggested adding additional flavor with seasonings when cooking.

3). Texture

Consumers' texture ratings of PAC (5.7) were comparable to most commercial fish, with the exception of CHI and PER (Table 4.2.1): CHI was rated the highest (6.2) and PER was rated the lowest (4.1). LIN's firmness received the highest percentage of just-right responses (≈68%) and CHI and ARG were second and third (≈63% and ≈62%), respectively. More than 55% of consumers scored PAC's firmness as just-right and PAC was not significantly different in this attribute from DOV.

PAC's just-right distribution curve (Fig. 4.2.6d) skewed to the right, as 36% of participants rated it as too soft. Hatae et al., 1990 studied firmness of fish flesh and found that cooked muscle of fish species with firm texture had thin muscle fibers with considerable heat-coagulating material between them. The species that have soft texture had thick muscle fibers with little heat-coagulating material. They concluded that the diameter and mobility of muscle fibers are determinative of firmness of fish muscle tissue.

Although flavor characteristics were major determinants of preference as previously mentioned, Wesson et al (1979) found that texture was an extremely influential discriminant of preference when samples exhibited moderate to low intensities of fishy and/or oxidized flavors. Based on the consumer test, and especially the focus group discussions, texture was found not to be as an important determinant as flavor, appearance, and other factors. Hamilton and Bennett (1983) also found that texture was a neutral determinant of acceptability.

4). Overall Liking

Overall liking of participating consumers (Table 4.2.1) toward PAC (6.0) was not significantly different from other commercial fish, with the exception of PER, which was rated the lowest (3.8). PAC's overall rating was the third (6.0) and close to CHI and ARG which were the first (6.3) and the second (6.1), respectively. According to a discussion by the focus group participants (study 2) "... a fish is good if the overall characteristics of the fish is good", and they would buy it.

In summary, PAC compared well with other fish. Consumers rated most of PAC's attributes as high as other accepted whitings and whitefish. Hamilton (1980) investigated the relative importance of appearance, flavor, and texture in establishing overall acceptability in whitefish (i.e., sole, haddock, whiting, dab, cod, plaice, ling, and saithe). He found that very small differences in the sensory attributes were detectable, and that all three attributes contributed to overall acceptability. All samples tested were acceptable, but there were definite differences that correlated to price.

5). Consumers' purchase intention

After tasting the samples, consumers were asked to rate their intention to purchase the fish. More than 53% of participants (Table 4.2.1) indicated they would purchase CHI and more than 52% of participants indicated they would purchase ARG. Approximately 49% of consumers intended to purchase PAC: this result, with the exception of PER, was not significantly different from the other fish. Less than 18% of consumers indicated they would want to purchase PER. In general, CHI was favored by consumers in overall attributes, flavor, texture, and purchase intent. Conversely, PER was favored the least in every attribute. This was probably due to some of PER fillets seemed to be handled improperly, as discoloration at the fat layer was observed.

Inquiring about a consumer purchase intent was not synonymous with their actual purchase choices. There were some other considerations (i.e., household members, transition state of primary buyers, etc.) that affect consumers' purchasing decision. Food choices are determined by many socioeconomic characteristics of the household, as well as price of food and cultural eating habits (Lutz et al., 1993). The consumer decision-making task is generally a multifaceted nature.

For example, a typical consumer choice on fish consists of a set of alternatives, each described by several characteristics. The difficulty of a consumer's choice generally will increase (Bettman et al., 1991) (1) as the number of alternatives and characteristics increases, (2) if specific characteristic values are difficult to process, (3) if there is a great deal of uncertainty about the values of many attributes, and (4) as the number of shared attributes become smaller. Prior knowledge effectively influences many consumer decision processes.

4.2.2 Consumer Testing of Pacific Whiting IQF Fillets Stored for One Year and One Month

PAC IQF fillets, stored for two different time period, were studied to investigate possible rating differences. There were no significant sensory differences perceived between the one-year frozen storage PAC^y characteristics and the one-month frozen storage PAC samples (Table 4.2.2). Yet, consumers significantly preferred the appearance of the one-year PAC^y (6.00) to the one-month PAC (5.0). Approximately 65% of consumers found the firmness of the one-year PAC^y to be just-right, compared to the one-month PAC (58%). In addition, consumers' purchase intention was similar for the two storage-life PAC samples (≈44% of consumers would buy the fish). The results suggest that properly storing PAC in a freezer for one year will not change consumers' perception of fish quality. Nambudiri and Gopakumar (1992) observed a decrease in enzyme (adenosine triphosphatase and lactate dehydrogenase) activity in fresh water and brackish water fish stored frozen at -20°C over a period of 180 days. Highly significant negative

Table 4.2.2 Means and SD (standard deviations) for appearance, flavor, texture, overall characteristics, and purchase intent for Pacific whiting IQF fillet of two different storage ages: (1) one-year old and (2) one-month old from consumer testing.

Characteristic	Average[1] (Std. Dev.)		p-value
	1-year	1-month	
Appearance[1]	6.00 (2.06)	4.95 (2.27)	0.003
Thickness[2]	54.43%	39.24%	0.174
Color[2]	63.30%	49.37%	0.144
Overall[1]	5.47 (2.18)	5.47 (2.22)	0.966
Flavor[1]	5.47 (2.24)	5.32 (2.20)	0.666
Flavor Intensity[2]	37.97%	44.31%	0.593
Texture[1]	5.51 (2.14)	5.49 (2.14)	0.970
Firmness[2]	64.55%	58.23%	0.100
Purchase Intent[3]	44.30%	44.30%	0.952

Note: [1]The average ratings of a 9-point hedonic scale are presented. Standard deviations are in parentheses.
[2]The frequency of just-right rating (3) from a 5-point scale is presented instead of average ratings.
[3]The frequency of Probably- and Definitely-Would-Buy rating (4 and 5) from a 5-point purchase intent scale is presented instead of average ratings.
Level of Significance = 0.05.

correlation was observed between this enzyme activity and frozen storage. Significant linear correlations were also observed between decrease in enzyme activity and sensory scores. Perez-Villareal and Howgate (1991) found that at -30°C, changes in sensory properties, peroxide value and thiobarbituric acid value, lipid fatty acid composition, adenosine nucleotide degradation products, and dimethylamine and formaldehyde were negligible during frozen storage of European hake for up to 39 weeks.

4.2.3 Focus Group Discussions

Nine participants participated in three focus group discussions with the purpose of gathering information and insights into consumer thinking, reactions, and purchasing behavior toward PAC IQF fillets. The participants were also asked to express their opinions on fish sensory characteristics previously determined by the trained panel. The issues that were discussed were: perceptions of fresh and frozen PAC fillets, fish fillets and other muscle foods (e.g., scallop and beef), desirable and undesirable characteristics of PAC and other fish species, factors affecting participants' purchasing decisions toward fish, purchase decision of one fish compared to another, participants' purchasing behavior toward fish, cooking methods for PAC fillets, participants' willingness to try new species of fish, and advice from participants' to fish marketers.

4.2.3.1 Participants' perceptions of fresh Pacific whiting IQF fillets

Participants analyzed six attributes of raw PAC IQF fillets: appearance, color, shape, size, thickness, and odor. When looking at the appearance of the fillet, all participants felt the appearance of blood spots implied a bruised fish:

Claire: "The blood spots also imply a different texture and taste from the rest of the fish..."

Kim: "Discoloration in a white fish gives the impression that it may not be as fresh or as carefully handled as possible...if discoloration is in a fish that you are familiar with, and it is known to be normal for that fish (like Tuna), then it's not as bad as it is in an unfamiliar type of fish..."

Joy: "...or perhaps the fish had been improperly stored (i.e., had gone bad)..."

Sue: "...or too much handling..."

Some of the participants were concerned that blood spot areas would cook faster, and become tougher than the rest of the fish. They also commented that appearance to them signifies whether or not the fish was fresh, by looking at color and overall appearance ("...if the fillet looks battered you have the impression that it is gone through a lot of transportation and therefore is not fresh from the ocean," said Kim). The PAC fillets appeared fresh to them and, for the most part, were even in color.

All participants also indicated that a favorable color on both sides of the fillet was desirable. They found the pink or white colors (i.e., seen in most CHI and PAC fillets) to be desirable, but not a yellow color at the center of the fish's body (i.e., seen in most PER fillets). Most felt the yellow color would be tougher when cooked, "...yellow means freezer burn, freezing for too long...," "It's an old-look, chicken fat look-alike...," or "...having been exposed to something, or not being cleaned right." They also found a fish with a yellow color to be unappealing, signifying a poor flavor:

Joy: "...yellow coloring implies that the fish might be too old, freezer burned, or had gone bad."

Pat: "...yellow portions had a strong *fishy* flavor..."

Kim: "...yellow color has an unhealthy look to it. Unless you are familiar with the looks of the fish and know that the discoloration is normal, it will look unappealing."

Claire: "...unless I know that this particular fish has yellow flesh (i.e., catfish) it does make me suspect that it is old (not fresh)."

Pam: "...white or pink is an expected color, yellow is not expected. Yellow may be interpreted as not fresh..."

The participants spoke about the shape of the fillet. They felt the shape of the fillet represented careful handling, for example bad trimming (e.g., unsmoothed rims, rough and uneven sizes) demonstrated rough handling:

Kim: "The shape of the fillet was not that important to me, unless the fillet was to be used in a dish in which the appearance of uniformity would be important..."

They found evenly-cut fish appealing. However, they suggested that a thin, long, narrow end piece of a fillet which they considered undesirable, could be trimmed off at home:

Kim: "The thin long tail might cause a problem by cooking too quickly, but it was O.K."

The participants found the fish acceptable when it came in the individual size fillets as they saw in PAC and CHI fillets, provided during the discussion (approximately 80-100 grams in weight, 2.5-3.0 inches in width and 9.5-10.0 inches in length). Cooking speed of the fish was indicated to be affected by size uniformity and thickness of the fillet. Some of the participants found the thicker fillets to look more interesting and meaty. The thinner fillets presented a greater challenge when cooked. Overall, some of the participants found the thinner fillets to be unappealing as they lacked texture:

Claire: "...when frying or baking fish it is easier to handle a nice large fillet."

Kim: "...thinner fillets have to be cooked more carefully. They might be more likely to dry out."

Joy: "...prefer a good bite to the fish-thicker usually means better texture and firmer..."

Pam: "...thin fillet is also more delicate to prepare, and need more attention..."

Sue: "...thin fillets cooked too fast and become watery..."

Others were not concerned with the thickness. They would make stew with the thick fillets, and pan-fry the thin fillets.

Most participants preferred a mild fresh fish odor to a strong (gamey) fish smell, "...hard to tell what it looks like, but you know it is a raw fresh fish smell, not strawberry smell." However, each participant had their own odor preference. A fish that smelled mild to one participant may smell strong to another participant. Concerns for fish odor are frequently referenced criticisms by individuals. The participants found the odor of raw PAC fillets to be mild, fresh, not fishy, and thus not offensive.

4.2.3.2 Participants' perceptions of fresh and frozen Pacific whiting fillets

It was important to understand participants' perceptions of fresh versus frozen PAC, given PAC's likelihood of being supplied to the market in frozen fillet form. These findings will be helpful to marketers who are interested in selling either the fresh or frozen PAC fillet form.
To the participants, *fresh* and *frozen* mean as follow:

Pat: "...fresh means never been frozen...frozen means bought in a frozen state so that I can choose when to serve the fish."

Sue: "...fresh means right out of the water, maybe packed on ice or not older than 24 hours..."

Kim: "...frozen means at some point the fish was frozen, fresh means never having been frozen, directly from the ocean to the market."

Claire: "...fresh implies right off the boat, while frozen means caught/clean/frozen and shipped."

Joy: "...frozen means fresh fish that was frozen, fresh means has not been previously frozen..."

Pam: "...fresh--fish has not been frozen at any time, frozen--fish has been frozen after processing without being thawed..."

The participants generally bought fresh fish given its ready to cook form. They would occasionally buy frozen fish, depending on the length needed to refrigerate or freeze before use. When wanting to cook the fish that same day, they would usually buy fresh fish. They preferred buying frozen fish when planning to cook the fish later that week. This was in opposition of buying fresh fish and freezing it themselves. However, the purchased form depended on the fish species (e.g., They did not expect snapper to be in a frozen form so they did not purchase it. Yet, cod was permissible to buy frozen), and whether they had purchased that species previously in a particular form.

They did not view frozen fish as undesirable. In fact, the participants found the frozen fish to be advantageous. In comparison to the fresh fish, frozen fish has less juice, was not as messy, and smelled less fishy. The frozen fish mild smell was acceptable to the participants, while the fresh fish odor could encompass one's refrigerator.

Participants' feelings toward a fish product labeled "this product has been frozen and thawed" was unfavorable. To them, the label implied immediate usage, and to refrain from refreezing. They were suspicious of how long the fish had been thawed, and how long it was sitting in the display case. Many of the participants preferred fresh fish compared to *frozen and thawed* fish. Nevertheless, if *fresh* fish was not available they would prefer *frozen* over *frozen and thawed* fish.

The participants were not adverse to buying frozen fish, especially when they were not going to consume the fish immediately. The decision to buy frozen over fresh fish usually depended on their time constraints. They felt frozen fish was desirable for its convenience properties.

When asked what species of fish they usually bought, most participants indicated rockfish and cod. Participants felt these were preferable because of their low price, availability, and versatility. Salmon, halibut, red snapper, sole, tuna, trout, perch, catfish, and imitation crabmeat (e.g., for Jane) were also frequently purchased species. Participants assumed a fish was not available if a store did not have the fish display at a seafood counter, and usually purchased the fish they know. There were some species they knew you could purchase in the frozen form, i.e., cod and halibut. They were also aware that the name of the fish corresponded with the area from which the fish originated (e.g., "Alaskan..."). Where the fish originated could also be an indicator of whether the fish would be available in the frozen form. Providing a fish originality is a plus to them, but in general is not necessary:

Kim: "This doesn't necessary matter, but if it is a special from a local area I would expect it might be fresher..."

Claire: "...if it is caught close to Oregon I assume it will be fresher or better. I am suspicious of buying from far away, foreign islands..."

Pam: "I like to know that it is from this region. Something local may support it being fresh. I can understand why a fish from the Atlantic comes to the fish counter in a frozen form."

4.2.3.3 Perceptions on fish fillets and other muscle foods

This issue explored whether or not participants substituted other food choices, such as muscle food (e.g., beef, scallop, chicken, etc.) for fish. It may not be other fish that compete with PAC fillets, but other muscle foods.

Scallop and beef samples were placed next to the fish fillet sample, representing other muscle food or substitutions for fish. For the participants, beef is considered "common stuff" because of its abundant supply. Fish or seafood (i.e., shrimp, scallop, etc.) was considered "a delicacy", better, lighter, and more versatile. For example, participants will order fish or seafood instead of beef at a restaurant. Some participants limit their beef intake, given the nutritional value (e.g., higher fat) and the price (e.g., more expensive). While some participants order fish because they prefer seafood. Some believe fish is healthier, and prefer the smaller individual portions. The participants indicated that they have heard, and they believe eating fish can prevent cardiovascular disease. Fish to them is lean compared to beef or chicken (i.e., one pound contains less fat and bone compared to beef and chicken). Rose said her grandma told her "fish is brain food." She trusts her grandma and has eaten fish ever since.

Sue, with a large family, has a weekly planned menu including several kinds of meats and seafood for a balanced diet ("...the menu included a variety of food items but planned accordingly to advertised specials..."). Claire agreed that menu planning keeps herself budget her grocery money and not shop impulsively, while others had different opinions, e.g., Kim said "...I don't have a large family. Meals are rather spontaneous and unplanned..." The participants suggested that the tastes and preferences of the household members affect their purchase decisions.

If the participants could afford any of the meats being brought to the discussion, i.e., scallop, beef, and fish, most said they would prefer scallops. Even though they view scallops as expensive, they view them as a delicacy and unique. When buying for adults, Joy said she will choose to purchase scallop, but she would choose beef instead for children. Most participants had similar opinions. Pat said she and her family eat beef occasionally. Sue added that if she was buying for a mixed gathering, she would purchase scallop for the adults, and a less expensive food for small kids. For Claire, she would choose shrimp/clams or halibut/salmon equally with scallops. She said many children seem to like fish less than adults. Kim said "I love scallops, but I would not be able to afford them all the time. I don't usually eat beef." Joy agreed that "...scallops/seafood is more impressive than beef, also healthier..." Pam thought "...scallops seem to be for special occasions. In my home, beef is preferred."

Compared to scallops, fish is more common and is healthier. Time needed to prepared the meal was also stated as a consideration in food product choices. Beef, generally, could be cooked in an oven unattended, even though it takes longer time to cook. Fish requires greater attention, even though it is relatively easy to cook. However, some said they like to buy fish because it is relatively easy to prepare ("...cooked so quick..."), limiting their food preparation duration. Participants stated they are usually more careful with fish because of fish perishability. They remarked that they never leave fish to thaw on a counter:

Pat: "Fish is easy to prepare, and I am not a fussy cook."

Sue: "...you don't want to overcook it..."

Kim: "It does require attention in cooking. You can't walk off and leave fish frying, but it cooks quickly and overall takes less preparation."

Claire: "Fish requires greater attention but I'm in the kitchen preparing the meal just before we eat anyway. Since it takes so little time to cook it's not a problem..."

Joy: "...fish cannot be left too long because of overcooking, but does not need constant watching...just careful timing and reasonable surveillance..."

Pam: "...I tend to overcook fish. I think I have to pay more attention to it in order for it to come out right. I have more success with the fish that takes longer to cook..."

Most of the participants prefer fish when they are watching their weight. For a given week, most participants try to purchase foods that will provide balance and diversity to their diets.

4.2.3.4 Characteristics of Pacific whiting and other fish species found desirable and undesirable to participants

It is advantageous to understand the preferences of consumers concerning fish. Knowing what consumers find desirable and undesirable assists marketers in producing quality profitable products.

The focus group participants do not want to hassle with bones in fish. They also stated that they avoid stronger fishy flavored seafood, i.e., oyster. To them, whitefish flavor is milder and you can always add spices. There were also some fish found unappealing to these participants (e.g., Jane does not care for salmon). The participants cited several reasons why they may not prefer a particular fish: strong flavor (i.e., too fishy, overpowering), texture (too soft, too hard, different from what they typically found in other fish), or less cooking success (i.e., it does not make a good meal):

Pat: "...strong flavor/texture is less desirable...less cooking success is disappointing."

Sue: "...too fishy in flavor and too chewy and coarse in texture are not good. Not enough knowledge about cooking a certain fish results in less cooking success."

kim: "...I like some fish with strong flavor (e.g., salmon, fresh tuna). I also like more mild flavored fish (e.g., sole, halibut). I don't like fish with a mushy texture or dry texture. Some fish is easily over cooked (e.g., halibut)."

Pam: "...I do not like the flavor to dominate everything else and I don't want the house to smell fishy. I will prepare a fish I've had success with before trying something new, unless I have a lot of time."

Claire: "...I don't mind strong flavor in fish. Texture-I do not like it slimy. Soft is O.K. If I have had a hard time cooking it previously, I might try a new method of cooking (i.e., bake instead of fry)."

Joy: "...I don't like strong fishy taste; do not like "mushy" texture; if it cooks up badly I may not try again..."

The participants' perception of a "desirable" fish was exemplified by the demonstration fish (PAC and ARG whitings) provided for the discussion. The participants like their fresh fish odor. They stated that they found catfish fishy smell in some fish to be undesirable. However, odor is of lower priority when they are actually selecting the fish. If the cooked product is pleasing overall, they are satisfied with their purchase.

The following are fish fillet characteristics of concern to the participants, in general:

1). Appearance Color intensity: the color does not matter, as long as it reflects the known species characteristic, e.g., red snapper has red color, not white or pink. The focus group participants rated color consistency important, even though the trained panel found color intensity to be an appearance descriptor of fish samples. This may be because the trained panel evaluated relatively small pieces (1.3 X 1.3 cm) of fish fillet samples, while focus group participants evaluated the entire fillet. According to the consumer focus group, as long as color is true to species, the color consistency of the whole fillet was more important than its intensity. However, consumer testing results of appearance liking showed consumers preferred DOV the most and PER the least. According to the trained panel, DOV was the lightest in color intensity and PER was the darkest. This may mean that color intensity, how light or how dark the sample was, substantially affected consumers' perception, though this is not likely for focus group participants. Flakes size: most prefer thicker (bigger) flakes, as they feel there is substantial texture to bite into. However, flake size is of low priority to the participants.

2). Aroma Fresh fish aroma: the participants favor a pleasant fresh fish aroma. There is a certain "ideal" fish smell they desire when unpacking the fish at home. A strong fishy smell is undesirable because of its overbearing presence. They were unsure whether or not they have ever smelled a nutty or buttery aroma. They would enjoy having a buttery smelling fish. Unpleasant aroma was a concern to the participants.

3). Flavor Fish flavor must be enjoyable and have an overall pleasing taste. They do not enjoy an unpleasant fishy flavor, or fish that lack flavor intensity.

4). Texture Fish should hold its shape and have some texture or resistance when eaten. The fish should not fall apart. A mushy fish that stuck to the teeth was found to be unpalatable and unpleasant. They enjoyed a firm fish. Texture should be flaky and not tough.

The desirable characteristics of appearance, aroma, flavor, and texture obtained from the focus group discussion are summarized in Table 4.2.3, 4.2.4, and 4.2.5. Participants usually expected the appearance of the fish fillet to be clean and fresh looking (Table 4.2.3). The participants felt the fillets should be smooth, clean cut, with even color throughout, and no appearance of discoloration. The participants also felt the fish should have a mild fresh fish aroma, typical for that particular species. A strong fish smell would be undesirable. The participants desirable flavor (Table 4.2.4) was reflected by mild fresh fish with a certain level of intensity. Texture of the fish (Table 4.2.5) is preferred when it provides resistance when bitten. It should be flaky, not mushy.

All sensory terms used in the descriptive analysis (study 1) were discussed by the participants. Table 4.2.6 summarizes the participants level of importance indicated for each sensory term. The participants considered color consistency; fresh fish and fishy aroma; overall flavor intensity, fresh fish flavor, fishy flavor; and mushiness, hardness, moistness, flakiness, and size of flakes to be important characteristics. Flake size (appearance); shellfish flavor, saltiness, sweetness; and chewiness ("...fish should have good cohesiveness, not hard to chew...")

Table 4.2.3 Focus group participants desirable appearance and aroma characteristics of fish.

Characteristics	Desirable Characters
Appearance	Clean and fresh looking
	Even and overall light color
	Color intensity is not important as long as it is not extreme
	No discoloration, no yellow flesh
	Thick cut, no bloody spot, no bad spots, no bruises
	No curly edges, not too dry looking
	Not very small flakes (a good fork-size, full look), Large flakes that hold together
Aroma	Fresh fish
	Very light odor (mild fish)
	Not over-powering smell that permeate the whole house
	No strong/fishy smell
	Not pungent
	Type of odor is not as important as the strength of odor

Table 4.2.4 Focus group participants desirable flavor characteristics of fish.

Characteristics	Desirable Characters
Flavor	Mild flavor
	Flavor intensity is more important than specific type of flavor, should not be too light or too strong
	Fish should contain a favorable overall flavor intensity used to determine if one would continue eating the fish
	Fish should taste like it should, and true to their species
	Each fish has a distinctive flavor (that is why people like a variety of fish)
	Fishy flavor in Tuna is o.k.
	Very light fishy taste, very light salty flavor, does not leave aftertaste
	Fresh and nice flavor, no strong fishy taste, sweetness
	No old flavor

Table 4.2.5 Focus group participants desirable texture characteristics of fish.

Characteristics	Desirable Characters
Texture	Nice size flakes that do not disintegrate rapidly in the mouth
	Large flakes that cling together
	Flaky, medium-moist texture
	Not too moist, not too dry, cannot be mushy
	Not too firm (firm but not really hard) as from over-cooking, medium firmness, not too mushy
	Firm texture to bite into it. Not mushy or chewy (rubbery), should not fall apart
	Do not like soggy fish

Table 4.2.6 Focus group sensory terms rating from important to unimportant.

Characteristics	Important Characters	Somewhat Important Characters	Somewhat Unimportant Characters
Appearance	Color consistency	Flake size	Color intensity (light/dark)
Aroma	Fresh fish		Salty, nutty, buttery
	Fishy		
Flavor	Overall flavor intensity	Shellfish	Nutty/buttery
	Fresh fish	Salty	Bitter
	Fishy	Sweet	
Texture	Mushiness	Chewiness	Mouthcoating
	Hardness		Tooth stickiness
	Moistness		
	Flakiness		
	Size of flake		

were considered somewhat important. The rest of the characteristics were considered unimportant.

Participants tasted Pacific whiting through several cooking methods (a microwave oven, a conventional oven, a pan fry, etc.). Participants viewed PAC as having the ability to compete with other frequently purchased fish species (i.e., cod, snapper, sole, perch, halibut, and rockfish).

Most participants found that PAC had a similar quality concerning appearance, flavor, texture, and overall characteristics as the other fish they had experienced. All participants expressed a willingness to purchase PAC, if the price was competitive. Most said the odor and size of PAC fillets were more desirable. The participants viewed its flavor as mild and delicate, possibly needing added flavoring. The taste of the PAC fillets reminded the participants of Pacific cod, ling cod, rockfish, sole, pollock, and orange roughy:

Pat: "...taste is similar to cod/sole...so much depends on the preparation..."

Sue: "...it is versatile in use...its taste is not offensive..."

Kim: "...the fish had an overall pleasant taste. It was a mild flavor almost bland that could take an additional spices well..."

Joy: "...I like the taste of the fish. It was not overpowering. It cooked up very well with added flavoring..."

Gail: "...characteristics of the fish was very similar to cod, sole..."

Claire: "...the fish can compete with other fish I buy, and if the price is lower it should sell well."

4.2.3.5 Factors affecting consumer's purchasing decision toward fish fillets

The following were main factors the participants found in common and of importance when making a fish purchasing decision: (1) Flavor: flavor is the most important characteristic for almost all participants. However, flavor cannot be determined prior to purchases. Thus, this only applies to the fish that they have experienced before. To be desirable for them, the flavor must be pleasant, desirable, and typical for that fish:

Pat: "...the new fish gets one chance to taste good. If it does not I will not buy it again."

Pam: "...I would rely on other characteristics when buying for the first time (i.e., appearance). But the flavor will determine whether I purchase it again,"

(2) Appearance: although the participants are not always able to smell the fish prior to purchases, they can determine from the appearance what its taste may be. Joy said "...I would go by appearance, to look for characteristics similar to fish I do know, for example cut, color,..." Participants felt appearance was psychological, because it could attract them to buy or not buy the fish, (3) Price: as long as the fish is palatable, most participants will usually choose the fish with a lower price. To them, there is nothing wrong with a lower priced fish. However, the single individuals or those who infrequently consume fish are more willing to pay a higher price, given the fish is what they like. Claire added "...I think this is also because buying one fillet is, of course, cheaper than six. I would need six or seven of them..." Pam supported that "...single people buy for themselves and not family. They don't have

to please others preferences," (4) Thickness of fillet: thick pieces of fish provide a desirable texture. Some participants ranked texture as the second most important characteristic, (5) Texture: some participants stated they are not concerned with texture. As long as the fish texture is consistent and true to species, they do not expect the fish (e.g., sole) to be real firm. They actually look for more than one texture.
Some participants are uncertain whether it is the texture, or the way they cooked the fish that caused the undesirable texture:

Rose: "...overcooking can cause an undesirable texture..."

Claire: "I have poached fish and found that it firmed up in the water cooking but if left too long it became mushy or watery."

Pam: "...I don't have a lot of experience preparing fish. If something seems wrong, I blame my cooking ability first..."

The participants were asked if the following factors were important to them when making a fish purchase decision. Most stated these were not main concerns in their purchasing decision. (1) year-round availability: There are several seafoods available only for certain seasons, e.g., crab. Year-round availability was not that important as long as they knew the species availability. If the participants enjoyed a particular seasonal fish, they would purchase the fish during its season, (2) recipe attached: The participants felt that a recipe could be found anywhere. They felt a recipe was desirable for an inexperienced cook, but otherwise an added bonus. If a fish is new in the market, however, it will be good to provide a recipe, (3) advertising/ promotion: Most participants indicated they looked for sales. Rose noted that she has never bought a whole salmon before, but when the unit price (price/lb) was cheaper, she does not hesitate to buy it, and (4) low fat and cholesterols claim: All the participants view fish as a healthy food choice. Table 4.2.7 shows how each participant rated each characteristic for its importance in their fish purchasing decision.

4.2.3.6 Purchase decision of one fish compared to another

The types of fish the participants purchase depended on several factors and individual situations. Most of participants looked for the fish on sale. For example, some participants usually do not buy scallop, but they are likely to buy it when it is on sale. Participants who were single were less concerned with the price. They felt price would increase in priority if their living status changes (i.e., having a family). Some of the participants frequently buy the same fish because they are familiar and have the handling experience of that particular fish. Claire purchases fish every Friday because of religious traditions, and price is her primary concern. Others who occasionally invite guests for a meal stated that this affect their purchasing decision:

Joy: "...I might buy a slightly "better" fish (i.e., halibut over cod) for guests..."

Pam: "...I will prepare something I have had success with when I have company..."

Sue: "...lower priced fish is for casual meal, while higher priced fish is for special meal..."

Table 4.2.7 The modified multiattribute model form used in the focus group study.

Please rate the order of importance of each characteristic. The lowest number (1) means the characteristic is the least important to you. The highest number (10) means the characteristics is the most important.

Characteristics	Participant #								
	Pam	Gail	Jane	Joy	Sue	Claire	Kim	Rose	Pat
Appearance	10	7	10	7	6	8	9	8	10
Odor	6	8	9	4	10	6	8	7	6
Flavor	8	10	8	10	9	10	10	10	8
Texture	9	9	7	5	5	5	7	9	1
Thickness of fillet	7	6	6	6	4	7	6	6	2
Low in fat and cholesterol	4	4	5	8	8	4	5	4	5
Low price	5	5	3	9	7	9	4	5	9
Year-round availability	3	2	1	2	1	1	3	1	3
Advertising/promotion	2	3	2	3	2	2	1	3	4
Recipe attached	1	1	4	1	3	3	2	2	7

Pat: "...some fish can smell when cooking--not a great atmosphere for company..."

Kim: "If I am having guests I will usually spend more on the dinner to make something special," "...If I have extra money in my budget I am more likely to splurge. If it's the end of the month and not much money is available I would be looking for a bargain..."

Claire: "...for a large number of people a fish stew would be delicious and affordable because you can use the less expensive fish. Salmon steaks for a large number of people would discourage me because of cost..."

4.2.3.7 Purchasing behavior of participants toward fish

Each participant has a different buying style. All believed fish was good for their health. They usually purchase fish when it looked pleasing and was reasonably priced. Some do not search for more information prior to the purchase of the fish:

Pat: "I assume that the more expensive fish will be high quality. I prefer familiar fish to trying something new..."

They rely on their experience with the fish for future purchases. For those participants who also search for more information, they were concerned with the price per quantity of fish:

Claire: "I would want to know how much it cost, where it was caught, how it was handled between the time caught and when it arrived at the store. I would want to know what its taste was similar to (other fish) and how it was recommended to cook it."

Joy: "With three kids, I look for the best type of fish for the lowest price. I won't buy fish I don't like just because it is cheap; but I won't buy fish I like if it is too expensive."

4.2.3.8 Cooking methods for Pacific whiting IQF fillets

PAC was provided to each participant to take home and cook as they would normally cook fish. They were also asked to cook the PAC with a microwave oven without any seasonings. In general, most participants found cooking with a microwave oven to be easy, fast, and clean. They stated they can place the fish on a plate and just add seasonings. Many of the participants thought PAC was better (i.e., "...texture firms up") when cooked in a microwave oven.
The appearance characteristics of PAC found desirable by the participants (Table 4.2.8) were its overall appearance (i.e., shape, thickness, cutting), even color, and flaky appearance. After the fish was cooked in a microwave oven, the participants found the mild fresh fish smell to be desirable. Before trying the microwave oven cooking at home, most of the participants baked their fish. Frying and broiling were also common cooking methods. For most of them, this was the very first time they had used a microwave oven to cook fish (i.e., except for one individual--Gail). All but Claire and Kim enjoyed the fish when cooked in the microwave oven. However, they believed the fish would have a better taste if they had the time to cook the fish in an oven. The two participants who did not prefer the microwave oven cooking felt the fish had a stronger odor and had an unfavorable texture in some PAC fillets. They thought "...rapid pan-frying fish with little oil was also a good cooking method because it takes about 3-4 minutes and it comes out good." Table 4.2.9 summarizes the participants positive and negative feelings toward flavor and texture of PAC fillet cooked by a microwave oven. As mentioned, most participants thought PAC had a desirable

Table 4.2.8 Participants appearance and aroma descriptions of Pacific whiting IQF fillets cooked by a microwave oven.

Characteristic	Positive	Negative
Appearance	Looks very good	A little crumbly
	Flaky & white	Not uniform in size
	Good and even color	Dark color runs through the center of fish
	No discoloration	Colorless
	Very nice variation of color between pink and white	Bland
	Good thickness	
	Good shape and clean	
Aroma	Pleasant, mild fish odor	Very fishy, strong smell
	Good, fresh fish smell	Stronger than cooking by their own ways
		Strong odor when removed from a microwave (but o.k. when eaten).

Table 4.2.9 Participants flavor and texture descriptions of Pacific whiting IQF fillets cooked by a microwave oven.

Characteristic	Positive	Negative
Flavor	Not too strong	Somewhat too strong
	Not too fishy, not bad tasting	Too bland
	Very nice taste, very tasty	
	Fairly mild	
	Similar to fresh trout (really good)	
	Pleasant flavor	
Texture	Nice, springy, not mushy	Too soft, a little mushy
	Not too soft, not too dry	Soft, very tender
	Very moist & flaky (similar to fresh trout).	Falls apart easily

flavor and texture. Its flavor was mild, not too fishy, and not too strong. PAC to participants had a desirable texture, because it was flaky, not too mushy, and not too dry. The participants who found the microwave cooking of PAC undesirable, felt the texture was too soft.

4.2.3.9 Consumer willingness to try new species of fish

This issue was raised because of the limited knowledge consumers have toward some specific types of fish e.g., PAC. Inexperience and unfamiliarity of a fish may affect their purchasing decisions:

In trying a new fish, participants preferred information indicating the origin of the fish, a reasonable price, recommendations by individuals at seafood counters, a recipe, advice on preparation, and sampling of the product at the point of purchase. Promoting the fish effectively will yield positive word of mouth. The participants indicated they would repurchase a new fish, if the fish tastes good, the family enjoys it, and the price is reasonable. Most participants were willing to try something new:

Kim: "Perhaps samples given out at fish markets would be a way to introduce a new fish. Putting a new fish on sale at a greatly reduced price might convince people to try an unknown flavor..."

Claire: "I think advertising and tasting stands in stores is critical. If the fish was advertised as *tasting like sole* for example, it would encourage people who like sole to try it."

Pam: "...If it is new to me and looks appealing, having a recipe or directions might encourage me to buy it..."

4.2.3.10 What consumers want to tell a fish marketer

Most of participants agreed that it would be useful to know the source of the fish product (i.e., where it comes from and the production process of the fish). In addition, they stated they would prefer a larger variety of fish, more recipes, and nutrition labels.

4.3 Study 3: Correlation of Sensory Texture Properties of Pacific Whiting IQF Fillets Resulting from a Descriptive Analysis with Biochemical and Instrumental Analyses

4.3.1 The Amount of Protease Activity in Pacific Whiting and Other Three Whitings

The means of protease activity (expressed as mmoles of tyrosine released) in four species of whiting is shown in Table 4.3.1.

PAC had the highest amount of protease activity, while CHI had the lowest. ARG, CHI, and PER had low levels of enzyme activity and were not significantly different from one another, but different from PAC. PAC showed the greatest variability (SD=214.05) for a mean of 162.64 mmoles in the enzyme activity. The reason for the high standard deviation becomes clear when the wide range of protease values can be observed (Fig. 4.3.1). Sixty percent of PAC samples contained from 1-100 mmoles. However, 21% of samples contained more than 300 mmoles, thus resulting in a SD larger than the mean.

Table 4.3.1 Means and SD (standard deviation) of protease activity levels in Chilean, Argentinean, Peruvian, and Pacific whiting IQF fillets.

Species	Means of Protease Activity	Range of Protease Activity
Chilean (CHI)	1.073 ^{a} (3.34)	0.00-19.41
Argentinean (ARG)	13.393 ^{a} (11.29)	0.00-48.57
Peruvian (PER)	28.235 ^{a} (53.26)	0.00-335.66
Pacific (PAC)	162.636 ^{b} (214.05)	0.44-796.10
Significance level	0.000	
LSD	42.25	

Note: Means with different letters, ^{a} and ^{b}, denotes a statistically significant difference
: Means are from two replicate samples, n = 90

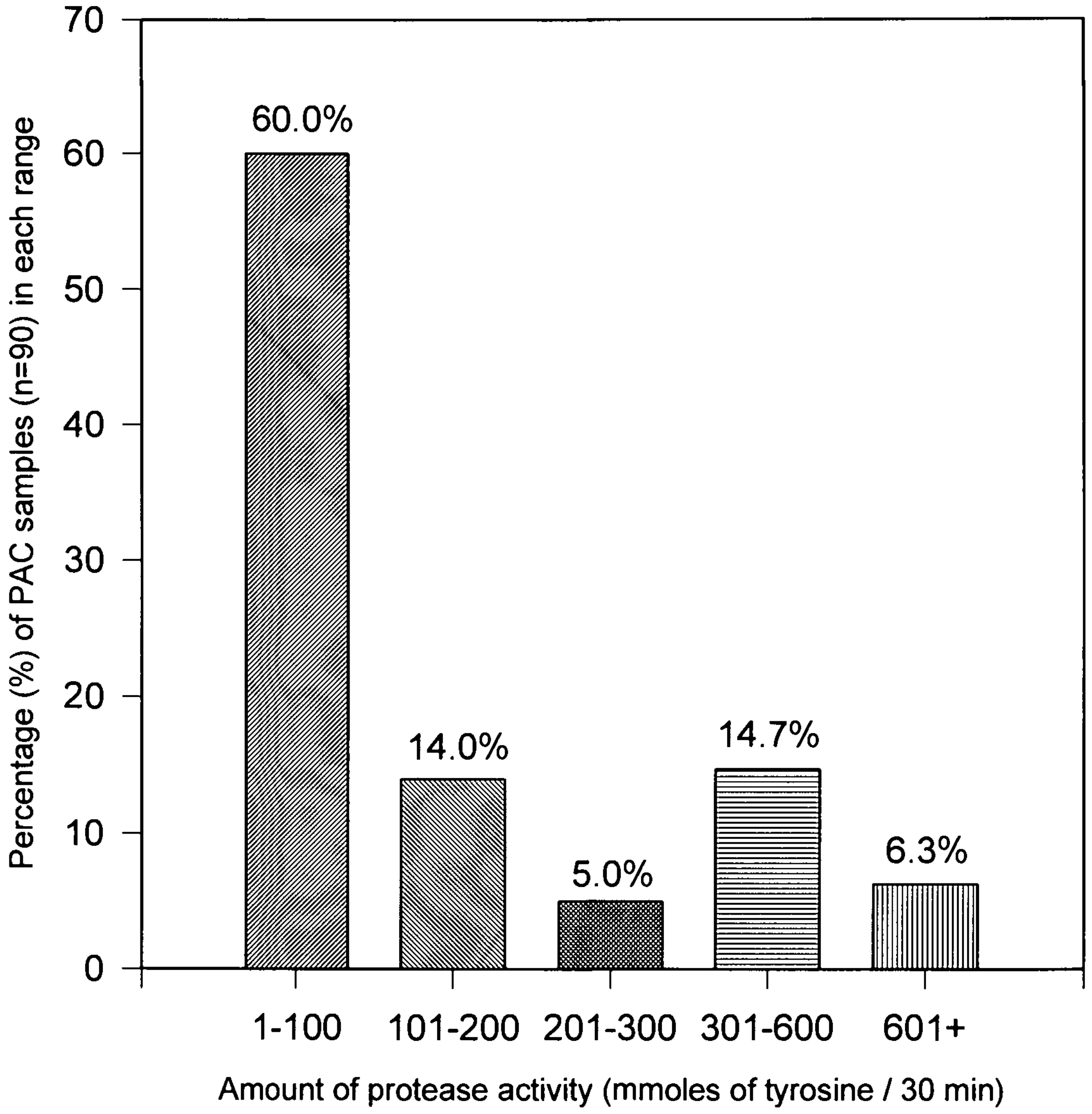


Figure 4.3.1 Distribution of the amount of protease activity in Pacific whiting IQF fillets.

4.3.2 Instrumental Texture Values of All Eight Fish Species

The means of instrumental texture characteristics of all fish is shown in Table 4.3.2. Many degrees of separation were achieved among the samples for all four texture attributes. PAC fell in the middle of the range for all attributes. Hardness1 and hardness2 of the oven-baked PAC was not significantly different from that of CHI, POL, and ARG. Microwave cooking of PAC resulted in higher ratings for hardness and chewiness values, but lower in cohesiveness.

The PCA plot (Fig. 4.3.2) visualizes in space the differences among fish samples and the correlation among attributes. Two principal components (PC) accounted for 99% of the total variance (Table 4.3.3). PC1 was weighted positively by chewiness, hardness2, hardness1, and cohesiveness. PC2 separated the samples based on cohesiveness (positive) and hardness1 (negative). To supplement the graphical information in Fig. 4.3.2, an ANOVA of the means scores on PC1 and PC2 was carried out (Table 4.3.4). The fish were separated well on two axes. PC1 (Fig. 4.3.2) showed a correlation among chewiness, hardness2, hardness1, and cohesiveness on the positive side, while PC2 showed a contrast between cohesiveness on the positive side with hardness1 on the negative side. There were three major groupings of fish (Table 4.3.4) based on the letter superscripts. On PC1, DOV was the sole member of the first group having the least in chewiness, hardness, and cohesiveness, while the second group was the mixtures from PAC (oven) to ROC. PER was the third group. The PC2 showed that the fish having negative means scores were LIN, PAC (microwave), ROC, and DOV. The fish on the positive axis were PAC (oven), POL, ARG, CHI, and PER.

Table 4.3.2 Means and SD (standard deviations) for texture characteristics of individually quick frozen (IQF) fillets of Pacific whiting and seven other whitings and whitefish.

Species	Hardness I		Hardness II		Cohesiveness		Chewiness	
Dover sole	3.79^{a}	(1.55)	3.22^{a}	(1.14)	0.25^{a}	(0.05)	6.99^{a}	(2.88)
Chilean whiting	5.46^{ab}	(0.86)	5.41^{b}	(0.80)	0.41^{d}	(0.05)	16.49^{b}	(4.96)
Pacific whiting (conventional oven)	6.17^{bc}	(1.14)	6.51^{b}	(1.23)	0.34^{bc}	(0.07)	15.40^{b}	(2.97)
Pollock	7.64^{bcd}	(1.51)	6.93^{b}	(1.59)	0.36^{c}	(0.03)	20.06^{bc}	(6.41)
Argentinean whiting	7.84^{cd}	(2.21)	7.39^{bc}	(2.01)	0.37^{cd}	(0.08)	21.26^{bc}	(4.96)
Pacific whiting (microwave oven)	8.90^{de}	(1.79)	9.11^{cd}	(1.83)	0.31^{b}	(0.04)	19.75^{bc}	(7.92)
Peruvian whiting	10.41^{e}	(3.21)	10.51^{d}	(2.98)	0.50^{e}	(0.07)	38.82^{d}	(9.56)
Rockfish	10.86^{e}	(5.51)	10.25^{d}	(4.81)	0.33^{bc}	(0.04)	26.58^{c}	(13.91)
Ling cod	10.91^{e}	(3.20)	9.91^{d}	(3.17)	0.30^{b}	(0.05)	24.29^{c}	(14.08)
Significance Level	***		***		***		***	
LSD	2.19		2.01		0.04		6.90	

Note : Means with different letters within a column denote a statistically significant difference
: The analysis was performed at confidence level of 95%.
: Significant level, ***, refers to significant at $p \leq 0.001$.
: LSD refers to "Least Significant Difference", a criterion serving as a mean separator for a multiple comparison (Petersen, 1985).
: * of two replicate samples, n = 12

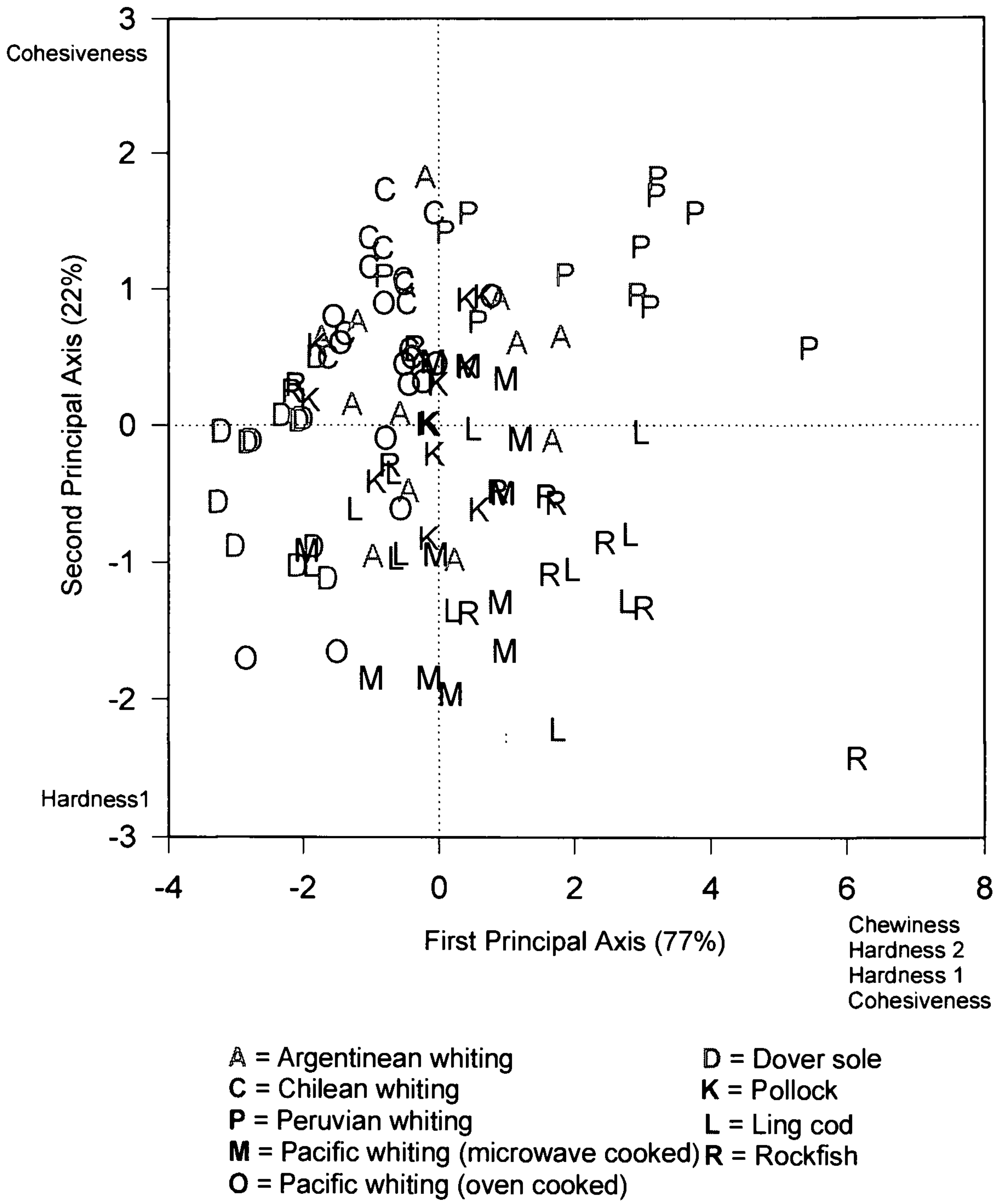


Figure 4.3.2 Principal component analysis: principal axes 1 and 2 of instrumental texture characteristics of eight fish species. Twelve points of a letter represent twelve replications of each species. The data analyzed are from instrumental texture analysis.

Table 4.3.3 Principal component analysis for instrumental texture characteristics of individually quick frozen (IQF) fillets of Pacific whiting cooked by two different methods and seven other whitings and whitefish.

Instrumental Texture Characteristic	Eigenvector	
	Principal Component 1	Principal Component 2
Hardness1	0.533	-0.367
Hardness2	0.546	-0.286
Cohesiveness	0.319	0.876
Chewiness	0.562	0.129
Eigenvalue	3.07	0.89
Proportion (%)	76.63	22.35
Cumulative (%)	76.63	98.98
Characterizing attribute(s)		
Loading (+)	Chewiness, Hardness2, Hardness1, Cohesiveness	Cohesiveness
Loading (-)		Hardness1

Table 4.3.4 Principal component (PC) axis 1 and 2: mean values for instrumental texture characteristics of Pacific whiting cooked by two different methods (conventional and microwave ovens) and seven other whitings and whitefish.

Species	PC1 Means	Species	PC2 Means
Dover sole	- 2.412 ^{a}	Ling cod	- 0.890 ^{a}
Pacific whiting (conventional oven)	- 0.826 ^{b}	Pacific whiting (microwave oven)	- 0.817 ^{a}
Chilean whiting	- 0.752 ^{b}	Rockfish	- 0.653 ^{a}
Pollock	- 0.262 ^{bc}	Dover sole	- 0.341 ^{ab}
Argentinean whiting	- 0.046 ^{bc}	Pacific whiting (conventional oven)	0.058 ^{bc}
Pacific whiting (microwave oven)	0.204 ^{bcd}	Pollock	0.110 ^{bc}
Ling cod	0.668 ^{cd}	Argentinean whiting	0.260 ^{c}
Rockfish	1.044 ^{d}	Chilean whiting	1.029 ^{d}
Peruvian whiting	2.233 ^{e}	Peruvian whiting	1.223 ^{d}
Significance Level	0.000		0.000
LSD	1.081		0.565

However, there were significant differences between the group of PAC(oven)/POL/ARG and CHI/PER.

4.3.3 The Relationship of Biochemical and Sensory Texture Descriptive Analysis

The sensory scores for each textural attribute obtained from the descriptive trained panel and the amount of protease activity were analyzed using correlation analysis. The coefficient of correlation and significant level of each paired variable for both cooking methods are shown in Table 4.3.5. There were correlations between the amount of protease activity in PAC and its sensory texture attributes for the overall trained panel. Cooking PAC in a conventional oven, however, showed higher correlations of protease activity and hardness (-0.49 vs -0.33) and mushiness (0.48 vs 0.41) when compared to cooking PAC in a microwave oven. Among textural attributes (hardness, mushiness, moistness, chewiness, and mouthcoating), mouthcoating ratings appeared to show high correlation with protease activity, followed by hardness, mushiness, and chewiness.

4.3.4 The Relationship Among Sensory Texture Characteristics

There were also correlations among sensory textural characteristics (Table 4.3.5). Hardness negatively correlated with mushiness, moistness, and mouthcoating, and positively correlated with chewiness. Mushiness negatively correlated with chewiness, and positively correlated with moistness and mouthcoating (Table 4.3.5).

Table 4.3.5 Correlation of sensory texture attributes of Pacific whiting IQF fillets cooked by two different methods and the amount of protease activity.

Attribute	Hardness	Mushiness	Moistness	Chewiness	Mouthcoating
Protease Activity	- 0.490[1] (0.000) - 0.333[2] (0.002)	0.483[1] (0.000) 0.414[2] (0.000)	0.272[2] (0.013)	- 0.381[1] (0.001) - 0.426[2] (0.000)	0.522[1] (0.000)
Hardness		- 0.541[1] (0.000) - 0.571[2] (0.002)	- 0.220[1] (0.049)	0.632[1] (0.004) 0.491[2] (0.000)	- 0.450[1] (0.000)
Mushiness			0.522[1] (0.000) 0.261[2] (0.018)	- 0.256[1] (0.021) - 0.419[2] (0.000)	0.590[1] (0.000)
Moistness					0.455[1] (0.000) 0.221[2] (0.046)
Chewiness					- 0.342[1] (0.002)

Note: Pacific whiting IQF fillets were cooked by a conventional oven[1] and microwave oven[2] . Coefficient of correlation are shown. p-value are in parentheses. A blank space in rows represents non-significance in their correlations.

The correlation were generally higher in PAC cooked in a conventional oven.

The fitted model for sensory texture characteristic is shown in Table 4.3.6. The *amount of protease activity* was the independent variable (X) while each *sensory textural attribute* was the dependent variables (Y). The ratings of sensory textural characteristics for the overall trained panel in this study can be explained and determined for both cooking methods (i.e., a microwave and a conventional oven) by the amount of protease activity. The log and square root function in the model explained the relationships of those two variables. Figures 4.3.3 and 4.3.4 show the relationships between sensory hardness (Fig. 4.3.3) and sensory mushiness ratings (Fig. 4.3.4) of PAC cooked in conventional and microwave ovens and the protease activity. Negative and positive correlations were observed in sensory hardness and mushiness, respectively. The relationships can be explained using the equations derived from the fitted model (Table 4.3.6).

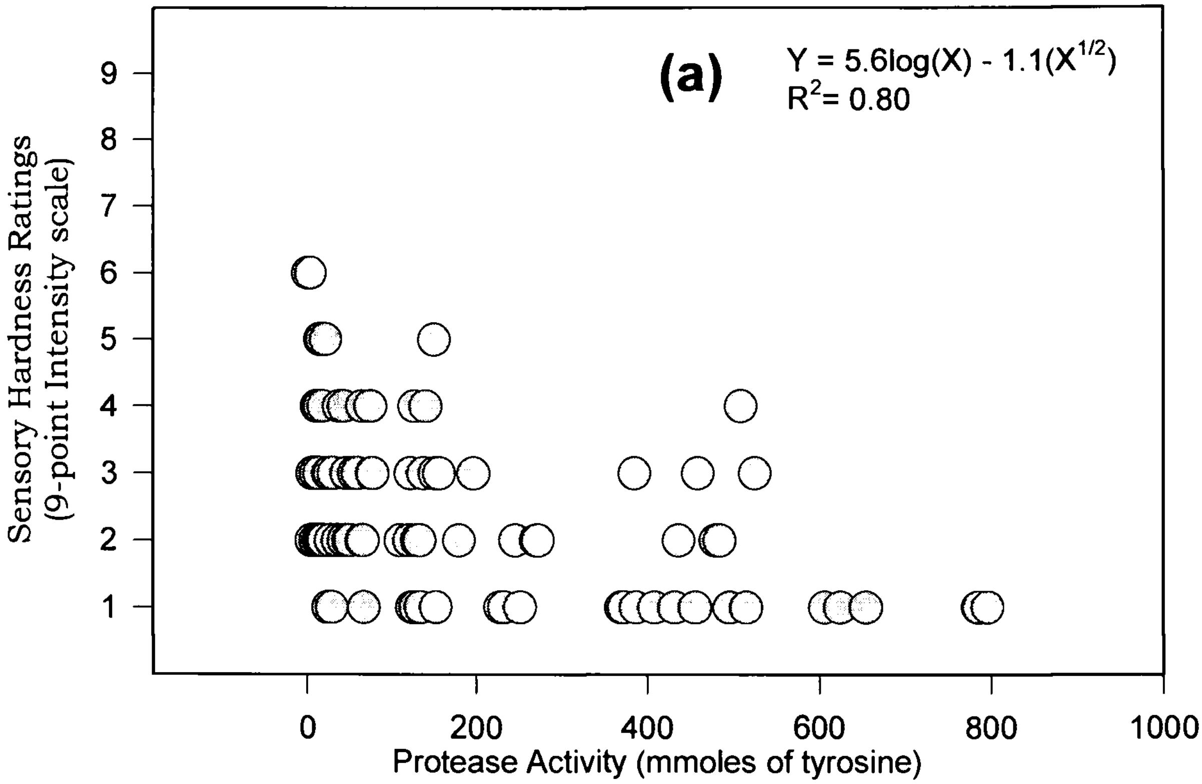
4.3.5 The Relationships of Biochemical and Instrumental Texture Analysis

The texture values obtained from the instrumental analysis (hardness cycle 1 and 2, cohesiveness, and chewiness) were analyzed with the protease activity. It was found (Table 4.3.7) that the instrumental hardness values of PAC (cooked in a conventional oven) and the enzyme activity did not correlate well with each other (-0.28 and -0.24). Instrumental cohesiveness and chewiness values showed higher (negative) correlation with the enzyme activity (-0.47 and -0.47).

Table 4.3.6 Model fitting results for the overall panel of the sensory texture values (Y) of Pacific whiting IQF fillets and the amount of protease activity (X).

Attribute	Sensory texture model	R^2 adjusted	Significant Level
Hardness	$Y = 5.55 \log(X) - 1.09 (\sqrt{X})$[1]	0.80[1]	*** 1
	$Y = 1.45 \log(X) - 0.30 (\sqrt{X})$[2]	0.76[2]	*** 2
Mushiness	$Y = 1.67 \log(X) - 0.13 (\sqrt{X})$	0.91	***
	$Y = 0.90 \log(X)$	0.80	***
Moistness	$Y = 1.93 \log(X) - 0.28 (\sqrt{X})$	0.87	***
	$Y = 1.83 \log(X) - 0.23 (\sqrt{X})$	0.88	***
Chewiness	$Y = 1.55 \log(X) - 0.33 (\sqrt{X})$	0.77	***
	$Y = 2.45 \log(X) - 0.62 (\sqrt{X})$	0.87	***
Mouthcoating	$Y = 2.56 \log(X) - 0.47 (\sqrt{X})$	0.94	***
	$Y = 3.22 \log(X) - 1.15 (\sqrt{X})$	0.89	***

Note: Pacific whiting was cooked by a conventional oven[1] and a microwave oven[2]. The amount of protease activity was obtained from a biochemical analysis. *** refers to significance at $p \leq 0.001$



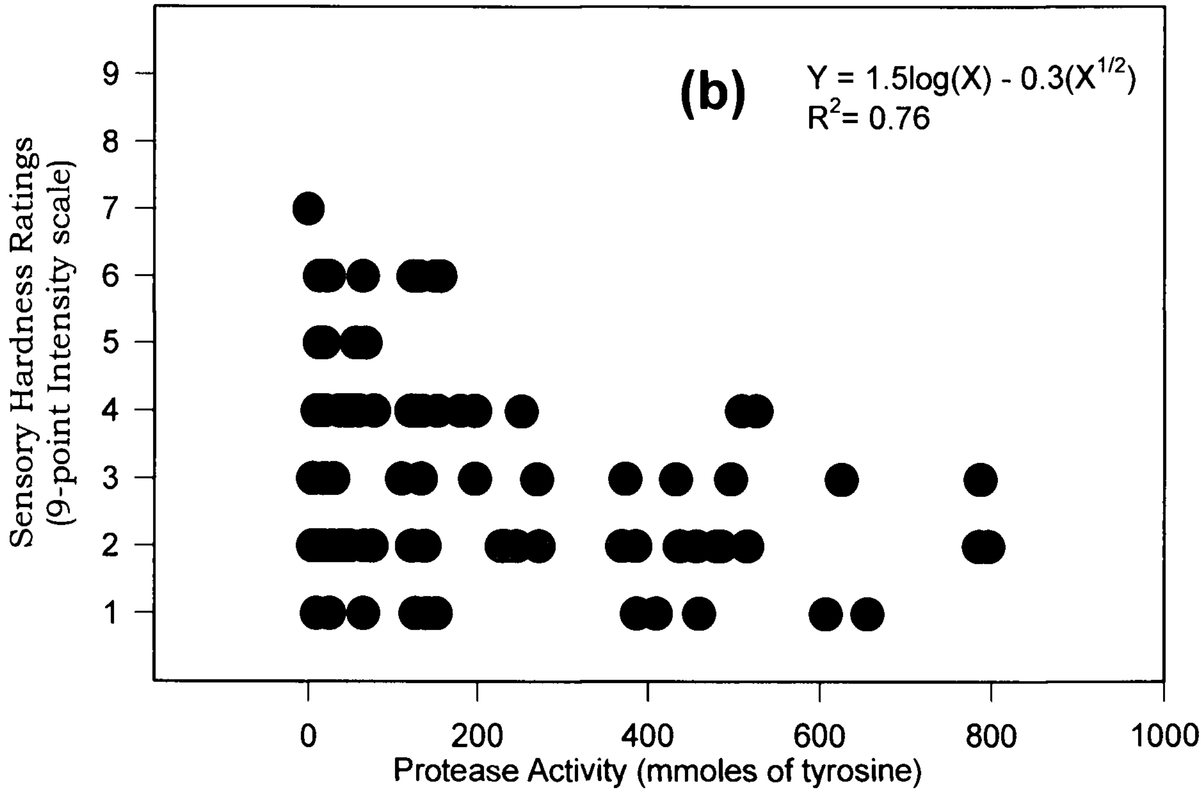


Figure 4.3.3 Correlation of sensory hardness ratings and protease activity of Pacific whiting fillets cooked in conventional (a) and microwave (b) ovens, n=90.

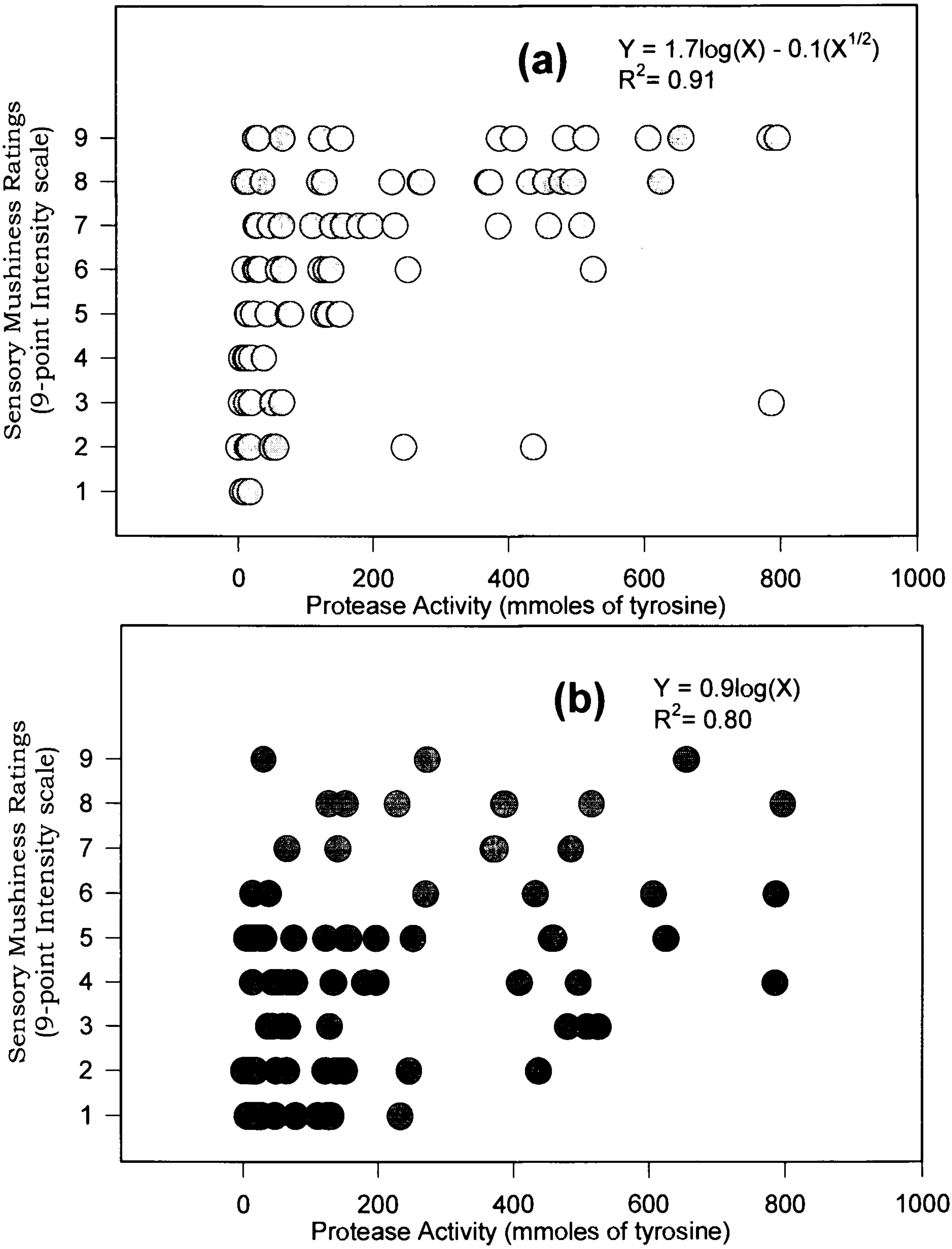


Figure 4.3.4 Correlation of sensory mushiness ratings and protease activity of Pacific whiting fillets cooked in conventional (a) and microwave (b) ovens, n=90.

Table 4.3.7 Correlation of instrumental texture attributes of Pacific whiting IQF fillets from Texture Profile Analysis using a texture instrument.

Attribute	Hardness1	Hardness2	Cohesiveness	Chewiness
Protease Activity	-0.278[1] (0.009)	- 0.240[1] (0.025)	- 0.470[1] (0.000) - 0.215[2] (0.044)	- 0.467[1] (0.000)
Hardness1		0.992[1] (0.000) 0.996[2] (0.000)	-0.218[2] (0.049)	0.861[1] (0.000) 0.861[2] (0.000)
Hardness2				0.845[1] (0.000) 0.875[2] (0.000)
Cohesiveness				0.281[1] (0.011) 0.234[2] (0.034)

Note: Pacific whiting was cooked by a conventional oven[1] and microwave oven[2]. Coefficients of correlation are shown. p-value are in parentheses. A blank cell in rows represents non-significance in their correlations.

Figure 4.3.5 illustrates the correlation of instrumental hardness and protease activity, which was lower compared to that of sensory hardness (Fig. 4.3.3). Feinstein and Buck (1984) studied the relationship of chemical measurements and texture of flounder and cusk. They found that collagen solubility and pH had little or no effect on mechanical texture measurements. Total collagen, sampling location, and age had no effect on texture in the two cooked fish. They indicated that no consistent linear relationships between texture and the chemical measurements were found.

4.3.6 The Relationships Among Instrumental Texture Characteristics

The correlations among the characteristics received from texture profile analysis is shown (Table 4.3.7). Hardness1 was highly correlated with hardness2 (0.99) and chewiness (0.86) for both microwave and conventional cooking. The relationship between instrumental texture values and the amount of protease activity are shown in Table 4.3.8 using the fitted "Regression Models" in Statgraphic version 7.0. Those relationships can also be explained using the log and square root functions.

4.3.7 The Relationship Between Sensory and Instrumental Texture Characteristics

Figure 4.3.6 compares the PCA from both sensory and instrumental texture analysis. DOV and PAC (oven) were on the negative PC1 axis for both instrumental and sensory texture. It was less in

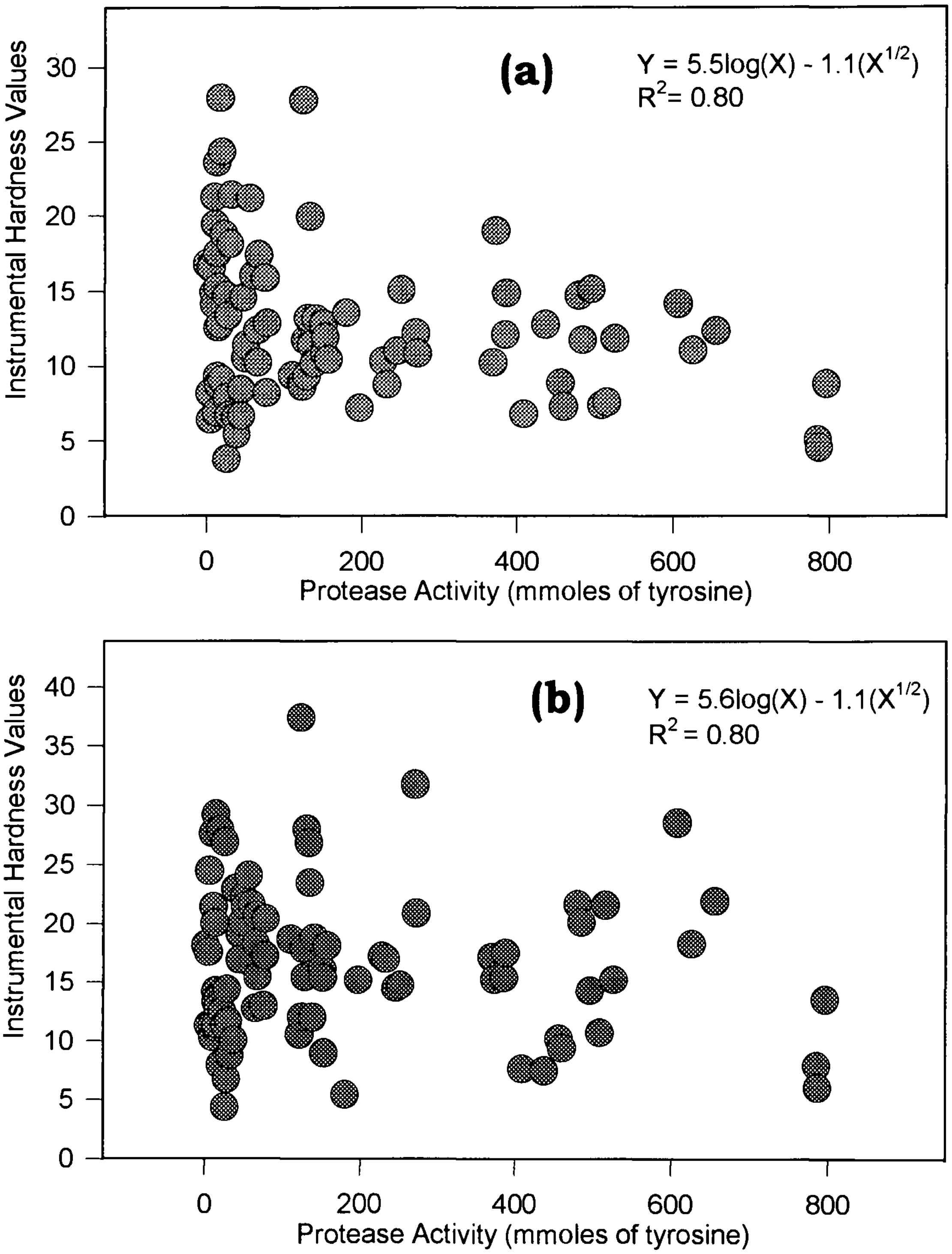


Figure 4.3.5 Correlation of instrumental hardness values and protease activity of Pacific whiting fillets cooked in conventional (a) and microwave (b) ovens, n=90.

Table 4.3.8 Model fitting results for the overall panel of the instrumental texture values (Y) of Pacific whiting IQF fillets and the amount of protease activity (X).

Attribute	Instrumental texture model	R^2 adjusted	Significant Level
Hardness1	$Y = 5.55 \log(X) - 1.09 (\sqrt{X})$[1]	0.80[1]	*** 1
	$Y = 5.56 \log(X) - 1.10 (\sqrt{X})$[2]	0.80[2]	*** 2
Hardness2	$Y = 5.74 \log(X) - 1.11 (\sqrt{X})$	0.80	***
	$Y = 6.81 \log(X) - 1.19 (\sqrt{X})$	0.83	***
Cohesiveness	$Y = 0.18 \log(X) - 0.04 (\sqrt{X})$	0.93	***
	$Y = 0.10 (\sqrt{X}) - 0.01 (X)$	0.95	***
Chewiness	$Y = 18.8 \log(X) - 5.05 (\sqrt{X})$	0.81	***
	$Y = 14.35 \log(X) - 2.67 (\sqrt{X})$	0.83	***

Note: Pacific whiting was cooked by a conventional oven[1] and a microwave oven[2]. The amount of protease activity was obtained from a biochemical analysis. *** refers to significance at $p \leq 0.001$

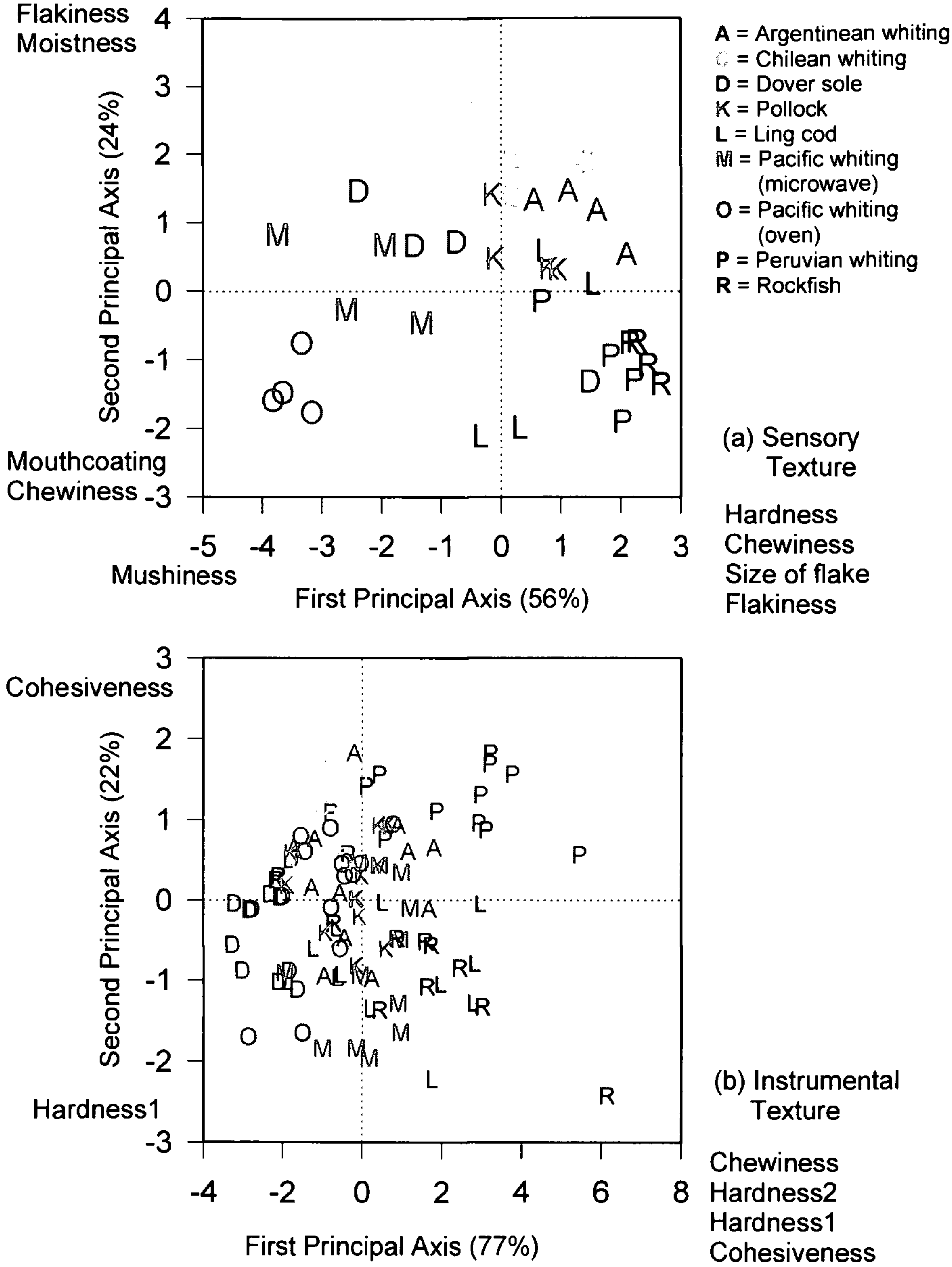


Figure 4.3.6 Principal component analysis: principal axes 1 vs 2 of sensory (a) and instrumental (b) texture characteristics of eight fish species. Four (a) and twelve (b) points of a letter represent replications of each species.

chewiness, hardness, flakiness (sensory texture) and less in chewiness, hardness, and cohesiveness (instrumental texture). PER and ROC were on the positive PC2 axis for both instrumental and sensory texture and were high in hardness, chewiness, and flakiness (sensory) and high in chewiness, hardness, and cohesiveness (instrumental). The remaining fish were mixed and spread around the middle axis. Table 4.3.9 shows the relationship between sensory and instrumental texture. There were low correlations between instrumental and sensory texture values and only PAC cooked in a conventional oven showed significant correlations. Low correlations (0.26) were found between instrumental cohesiveness, chewiness, and sensory hardness ratings for the trained panel. Sensory mushiness ratings (Table 4.3.9) of conventional cooked PAC were negatively correlated with instrumental chewiness (-0.35) for the overall trained panel. Buck et al. (1986) employed Warner-Bratzler shear measurements to investigate the changes in texture in red hake sticks. They found that cooking methods had a highly significant effect on texture. Deep fat frying was significantly higher in shear values than oven baking. Snapper and rockfish were evaluated by Sawyer et al. (1984) using a punch and die test cell. Sensory and instrumental data showed good correlations between both sensory hardness and chewiness and the instrumental parameter of maximum shear stress. However, the correlation between flakiness and strain at failure was not as good as obtained for the attributes of hardness and chewiness.

In conclusion, there were good correlations between sensory texture scores of PAC IQF fillets and the amount of protease activity in the fillets. The correlations were especially high in PAC cooked in a

Table 4.3.9 Correlation of sensory and instrumental texture attributes of Pacific whiting IQF fillets from a sensory descriptive panel and Texture Profile Analysis.

Sensory	Instrumental Texture			
Texture	Hardness1	Hardness2	Cohesiveness	Chewiness
Hardness			0.258[1] (0.020)	0.264[1] (0.018)
Mushiness				- 0.346[1] (0.002)
Moistness				
Chewiness				
Mouthcoating				- 0.244[1] (0.026)

Note: Pacific whiting was cooked by a conventional oven[1] and microwave oven[2]. Coefficients of correlation are shown. p-value are in parentheses. A blank cell in rows represents non-significance in their correlations.

conventional oven. Cooking PAC in a microwave oven did not show good relationship with protease activity compared to a conventional one. This suggests that fast cooking methods such as a microwave cooking substantially reduces the effect of protease activity on texture of the PAC fillets. The undesirable texture characteristics of fish resulting from a slow conventional cooking could be restrained.

The instrument chosen for this study (i.e., uniaxial compression test) was to imitate the trained panel's sensory hardness evaluation technique. The instrumental analysis did not result in high correlation between instrumental hardness and the protease assay. The results showed its correlation was lower than that of the trained panelists, as lower linear correlation coefficients are shown (Table 4.3.7). However, instrumental cohesiveness and chewiness showed higher correlation with the protease activity. Instrumental hardness could possibly be measured and correlated better using other techniques. This could include the Warner-Bratzler shear as performed by Buck et al. (1986), a punch and die test cell as employed by Sawyer et al. (1984), or Kramer-Shear-Cell which proved to be a very useful means for describing the sensory firmness of various fish products (Borderias et al., 1983; Ma et al., 1983).

Based on rheological measurements on foods, the instrumental analysis generally are complicated by the following facts (Bourne, 1982): (1) foods especially fish are generally heterogeneous. They often consist of discrete components such as fibres, cells, fat crystals and droplets, air bubbles, and protein particles. Therefore, relatively large samples must be used compared with the dimensions of the heterogeneity (1.3 x 1.3 cm piece samples were used throughout the study), (2) the rheological behavior of foods is generally non-linear, and (3) the rheological properties of foods generally depend on their deformation history. Manipulation of the sample prior to the actual measurement and the actual measurement itself can have a dramatic effect on the rheological properties of the materials (Prins and Bloksma, 1983). Casiraghi et al. (1985) also found that a response of a material under uniaxial compression depends both on the bulk material properties and on the frictional effects at the sample-platen interface. Those reasons partially explain why evaluating fish hardness with instrumental technique in this study was difficult, and why its sensitivity to the protease activity was lower than that of sensory texture descriptive analysis.

A properly trained texture descriptive panel complies with the two criteria of objectivity: (1) freedom from personal bias and (2) repeatability. The data obtained were partly quantitative and partly descriptive, but always objective because the panelists were trained to take an analytical approach and use intensity scaling, not acceptability scaling.
The panelists were trained to observe and record data, not allowing their personal likes and dislikes to influence their results. The study showed that the results were repeatable.

In this study, advantages of the sensory texture descriptive analysis over instrumental method are shown. This particular scientific instrument (the trained mouth) can measure a number of textural parameters (i.e., mushiness, moistness, and mouthcoating) that could not be measured by the instrumental method. In this study, it measured a given textural parameter with greater linear correlations with the protease activity than the instrumental texture analysis employed.

CHAPTER 5. CONCLUSIONS

5.1 Summary

This study was an initiator to systematically investigate consumer acceptability of Pacific whiting IQF fillets. Sensory property characteristics of Pacific whiting fillets was, for the first time, evaluated. Its unique texture characteristics was also studied in correlation to its intrinsic quality (i.e., proteases). The findings should be helpful to marketers and processors who are interested in either in IQF fillet or future product design.

5.1.1 Study 1: Sensory Characteristics of Pacific Whiting and Other Whitings and Whitefish

Sensory properties of Pacific whiting IQF fillets determined by a sensory trained panelists can be summarized as follows: (1) *appearance profile*: medium to medium dark in color intensity, and medium flake size when compared to the rest of the commercial fish studied, (2) *aroma profile*: moderate in fresh fish aroma; slight to moderate in fishy and salty; and slight in nutty and buttery aroma, (3) *flavor profile*: medium in overall flavor intensity and fresh fish flavor; slight to medium in fishy, shellfish, nutty and buttery flavor, and sweetness; and slight in saltiness, and (4) *texture profile*: medium in flakiness and toothstickiness; slight to medium in size of flakes in mouth, hardness, and chewiness; and above medium in mushiness, moistness, and mouthcoating.

A number of sensory characteristics of Pacific whiting IQF fillets were similar to the highest rated fish species evaluated in this study (i.e., Chilean). The trained panelists rated Pacific whitings' shellfish flavor as the highest of all the fish evaluated. Hardness of Pacific whiting IQF fillets was similar to Chilean whiting, and its mushiness was similar to Dover sole when cooked in a microwave. Cooking by a microwave oven improved texture attributes (i.e., increased flakiness, hardness, chewiness, and reduced mushiness and mouthcoating). Yet, microwave cooking did not change aroma and flavor characteristics of Pacific whiting. Therefore, cooking by a rapid method is highly recommended given improved texture characteristics, but not a loss in aroma and flavor characteristics.

5.1.2 Study 2: Consumer Acceptability of Pacific Whiting IQF Fillets: Consumer Testing and Focus Group Sessions

Results of the consumer testing showed surveyed consumers to have an overall favorable opinion of Pacific whiting IQF fillets. Additionally, texture Hedonic scores for Pacific whiting were not different from most commercial fish studied. Its firmness scores were just-right for more than 54% of the consumers. The consumers did not find texture to be a negative attribute of Pacific whiting IQF fillets. One-year old and one-month frozen storage Pacific whiting were similar in acceptability for all main characteristics. That is, if stored and handled properly, there would not be a detectable difference between the one year and one month frozen storage Pacific whiting fillets, and consumers would not perceive them differently. These results suggest that marketers may be able to supply Pacific whiting IQF fillets yearly. Results also suggest that if the price is competitive, the product will be successful in the market.

The focus group study showed flavor as the most important factor affecting participants purchase decision, also exhibited in the consumer testing. For the participants, texture and other factors were not as important as flavor, appearance, price, and thickness of fillets.
The flavor must be fresh, mild, pleasant, and not overpowering.
Strong fishy flavor, found in Peruvian whiting, was undesirable.
There were also sensory characteristics considered important: color consistency, fresh fish aroma, fishy aroma, overall flavor intensity, fresh fish flavor, fishy flavor, and shellfish flavor. Hardness, mushiness, moistness, and flakiness were the most important concerns for texture. Pacific whiting's mild fresh fish odor, flavor, and flaky texture elicit positive feelings from the participants. In general, the Pacific whiting IQF fillets were acceptable to these focus group participants. They were willing to purchase the Pacific whiting IQF fillet if the price was competitive. They indicated they would repurchase the product as long as the flavor was mild and favorable. Pacific whiting's market success will depend on how marketers introduce the product, and how they educate both retailers and consumers on the handling of the fish to bring out its desirable characteristics.

5.1.3 Study 3: Correlation of Sensory Texture Properties of Pacific Whiting IQF Fillets Resulting from a Descriptive Analysis with Biochemical and Instrumental Analyses

There were correlations between the amount of protease activity in Pacific whiting IQF fillets, and its sensory texture characteristics for both cooking methods. Cooking in a conventional oven showed higher correlations of the enzyme activity with hardness, mushiness, and mouthcoating. Correlations between the amount of protease activity and texture instrumental values were high only at a higher level of activity for both cooking methods. In this study, the sensory profile analysis was more sensitive to the amount of protease activity than the instrumental analysis. There were also correlations among attributes of sensory texture and instrumental texture characteristics. Hardness negatively correlated with sensory mushiness and moistness, and positively correlated with chewiness and cohesiveness of the instrument.

Sensory evaluations are the ultimate method for calibrating instrumental analysis of texture measurement. Even though sensory methods are generally time consuming, expensive, and not subject to absolute standards, important insights can be gained through measurements of the subjective human senses, as in a consumer testing and focus group discussions. The results here show that an objective measurement should be calibrated against the subjective human senses. That is, given the human palate sends a valued judgment message saying the food has undesirable textural properties, then the texture is undesirable regardless of the readings obtained by any instruments.

5.2 Implications of The Studies

1. The obtained sensory profiles can be used as a basis for either future Pacific whiting sensory study or product design. Having a based characters set help assist in strengthen the desired attributes and weaken the undesirable characteristics for a future specific market.

2. The findings suggest that marketers and retailers could launch Pacific whiting as a value-added product, IQF fillets, without aversion from consumers. However, they must provide appropriate handling and cooking recommendation, sell at a competitive price, and promoted effectively.

3. Based on focus group discussions, if the product is properly introduced to the market, it could be a substitute for other whitefish such as Pacific cod, ling cod, rockfish, sole, pollock, and orange roughy.

4. Consumer testing on one-year frozen storage Pacific whiting IQF fillets suggests a year long market product provided there is proper freezing and handling methods.

5. Individuals who are properly trained could be used to detect mushiness of cooked Pacific whiting fillet. Thus, they could be helpful in Quality Assurance to monitor softening problem in fish flesh.

6. Nowadays, sensory properties and consumer expectations play an important part in the food industry. Results of a profile panel, consumer panel acceptance/aversion, and integration of sensory evaluation and market research can be used in a fish industry or in fish future sensory research.

5.3 Recommendations for Future Research

1. There are two modes of sample presentations that should be considered in conducting sensory evaluation experiments on consumers: (1) monadic presentation (panelists rate only one sample per session) and (2) side-by-side presentation (samples are presented simultaneously). McBride (1986) found no significant difference between the two grades of sultanas on any of the sensory properties presented in single mode. But in the side-by-side condition the difference is highly significant on all sensory properties. Further research in consumer testing may investigate consumers' perception on Pacific whiting fillet without comparison to other species, or under normal usage.

2. To optimize Pacific whiting resources, further exploratory research should concentrate on determining other consumer acceptable value-added Pacific whiting products.

3. Increasing the use of focus groups in future research will assist in receiving added insights and information of customer perceptions of fish from different types of consumers group.

4. Having a trained panel separately evaluate the whole fish fillet, researchers would get more information on appearance of fish species in a big picture rather than having them solely evaluate 0.5 X 0.5 pieces of fish.

5. Even though there were correlations in sensory texture ratings of trained panelists and amount of protease activity, this study did not investigate at what enzyme activity amount did a panelist start perceiving fish flesh mushiness. Future work could be done to concentrate on quantifying the amount, if possible.

6. Since this study investigated only the instrumental technique that simulate trained panelists' technique when evaluating fish flesh *hardness*, researchers should also consider finding other instrumental texture equipments or techniques that could correlate well with the protease amount in the fish or other sensory texture characteristics.

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APPENDICES

APPENDIX A

Survey Instrument

Appendix A 3.1 A ballot used in the sensory descriptive analysis of Pacific whiting IQF fillets and seven other commercial whitings and whitefish.

DESCRIPTIVE ANALYSIS 1

Panel Name:
Date:

Directions: You are to descriptively evaluate samples of fish fillet. Using the ballot which comes with possible descriptors, write down any additional perceptions to describe the aroma, appearance, flavor, and texture. Proceed slowly and thoughtfully remembering that adaptation may occur. Nine (9) point intensity scale is used for each attribute. Assign number where appropriate for each sample.

DESCRIPTORS

1. AROMA

DESCRIPTOR	286	325	694	872
Fresh fish				
Fishy				
Salty				
Nutty				
Buttery				
YOUR OWN DESCRIPTORS				

2. APPEARANCE

DESCRIPTOR	286	325	694	872
Color Intensity				
Flake size				
YOUR OWN DESCRIPTORS				

Appendix A 3.1, Continued

3. FLAVOR

DESCRIPTOR	286	325	694	872
Overall flavor intensity				
Fresh fish				
Fishy				
Shellfish				
Nutty				
Buttery				
Sweet				
Salty				
Bitter				
YOUR OWN DESCRIPTORS				

4. TEXTURE

DESCRIPTOR	286	325	694	872
Flakiness				
Size of flake				
Hardness				
Mushiness				
Moistness				
Tooth stickiness				
Chewiness				
Mouthcoating				
YOUR OWN DESCRIPTORS				

Appendix A 3.2 A ballot used in the sensory descriptive analysis of Pacific whiting IQF fillets cooked with two different methods, and three other whitings.

DESCRIPTIVE ANALYSIS 2

Panel Name:
Test Date:

Instruction: In front of you are 5 samples of individually quick frozen (IQF) fillets. Rate each sample for each attribute using a 9-point category scale. Place each sample a NUMBER (1 to 9) which best describes its intensity as you perceived.

Attribute	**Sample No.**				
	286	**325**	**694**	**872**	**913**
1. Aroma					
Fresh fish (+)					
Fishy (-)					
2. Flavor					
Overall flavor intensity					
Fresh fish (+)					
Fishy (-)					
3. Texture					
Mushiness					
Hardness					
Moistness					
Chewiness					
Mouth coating					

Appendix A 3.3 A nine-point Hedonic scale used in the questionnaire in the consumer testing.

: used to indicate degrees of unacceptable to acceptable.

: used in questions of general appearance, overall liking, overall flavor, and texture.

- ☐ Like extremely
- ☐ Like very much
- ☐ Like moderately
- ☐ Like slightly
- ☐ Neither like nor dislike
- ☐ Dislike slightly
- ☐ Dislike moderately
- ☐ Dislike very much
- ☐ Dislike extremely

Score: Dislike extremely = 1

Like extremely = 9

Appendix A 3.4 A five-point Just Right scale used in the questionnaire in the consumer testing.

: used to assess the intensity of an attribute of interest relative to some mental criterion of the subjects.

: used in the questions of thickness of fillet, color, flavor intensity, and firmness.

: An example,

- ☐ Too dry
- ☐
- ☐ Just right
- ☐
- ☐ Too moist

Score: Too dry = 1, Just right = 3, Too moist = 5

Appendix A 3.5 A five-point Purchase Intent scale used in the questionnaire in the consumer testing.

: used to indicate degrees of unacceptability to acceptability based on participants' willingness to buy.

- ☐ Definitely would buy
- ☐ Probably would buy
- ☐ Maybe/ Maybe not
- ☐ Probably would not buy
- ☐ Definitely would not buy

Score: Definitely would not buy = 1
Definitely would buy = 5

Appendix A 3.6 The questionnaire used in the consumer testing.

In front of you are 4 samples of individually quick frozen (IQF) fish fillets. Please read the instructions for each question before marking your answer. If you have any questions, please ask for help from one of the technicians. Circle a number that corresponds to your level of satisfaction for each sample.

ANSWER QUESTIONS #1 TO #3 BEFORE TASTING SAMPLES

1. How much do you like or dislike the general **appearance**?

Sample	Dislike Extremely		Dislike Moderately		Neither Like nor Dislike		Like Moderately		Like Extremely
#286	1	2	3	4	5	6	7	8	9
#325	1	2	3	4	5	6	7	8	9
#694	1	2	3	4	5	6	7	8	9
#872	1	2	3	4	5	6	7	8	9

2. How do you like or dislike the **thickness**?

Sample	Too Thick		Just Right		Too Thin
#286	1	2	3	4	5
#325	1	2	3	4	5
#694	1	2	3	4	5
#872	1	2	3	4	5

Appendix A 3.6, continued

3. How do you like or dislike the **color**?

Sample	Too Light		Just Right		Too Dark
#286	1	2	3	4	5
#325	1	2	3	4	5
#694	1	2	3	4	5
#872	1	2	3	4	5

PLEASE **TASTE** THE SAMPLES AND ANSWER THE REMAINING QUESTIONS

4. How much do you like or dislike these samples **overall**?

Sample	Dislike Extremely		Dislike Moderately		Neither Like nor Dislike		Like Moderately		Like Extremely
#286	1	2	3	4	5	6	7	8	9
#325	1	2	3	4	5	6	7	8	9
#694	1	2	3	4	5	6	7	8	9
#872	1	2	3	4	5	6	7	8	9

Appendix A 3.6, continued

5. How much do you like or dislike the overall **flavor** of these samples?

	Dislike Extremely		Dislike Moderately		Neither Like nor Dislike		Like Moderately		Like Extremely
Sample	1	2	3	4	5	6	7	8	9
#286	1	2	3	4	5	6	7	8	9
#325	1	2	3	4	5	6	7	8	9
#694	1	2	3	4	5	6	7	8	9
#872	1	2	3	4	5	6	7	8	9

6. How do you like or dislike the **fish flavor intensity**?

Sample	Too Light		Just Right		Too Strong
#286	1	2	3	4	5
#325	1	2	3	4	5
#694	1	2	3	4	5
#872	1	2	3	4	5

7. How much do you like or dislike the **texture** of these samples?

Sample	Dislike Extremely		Dislike Moderately		Neither Like nor Dislike		Like Moderately		Like Extremely
#286	1	2	3	4	5	6	7	8	9
#325	1	2	3	4	5	6	7	8	9
#694	1	2	3	4	5	6	7	8	9
#872	1	2	3	4	5	6	7	8	9

Appendix A 3.6, continued

8. How do you like or dislike the **firmness** of these sample?

Sample	Too Soft		Just Right		Too Hard
#286	1	2	3	4	5
#325	1	2	3	4	5
#694	1	2	3	4	5
#872	1	2	3	4	5

9. After tasting these products, how likely would you be **to buy** them, if the price is competitive?

Sample	Definitely Would Not Buy		Might or Might Not Buy		Definitely Would Buy
#286	1	2	3	4	5
#325	1	2	3	4	5
#694	1	2	3	4	5
#872	1	2	3	4	5

Appendix A 3.6, continued

10. How important are the following characteristics to you when purchasing seafood?

	Not Important				Very Important
Appearance	1	2	3	4	5
Flavor	1	2	3	4	5
Texture	1	2	3	4	5
Price	1	2	3	4	5

11. Please tell us about yourself.

a). What is your gender? __________ Female __________ Male

b). What is your age?

___ under 18 ___ 18-29 ___ 30-44 ___ 45-59 ___ 60+

c). How many people are in your household including yourself?

________ (please specify)

d). What was your approximate 1993 household income before taxes?

_____ less than $20,000 _____ $20,000 - $40,000

_____ $40,001 - $60,000 _____ $60,001 - $80,000

_____ greater than $80,000

Appendix A 3.6, continued

e). What is your level of education?

___high school or less ___tech./community college

___4-yr. college ___graduate degree

f). Where do you live?

___Oregon Coast ___Willamette Valley

___Central/Eastern Oregon ___outside Oregon

g). Are you the primary person responsible for buying seafood in your family?

___ Yes ___ No ___ Equally shared

h). How often do you consume seafood?

___ 2-3 times/week ___ once/week ____ twice/month

___ once/month ___ less than once a month
(please specify)

i). Where do you purchase the majority of your seafood?

___ Store ___ Fast-food ____ Restaurant

___ Seafood Market _________ Other
(please specify)

Thank you for participating in the OSU Seafood Laboratory Survey. Please notify an attendant that you are finished. Don't forget to pick up a candy and enjoy the Oregon State Fair!

APPENDIX B

Focus Group Participants' Autobiographies

Focus group participant #1: Pam

Pam, 33
Married
Full-time job
$20K-40K

"I am very active. My husband and I enjoy camping, hiking, whitewater rafting, and kayaking. We spend a great deal of time training our hunting dog. We are usually outdoors. I grew up in a large family of nine. I am the only one of my family living on the west coast."

"I try to choose healthy foods. I don't like to cook. Sometimes the easiest food to prepare is not as healthy as I like. I choose fresh foods before processed or frozen foods. Cost is also important. I try to get the most with my money. But sometimes I will get something special."

"Usually I purchase fresh fish. Sometimes I'll purchase frozen if I'm familiar with it. I usually purchase items I've tried before and seldom purchase something unfamiliar."

"My involvement when making a purchase decision toward fish is not much different than other foods. Its appearance is what I base my decision upon."

"Like meat, I look for freshness (color and meatiness) of the fish product. I like to know if it will work in the dish I am preparing. I look for items which don't require a lot of fuss."

Focus group participant #2: Kim

Kim, 42 Married Full-time job $60K-80K	"I have a very active lifestyle. I participate in running, kayaking, and softball. My schedule is very busy with school and a new baby. I am from a middle class family and have a fairly typical American upbringing. My home currently would also be considered middle class."

"I chose food primarily based on flavor and secondary based on health. I don't eat or buy much beef. I like seafood, chicken, and pork. Spice is important in the foods I cook. I don't like bland food. I would chose food with better flavor that cost more over food that is cheap but not flavorful." "I purchase fish fairly regularly. I usually shop at the Bay City Crab Co., in Corvallis or at the fish department of Albertsons grocery. Occasionally, I will buy pre-packaged fish at other supermarket. I probably purchase chicken more frequently than fish, almost two times as often. I purchase more fish than pork and almost never purchase beef. Fish is usually more of a treat to eat not as everyday as chicken."

"I look for fish that I like the flavor of and that is a good price. If it is fresh caught in the fish market I am more inclined to purchase it... Most importantly the fish must have a flavor that I like. If the fish isn't flavorful, I won't be inclined to eat much of it."

Focus group participant #3: Sue

Sue, 47
Married
Homemaker
$20K-40K

"I am a wife. I am a mother of four children... They are all home at this time. I have a college degree in Home Economic Adult Education and a second in Nutrition. I like to cook and make many meals from scratch. Our family like entertain and we love to cook for each event."

"We eat a variety of meats, wild and domestic. We try to vary from red meats, poultry, fish, cheese, for protein sources. I like fresh sources when available but used frozen and canned when the need arises. I like to try new recipes at least once a week. Our family votes on the recipe whether to do again or not. I feel this is a way to get my family to try new things."

"... We eat a variety of protein sources, fish being one. I try to buy it fresh and witching a budgeted amount. We try to stay with fish in season for special dinners. I will buy cheaper kinds year around for chowders and soups or fish patties. The recipe defines the fish I purchase as well as the season and price." "I am the planner of meals and the main purchaser of foods. I get ideas from my family, but I have the last say in the decisions on purchases of food."

"Freshness is the most important characteristic in fish. First, it must smell fresh, not fishy or spoiled. Second, the color must be good for its type and not look old. Third, the texture must be firm and not slimy from being old."

Focus group participant #4: Joy

Joy, 33
Homemaker
Separated
$60K-80K

"I am a full-time "stay-at-home" mom. I volunteer at the children's school. I have three children ages 13, 12, and 8."

"I like food that is simple to prepare, nutritious, and that all of my family enjoys. I do not eat red meat or pork and limit my children's intake of these."

"I prefer fish over red meat and pork. It isn't as versatile as chicken, but I like to serve it in place of other meats. I prefer to buy fish when I need it, instead of stocking up, as I would with chicken."

"If I am shopping for food for that day or soon after, I may choose fish. If I am doing shopping for a longer time ahead, I probably would not buy fish. I prefer to consume it right away rather than let it sit for weeks in the freezer."

"Price is important when buying a fish."

"Taste is the most important characteristic in fish. If it doesn't taste good, the kids won't eat it and I would not buy it again. We like a mild fishy taste, with a good aftertaste."

Focus group participant #5: Pat

Pat, 43 Married Full-time job $40K-60K	"I am married with two children. I work full time and have a busy lifestyle." "I am not picky. I do not spend a great deal of time making food choices. It is not a high priority." "I am more selective when purchasing fish compared to other foods. I do not want to be wasteful so I only choose what is pleasant to look at and smell. Appearance is the most important characteristic that I am concerned with in fish".

Focus group participant #6: Rose

Rose, 32 Single (getting married) Full-time job $20K-40K	"I like a very casual lifestyle. My apartment is furnished in "grad student sloppy," and I don't have a lot of time to spend on housecleaning, cooking, etc." "My food choices must be easy to prepare. My fiancé is working on changing my attitude to increase nutrition vela and decrease fat content." "When I buy fish, I really look at the product--which I usually don't for other food item. The look and smell are important." "I like fish that is quick to prepare, healthy, and relatively inexpensive. I buy it more often than I buy meat." "How the fish looks is the most important characteristic. I like it to look fresh--no ugly discolorations. I look for even colors and thickness."

Focus group participant #7: Jane

Jane, 35
Single
Full-time job
$20K-40K

"I am single. I live by myself. I have friends over to my house for a meal at least once or twice a week. I am active. I exercise, walk, swim, and bike. I shop mostly at the First Alternative Coop. But sometimes at Fred Myer or Safeway or Cub. I work full time. I like to prepare special meals and I rarely eat fast food."

"I am primary vegetarian. I eat very small amounts of fish, chicken, cheese, and dairy. I eat mainly eggs, tofu, beans, vegies, fruits, soy, nuts, brown rice, bread, pasta, and etc. I eat very little desserts. I purchase only quality food items."

"I am more careful when I purchase fish because I check for healthy looking skin, white color, few bones, and no fishy smell. I look at date on the package to check to check for freshness. Price is not so important to me because when I decide to buy fish, I will make sure it is a good quality fish (i.e., not too cheap, not too expensive)."

"I also like to know where the fish comes from (lake, stream, ocean) and where it was caught. Also, I like to know if the fish is a bottom feeder and if it lives in clean waters."

"Sight (the way it looks when I am thinking about purchasing it) is the most important characteristic in fish."

Focus group participant #8: Claire

Claire, 47
Married
Homemaker
$40K-60K

"I am married, the mother of four grown children. My husband is in business for himself, a general contractor. I keep the books for his business and manage the home office. We both got our undergraduate degrees from OSU-my degree, a BA in Advertising Design. We eat out very infrequently but have friends in for dinner several times a month. Three of our children are in college. One of them works in the construction industry with my husband. We try to live frugally most of the time, not buying into the consumer mentality, not too materialistically."

"Our income allowed us to choose a wide variety of foods. However, price is always a concern for us. Since I have always worked at home, I have been able to keep track of food costs and avoid buying expensive, fast foods. We try to eat fish at least once a week and have several meatless meals each week also. I try to make our meals nutritionally sound and also pleasant to look at."

"When it comes to buying fish, I know what we like and if the price is reasonable I will buy what we like.
My husband does not like a "fishy" tasting fish, likes the more mild flavor of a sole or halibut, for example. If the price is low, I will try something new. I almost always buy fresh fish for our weekly fish meal. Occasionally, we will use a can of tuna."

"Generally, I look over all the fresh fish. The first thing I check is the price. Then if I think I can afford it, I look over the particular fish I'm interested in. If it "looks" good, I will buy it. Looks based on looking clean, fresh (or nicely frozen), and size of pieces. If I am buying for a special occasion-price is not as critical, I am willing to spend more."

"The most important characteristic in the fish is its flavor. However, the most important concern when buying fish is the price. If it's too expensive I won't buy it (no matter how good it is). If the price is low enough, I'll try almost anything."

Focus group participant #9: Gail

Gail, 34
Divorced
Full-time job
$20K-40K

"Working single parent (8 yr old son). I am overweight and don't eat very healthily or exercise much. I am very busy with work, parenting, and my church. I like normal "Oregon" activities such as gardening, sewing, and hiking. I also enjoy watching baseball on TV, although I usually do something else at the same time (i.e., read newspaper, sewing). I also get up during commercials to do a little chore or such.

"I like foods that are easy to cook, eat, and clean up. I like foods that are healthy and easy on my pocketbook. Sometimes, though, I splurge and get something expensive and unhealthy."

"My purchasing behavior on fish is sporadic, but usually twice a month. I check ads in newspaper for good buys, based on "fresh" fish and per pound cost. I often times settle on buying imitation crab meat, and usually get 2-3 lbs at a time. I don't usually buy much meat either except for hamburger. However, I don't rely on meat or fish as a daily source of protein. I also eat eggs, cheese, beans,..."

"I do not buy fish on an impulse compared to other foods, like candy or bakery goods. I will, on occasion, do taste test on cooked fish in the store, and buy it..."

"Taste of the fish is what I am most concerned with. I like mild fish because I enjoy using some spices when I cook it, and also because a strong fish smell (either raw or cooked) turns me off to eating it. Since my son also likes mild-tasting fish, and won't eat something like salmon. He also likes fish that goes with tartar sauce, and the mild fish seems to fit the bill. "

APPENDIX C

Focus Group Moderator's Guide.

1. Introduction of Research

I would like to thank all of you folks very much for being here today. My name is Weeraporn, but I go by "Goy". I am a Ph.D. candidate in Food Science and Technology, majoring in Seafood Processing. My work is about sensory evaluation and marketing research in fish. The fish of my interest is an underutilized species and has not gained wide acceptance yet in domestic fisheries. It is abundant along the coast of Oregon, California, Washington, and British Columbia. A large part of the harvest of this fish has been used successfully for surimi production (surimi is a major ingredient of imitation crab meat). However, there has been a great interest of having this fish as a fillet form, supplied to the market. Before getting to that point, we need to know first what potential customers, like you all, really think about and what are in your minds after you get to know the fish.

Your being here today can help my research to be meaningful and completed, by sharing your opinions and comments. My professor and I hope to get the insight information as most as possible so that we could partly help develop Oregon fisheries and economics in the near future. So your involvement and full participation throughout the work is really needed here and would be greatly appreciated.

There are several issues that we need to discuss today and throughout our meetings. There are no right or wrong answers. All that count are your own opinions and comments. So during discussion, please do not hesitate to share whatever you feel toward that particular issue. An individual will have her own idea and different comment. Agreements and disagreements are what I expect in our discussion. So, please remember that what you feel and comments are the most important part of my work, and are the matters of why we are here.

What we will discuss today and throughout our meetings will be recorded by videotaping and cassette taping. The tape will be analyzed by myself for research purposes only. I promise you will not appear on television whether you want to or not. Before starting our work, I hope you do not mind to introduce yourself briefly: what your name is and what you do.

2. Meeting I Discussion

I. The moderator brought out 3 species of raw frozen fillets (Pacific, Chilean, Peruvian, and Argentinean) to the focus group, to initiate the discussion within the group.

Some of scripts for the moderator:

- What do you see on these products?
- Can you describe them to me?
- Are they appealing to you? Why or why not?
- Are there any differences among them? Why or why not?
- Do you realize there are frozen fish fillet available to you in the market?
- What do you think about frozen foods? What about frozen fish?

II. The moderator brought out raw *fresh* fillets of the same species, as above, to the group.

Some of scripts for the moderator:

- What are differences can you see between these ones and the first ones?
- What do you think about their quality?

- Which one do you prefer to buy, the freshs or the frozens ? Why?
- Will you buy the frozen fish if the fresh ones (of the same species) are not available?
- When you see a label saying "This product has been frozen and thawed", does it mean anything to you? Positive? Negative?
Do you mind buying such products? Will you consider it as "fresh" fish?
- What do you think are bad/negative points about frozen fish?
- Does it apply to other frozen foods as well?
- What characteristics do you think the fresh ones have but the frozen ones do not?
- Will there be any way that can convince you to try the frozen one?

III. The moderator brought out raw fresh meat to the group, side by side to the fish.

Some of scripts for the moderator:

If you go to the market and see these products:-
- Which one will you prefer to buy if you could afford all of them, but you could choose to purchase only one?
- Does buying meat or not buying meat affect your decision to buy fish at the time you shop? Is it dependent on each other?
- Why do you buy meat instead of fish?
- Is meat healthier than fish? What do you believe toward fish and beef?

IV. The moderator brought out scallops, side by side to the fish and meat:

Some of scripts for the moderator:

- Which one(s) do you prefer to buy if you can afford all of them?

- Does buying or not buying other seafood affect your decision to buy fish?
- What make you buy other meat or seafood instead of fish?
- What are your concerns when you buy fish?
- What are desirable/undesirable characteristics do you look for or avoid in a fish you want to buy?

3. Meeting II Discussion

I. The moderator displayed raw samples of four fish species: Pacific, Argentinean, Peruvian, and Chilean whitings.

Some of the moderator's guide:

-What are good appearances/characteristics do you look for and bad appearances/characteristics do you avoid for *raw* fish? What about characteristics of *cooked* fish?

-Are there any factors that affect your purchasing decision on fish?

-Do you normally think a lot when you do shopping on food esp. fish?

II. Evaluating cooked samples

The moderator asked the participants to take a look and smell microwave cooked Pacific whiting and rockfish fillet first.

Some of the moderator's guide:

- How do they look and smell? How do you like them? Which one you prefer? Why?
- Are they like what you usually see or smell when you cook fish?
- Are there anything that you don't like about their looks and smell?
- Do the following appearances and smell (the List of term from sensory trained panel was provided) mean something to you?

Then, the moderator asked them to taste microwave cooked Pacific whiting and rockfish fillet.

Some of the moderator's guide:

Emphasis on Flavor

- How do you like the flavor? Can you explain what their flavors are like?
- Do you think you perceive the following flavors as obtained from a trained panel? Do you think it is important to you? (the list of flavor characteristics was available to them)

Emphasis on Texture

- How do you like their texture? What do they look like? Do you perceive the following textural characteristics? (the texture list was available)
- Have you ever thought of those characteristics during eating a fish? Do you think the recipe with spices/seasonings or the fish itself that make you think the meal is delicious!
- Even though a fish might have a strong or negative flavor, will you think you can fix it using your own recipe?
- What about texture, if a fish doesn't have a good texture, for example, it may be too soft for you, do you think you can improve the texture in any way?

III. Cooking Methods

The participants compared both cooking methods (i.e., microwave and convection oven).

Some of the moderator's guide:

- How do you usually cook/prepare fish at home? What method do you use most often?

- Do you usually eat fish with or without any seasoning mix or sauce?
- Do you think the take-home product that you have tried twice was better when you eat it plain or with sauces/spices, and why is that?
- How does cooking fish by microwave oven in 3-4 min sound to you?
- Do you often cook fish using an oven? If there is a fish out there in the market that is not highly recommended for an oven, but recommended for a rapid cooking (i.e., microwave) only, would it be O.K. for you, will you accept it?
- Was the take-home product getting better when you cooked by a microwave?
- All frozen fish in the market are kept frozen back in freezers, so you usually won't see it until you ask for it. To your knowledge, what fish will be available in frozen form? What do you think are the main reasons that it always come out in that form?
- Do you think having the nutrition facts with a fish, for example, "This product contains 3 % fat, 18% protein,..." is necessary for consumers?

4. Meeting III Discussion

I. The discussion got more deeply into the characteristics of those two fish. The moderator provided them with cooked Pacific whiting and other fish.

Fish desirable/undesirable characteristics (Continued)

Some of the moderator's guide:

- What are good/bad characteristics in fish that you are concerned with?
- What kind of fish do you usually buy? Why do you think you buy it?
- Do you think all fish are pretty much the same? What is the most important attribute that you think make them different from one

another---flavor, texture, appearance, or odor? (Which one is the most important in order to distinguish one species from the others?) If you close your eyes during tasting several kinds of fish, can you tell this is Salmon, this is Snapper? By flavor or texture or anything else?

II. Factors affecting purchasing decision were discussed.

Some of the moderator's guide:

- What make you purchase a fish over another?
- What make you purchase other muscle food over fish?
- What are your concerns when you buy fish? Internal factors (flavor, texture, aroma, appearance)? External factors (advertising, pricing,...)?
- Will fish's appearance affect your purchasing decision?
- Do you like to buy round fish, fillets with skin, fillet without skin?
- What make you go back and buy the same kind of fish again and again?
- Have you ever tried any food that is really new to you (you have never heard about it before)?

APPENDIX D

Consumers' Demographics

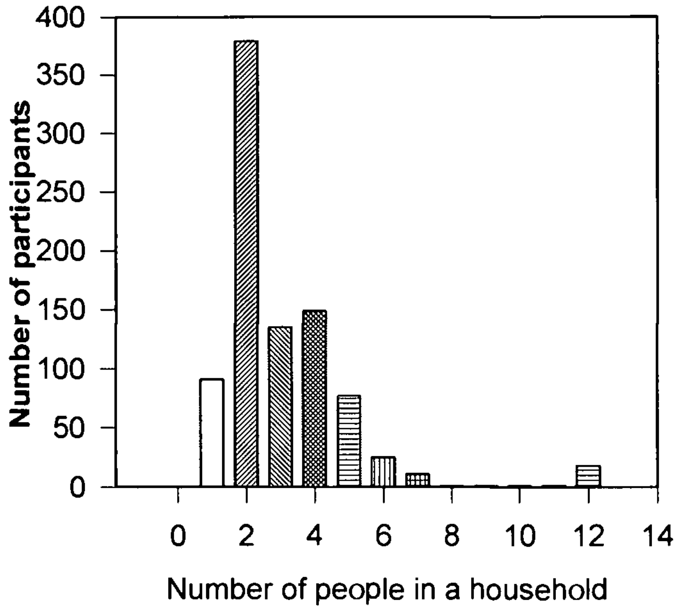

Figure D 4.2.1 Frequency percentage of consumers household size who participated in the consumer testing.

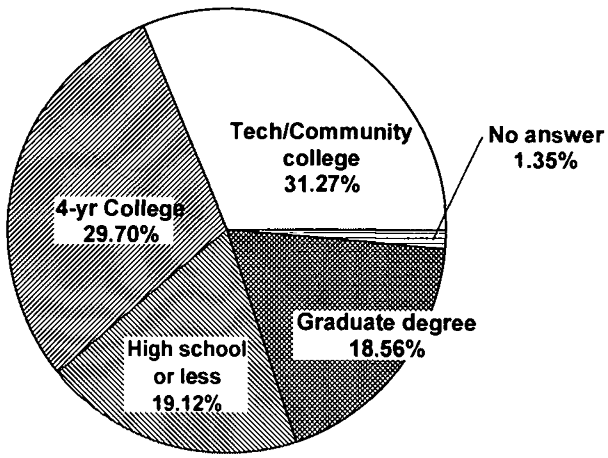

Figure D 4.2.2 Frequency percentage of consumers education level who participated in the consumer testing.

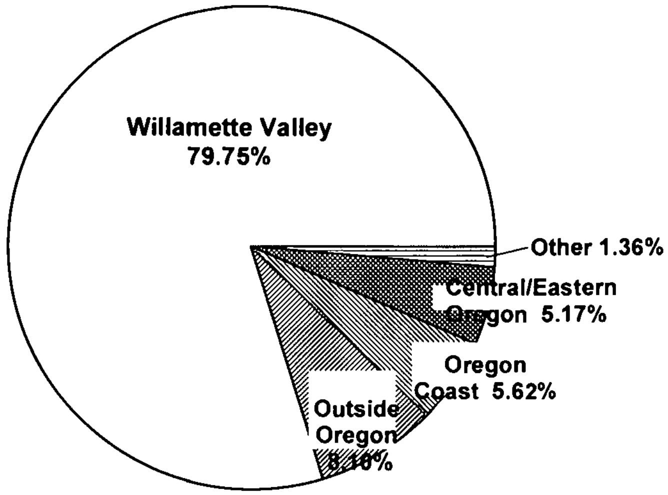

Figure D 4.2.3 Frequency percentage of consumers participating in the consumer testing who live in different areas of Oregon.

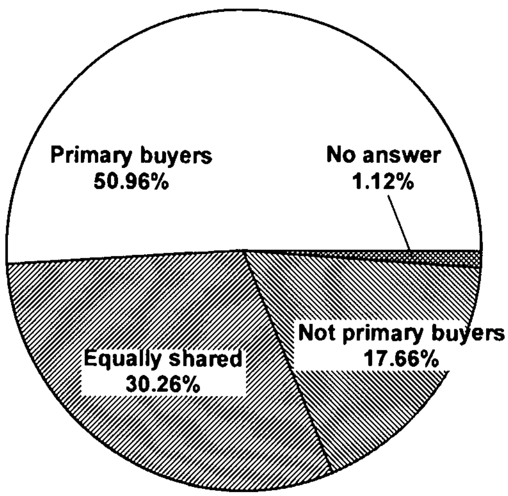

Figure D 4.2.4 Frequency percentage of consumers participating in the consumer testing who were or were not the primary seafood purchaser of the household.

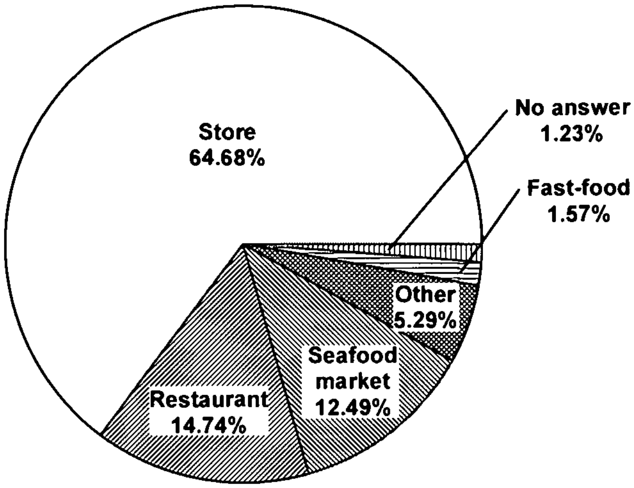

Figure D 4.2.5 Frequency percentage of seafood distribution locations from where participating consumers in the consumer testing usually purchased.

APPENDIX E

Additional Tables for Results and Discussion

Table E 4.3.1 Correlation of sensory texture attributes of Pacific whiting IQF fillets cooked by two different methods and the amount of protease activity.

Attribute	Panelist#	Hardness	Mushiness	Moistness	Chewiness	Mouthcoating
Protease Activity	1		0.764[1] (0.027)			
	2	-0.692[1] (0.027) -0.669[2] (0.035)	0.659[1] (0.038) 0.669[2] (0.034)	0.731[1] (0.016) 0.710[2] (0.021)	-0.733[1] (0.016)	0.776[1] (0.008)
	3		0.836[1] (0.005)			0.801[1] (0.009)
	4	-0.786[1] (0.012)	0.717[1] (0.030) 0.883[2] (0.002)		-0.381[1] (0.001)	
	5	-0.812[1] (0.0043)	0.847[2] (0.002)			0.875[1] (0.001)
	6					
	7				-0.720[2] (0.044)	0.808[1] (0.015)
	8	-0.680[1] (0.044)	0.860[1] (0.003)		-0.714[1] (0.031)	
	9		0.699[1] (0.054)		-0.860[1] (0.006)	-0.685[2] (0.042)

Note: Pacific whiting IQF fillets were cooked by a conventional oven[1] and microwave oven[2]. Coefficient of correlation are shown. p-value are in parentheses. A blank space in rows represents non-significance in their correlations.

Table E 4.3.2 Correlation of sensory hardness ratings and sensory and instrumental texture attributes of Pacific whiting IQF fillets for individual trained panelists.

		Sensory				Instrumental			
Attribute	Panelist	Mushiness	Moistness	Chewiness	Mouthcoating	Hardness 1	Hardness 2	Cohesiveness	Chewiness
Hardness	1	-0.944[2] (0.000)		0.918[2] (0.001)					
	2	-0.922[1] (0.000)	-0.834[1] (0.003)	0.715[1] (0.020)	-0.877[1] (0.001)				
		-0.849[2] (0.002)	-0.805[2] (0.005)		-0.734[2] (0.016)				
	3	-0.685[1] (0.042)		0.682[1] (0.043)	-0.736[1] (0.024)				
			-0.643[2] (0.045)						
	4	-0.805[1] (0.009)		0.831[1] (0.006)					
		-0.707[2] (0.033)		0.839[2] (0.005)					
	5	-0.776[1] (0.008)			-0.682[1] (0.030)	0.848[1] (0.002)	0.808[1] (0.005)		0.912[1] (0.000)
				0.885[2] (0.001)					
	6		-0.654[1] (0.021)	0.726[1] (0.017)	-0.646[1] (0.044)				
	7								
	8	-0.793[1] (0.011)		0.844[1] (0.004)					
		-0.917[2] (0.001)							-0.712[2] (0.032)
	9		-0.918[2] (0.001)	0.763[2] (0.017)					

Table E 4.3.3 Correlation of sensory mushiness ratings and sensory and instrumental texture attributes of Pacific whiting IQF fillets for individual trained panelists.

Attribute	Panelist	Sensory			Instrumental			
		Moistness	Chewiness	Mouthcoating	Hardness1	Hardness2	Cohesiveness	Chewiness
Mushiness	1		-0.897[2] (0.003)					
	2	0.863[1] (0.001) 0.847[2] (0.002)	-0.792[1] (0.006) -0.712[2] (0.021)	0.859[1] (0.002) 0.670[2] (0.034)				
	3			0.888[1] (0.001)			-0.745[1] (0.021)	
	4		-0.787[1] (0.012) -0.704[2] (0.034)					
	5			0.649[1] (0.042)				
	6	0.710[1] (0.021)						
	7			0.772[1] (0.025)				
	8		-0.770[1] (0.015) -0.684[2] (0.042)					
	9		-0.885[1] (0.004)					

Table E 4.3.4 Correlation of sensory moistness ratings and sensory and instrumental texture attributes of Pacific whiting IQF fillets for individual trained panelists.

Attribute	Panelist #	Sensory		Instrumental			
		Chewiness	Mouthcoating	Hardness 1	Hardness 2	Cohesiveness	Chewiness
Moistness	1					-0.730[1] (0.040)	
	2	-0.810[1] (0.005) -0.671[2] (0.034)	0.821[1] (0.004)				
	3						
	4						
	5						
	6						
	7						
	8	-0.904[2] (0.001)					
	9						

Note: Pacific whiting IQF fillets were cooked by a conventional oven[1] and microwave oven[2] . Individual panelists were analyzed. Coefficient of correlation are shown. p-value are in parentheses. A blank space in rows represents non-significance in their correlations.

Table E 4.3.5 Correlation of sensory chewiness ratings and sensory and instrumental texture attributes of Pacific whiting IQF fillets for individual trained panelists.

Attribute	Panelist#	Sensory	Instrumental			
		Mouthcoating	Hardness 1	Hardness 2	Cohesiveness	Chewiness
Chewiness	1					
	2	-0.906[1] (0.000) -0.756[2] (0.011)	0.656[1] (0.040)	0.636[1] (0.048)		0.702[1] (0.024)
	3					
	4					
	5					
	6	-0.625[1] (0.053)			0.651[2] (0.041)	
	7					
	8					
	9					

Note: Pacific whiting IQF fillets were cooked by a conventional oven[1] and microwave oven[2] . Individual panelists were analyzed. Coefficient of correlation are shown. p-value are in parentheses. A blank space in rows represents non-significance in their correlations.

Table E 4.3.6 Correlation of sensory mouthcoating ratings and instrumental texture attributes of Pacific whiting IQF fillets.

Attribute	Panelist #	Hardness 1	Hardness 2	Cohesiveness	Chewiness
Mouth coating	1				
	2	-0.717[1] (0.020)	-0.674[1] (0.033)		-0.745[1] (0.014)
	3			0.748[2] (0.021)	
	4				
	5			-0.661[1] (0.037)	-0.713[1] (0.021)
	6				
	7				
	8				
	9				

Note: Pacific whiting IQF fillets were cooked by a conventional oven[1] and microwave oven[2] . Individual panelists were analyzed. Coefficient of correlation are shown. p-value are in parentheses. A blank space in rows represents non-significance in their correlations.

Table E 4.3.7 Correlations of instrumental texture values and protease activity in Pacific whiting IQF fillets cooked in a conventional oven.

Level of protease activity (mmoles of tyrosine)	Hardness cycle1	Hardness cycle2	Cohesiveness	Chewiness
1-100	ns	ns	ns	ns
101-200	ns	ns	ns	ns
201-300	ns	ns	ns	ns
301-600	-0.470	-0.440	ns	-0.535
	(0.036)	(0.053)		(0.015)
>600	-0.882	-0.833	ns	-0.868
	(0.020)	(0.040)		(0.025)

Note: ns = The correlations were not significant
Coefficients of correlation are shown. p-value are in parentheses.

Table E 4.3.8 Correlations of instrumental texture values and protease activity in Pacific whiting IQF fillets cooked in a microwave oven.

Level of protease activity (mmoles of tyrosine)	Hardness cycle1	Hardness cycle2	Cohesiveness	Chewiness
1-100	ns	ns	ns	ns
101-200	ns	ns	ns	ns
201-300	ns	ns	ns	ns
301-600	ns	ns	ns	ns
>600	-0.887 (0.019)	-0.881 (0.020)	ns	-0.878 (0.022)

Note: ns = The correlations were not significant
Coefficients of correlation are shown. p-value are in parentheses.

Table E 4.3.9 Model fitting results for mushiness ratings (Y) of individual trained panelists obtained from the descriptive analysis of Pacific whiting fillets.

Panelist #	Mushiness Model	R^2 adjusted	Significant Level
1	$Y = 1.07 \log (X)$[1]	0.99[1]	***[1]
	$Y = 0.43 \log (X)$[2]	0.88[2]	***[2]
2	$Y = 1.33 \log (X)$	0.94	***
	$Y = 1.06 \log (X)$	0.91	***
3	$Y = 1.38 \log (X)$	0.98	***
	$Y = 0.67 \log (X)$	0.91	***
4	$Y = 1.29 \log (X)$	0.84	***
	$Y = 1.24 \log (X)$	0.93	***
5	$Y = 0.78 \log (X)$	0.73	***
	$Y = 0.01 (X)$	0.85	***
6	$Y = 1.35 \log (X)$	0.87	***
	$Y = 2.44 \log (X) - 0.45 (\sqrt{X})$	0.93	***
7	$Y = 8.65 \log (X) - 4.63 (\sqrt{X})$	0.99	*
	$Y = 2.06 \log (X) - 0.28 (\sqrt{X})$	0.93	***
8	$Y = 1.41 \log (X)$	0.99	***
	$Y = 1.18 \log (X)$	0.93	***
9	$Y = 3.85 \log (X) - 1.33 (\sqrt{X})$	0.99	*
	$Y = 0.42 \log (X)$	0.74	***

Note: Pacific whiting were cooked by a conventional oven[1] and a microwave oven[2]. The amount of protease activity (X) was obtained from a biochemical analysis. * and *** refer to significance at $p \leq 0.05$ and 0.001, respectively.

Table E 4.3.10 Model fitting results for hardness ratings (Y) of individual trained panelists obtained from the descriptive analysis of Pacific whiting fillets.

Panelist #	Hardness model	R^2 adjusted	Significant Level
1	$Y = 2.83 \log(X)$[1]	0.93[1]	***[1]
	$Y = 2.21 \log(X) - 0.4 (\sqrt{X})$[2]	0.95[2]	***[2]
2	$Y = 2.40 \log(X)$	0.60	**
	$Y = 0.64 \log(X)$	0.50	*
3	$Y = 24.53 \log(X) - 13.61 (\sqrt{X})$	0.90	**
	$Y = 14.48 \log(X) - 10.21 (\sqrt{X})$	0.96	**
4	$Y = 9.17 \log(X) - 2.68 (\sqrt{X})$	0.84	**
	$Y = 2.02 \log(X) - 0.6 (\sqrt{X})$	0.89	***
5	$Y = 6.36 \log(X) - 1.33 (\sqrt{X})$	0.80	**
	$Y = 2.85 \log(X) - 1.28 (\sqrt{X})$	0.85	**
6	$Y = 5.82 \log(X) - 1.11 (\sqrt{X})$	0.86	**
	$Y = 0.48 \log(X)$	0.81	***
7	$Y = 0.62 \log(X) - 0.11 (\sqrt{X})$	0.79	**
	$Y = 0.38 \log(X)$	0.63	**
8	$Y = 1.32 \log(X) - 0.34 (\sqrt{X})$	0.82	**
	$Y = 0.47 \log(X)$	0.81	***
9	$Y = 1.17 \log(X) - 0.27 (\sqrt{X})$	0.89	**
	$Y = 1.52 \log(X) - 0.36 (\sqrt{X})$	0.86	**

Note: Pacific whiting were cooked by a conventional oven[1] and a microwave oven[2]. The amount of protease activity (X) was obtained from a biochemical analysis. *, **, and *** refer to significance at $p \leq 0.05$ and 0.001, respectively.

Table E 4.3.11 Model fitting results for moistness ratings (Y) of individual trained panelists obtained from the descriptive analysis of Pacific whiting fillets.

Panelist #	Moistness model	R^2 adjusted	Significant Level
1	$Y = 2.53 \log(X) - 0.45 (\sqrt{X})$[1]	0.94[1]	***[1]
	$Y = 4.42 \log(X) - 1.45 (\sqrt{X})$[2]	0.98[2]	***[2]
2	$Y = 1.22 \log(X)$	0.88	***
	$Y = 1.14 \log(X)$	0.90	***
3	$Y = 0.93 \log(X)$	0.87	***
	$Y = 1.09 \log(X)$	0.81	***
4	$Y = 2.84 \log(X) - 0.83 (\sqrt{X})$	0.95	***
	$Y = 7.25 \log(X) - 4.17 (\sqrt{X})$	0.98	**
5	$Y = 0.42 \log(X)$	0.78	***
	$Y = 0.78 \log(X)$	0.65	**
6	$Y = 1.30 \log(X)$	0.85	***
	$Y = 1.37 \log(X)$	0.94	***
7	$Y = 2.74 \log(X) - 0.63 (\sqrt{X})$	0.97	***
	$Y = 0.26 (\sqrt{X})$	0.90	***
8	$Y = 1.75 \log(X) - 0.01 (X)$	0.98	***
	$Y = 8.20 \log(X) - 4.45 (\sqrt{X}) + 0.15 (X)$	0.99	**
9	$Y = 4.50 \log(X) - 1.63 (\sqrt{X}) + 0.03 (X)$	0.99	***
	$Y = 1.42 \log(X)$	0.91	***

Note: Pacific whiting were cooked by a conventional oven[1] and a microwave oven[2]. The amount of protease activity (X) was obtained from a biochemical analysis. ** and *** refer to significance at $p \leq 0.05$ and 0.001, respectively.

Table E 4.3.12 Model fitting results for chewiness ratings (Y) of individual trained panelists obtained from the descriptive analysis of Pacific whiting fillets.

Panelist #	Chewiness model	R^2 adjusted	Significant Level
1	$Y = 0.73 \log (X)$[1]	0.86[1]	***[1]
	$Y = 2.12 \log (X) - 0.4 (\sqrt{X})$[2]	0.92[2]	**[2]
2	$Y = 0.75 \log (X)$	0.62	**
	$Y = 0.87 \log (X)$	0.72	***
3	$Y = 1.13 \log (X)$	0.81	***
	$Y = 2.55 \log (X) - 0.47 (\sqrt{X})$	0.93	***
4	$Y = 5.53 \log (X) - 3.41 (\sqrt{X}) + 0.1 (X)$	0.94	**
	$Y = 2.03 \log (X) - 0.62 (\sqrt{X})$	0.87	**
5	$Y = 1.26 \log (X) - 0.27 (\sqrt{X})$	0.80	**
	$Y = 3.97 \log (X) - 1.78 (\sqrt{X})$	0.86	**
6	$Y = 0.73 \log (X)$	0.62	**
	$Y = 4.64 \log (X) - 1.95 (\sqrt{X})$	0.98	***
7	$Y = 0.92 \log (X) - 0.17 (\sqrt{X})$	0.93	***
	$Y = 2.12 \log (X) - 0.44 (\sqrt{X})$	0.88	***
8	$Y = 2.20 \log (X) - 0.55 (\sqrt{X})$	0.88	***
	$Y = 2.07 \log (X) - 0.42 (\sqrt{X})$	0.95	***
9	$Y = 21.27 \log (X) - 16.99 (\sqrt{X}) + 0.86 (X)$	0.99	**
	$Y = 4.04 \log (X) - 1.73 (\sqrt{X}) + 0.04 (X)$	0.98	**

Note: Pacific whiting were cooked by a conventional oven[1] and a microwave oven[2]. The amount of protease activity (X) was obtained from a biochemical analysis. ** and *** refer to significance at $p \leq 0.05$ and 0.001, respectively.

Table E 4.3.13 Model fitting results for mouthcoating ratings (Y) of individual trained panelists obtained from the descriptive analysis of Pacific whiting fillets.

Panelist #	Mouthcoating model	R^2 adjusted	Significant Level
1	$Y = 5.55 \log(X) - 2.22 (\sqrt{X})$[1]	0.99[1]	***1
	$Y = 2.02 \log(X) - 0.26 (\sqrt{X})$[2]	0.98[2]	***2
2	$Y = 1.28 \log(X)$	0.90	***
	$Y = 1.04 \log(X)$	0.81	***
3	$Y = 1.42 \log(X)$	0.97	***
	$Y = 1.76 \log(X) - 0.28 (\sqrt{X})$	0.94	***
4	$Y = 1.55 \log(X)$	0.91	***
	$Y = 9.42 \log(X) - 5.68 (\sqrt{X})$	0.98	***
5	$Y = 1.22 \log(X)$	0.93	***
	$Y = 4.08 \log(X) - 1.68 (\sqrt{X}) + 0.03 (X)$	0.91	**
6	$Y = 1.60 \log(X)$	0.90	***
	$Y = 6.74 \log(X) - 3.23 (\sqrt{X}) + 0.07 (X)$	0.99	***
7	$Y = 6.98 \log(X) - 3.51 (\sqrt{X}) + 0.11 (X)$	0.99	**
	$Y = 0.87 \log(X)$	0.88	***
8	$Y = 2.62 \log(X) - 0.44 (\sqrt{X})$	0.95	**
	$Y = 0.80 \log(X)$	0.83	***
9	$Y = 4.74 \log(X) - 1.80 (\sqrt{X}) + 0.04 (X)$	0.99	**
	$Y = 2.84 \log(X) - 0.83 (\sqrt{X})$	0.98	***

Note: Pacific whiting were cooked by a conventional oven[1] and a microwave oven[2]. The amount of protease activity (X) was obtained from a biochemical analysis. ** and *** refer to significance at $p \leq 0.05$ and 0.001, respectively.

Table E 4.3.14 Correlations of consumer acceptability of Pacific whiting for main sensory attributes, amount of protease activity, and sensory mushiness ratings received from the trained panel.

Variable 1	Variable 2	Coefficient of Correlation
Flavor acceptability	Texture	0.62***
[Protease activity]	acceptability	-0.14^{ns}
Appearance acceptability		0.38***
Flavor acceptability	Overall	0.65***
Texture acceptability	acceptability	0.71***
[Protease activity]		ns
Appearance acceptability		0.32**
Flavor acceptability		0.57***
Texture acceptability	Purchase intent	0.61***
Overall acceptability		0.79***
[Protease activity]		ns
Sensory mushiness ratings		-0.25*

Note: ns refers to a "not significant" correlation. *, **, and *** refer to "significant" correlation at $p \leq 0.05$, 0.01, and 0.001, respectively.