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AN INVESTIGATION INTO ASPECTS OF CONSUMER PREFERENCE FOR SOME FISH SPECIES USING SENSORY EVALUATION TECHNIQUES.

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Philosophy of the Council for National and Academic Awards.

The research was conducted in the School of Home Economics, Robert Gordon's Institute of Technology, Aberdeen with collaboration from the Torry Research Station, Aberdeen.

June, 1981

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AN INVESTIGATION INTO ASPECTS OF CONSUMER PREFERENCE FOR SOME FISH SPECIES USING SENSORY EVALUATION TECHNIQUES.

Morag Hamilton

Abstract.

The attitudes of consumers towards white fish are discussed, and the sensory features of flesh products and their quality are considered.

A review of the investigation of fish quality by sensory evaluation and instrumental techniques is presented and the use and analysis of relevant methods of evaluation are discussed in detail.

The wide variations found in intrinsic fish quality is described and the various factors which contribute to the variability are considered. The methods adopted to control variability in this investigation are described.

The results of sensory assessments by consumer panels on nine white fish species tested as plain steamed samples are analysed and discussed. There was some correlation between preferences established in the trials and the traditional buying habits of consumers. The relative preferences were not held very strongly by consumers and most fresh white fish species would appear to be acceptable substitutes for each other. Flavour was identified as being the most significant factor in determining the overall acceptability of fish, texture was found to be neutral and appearance either neutral or negative.

Two fish species were compared before and after incorporation into products. The preferences identified for the plain steamed forms were virtually eliminated in product form. The products were found to be equally and highly acceptable when made with either species.

CONTENTS

CHAPTER 1

General Introduction

Investigations into the reasons why people make particular purchasing decisions are fraught with complexity and are by no means well understood despite massive efforts by manufacturers and academic research workers. The purchase and choice of food-stuffs is one of the most complex areas of consumer research since more factors seem to be relevant to this area than to any other. There are primary factors such as price, freshness, quality etc. which may determine if a particular food is acceptable at the point of purchase. This purchasing decision will however only be made if the consumer is actually interested at the time in buying that particular food, and factors such as habit, advertising, chance, expressed preferences of family members etc. will affect this interest. The weighting of the various factors will again vary depending on whether an essential or an optional food-stuff is being purchased and whether or not available income is a serious constraint.

1.1 Consumer Attitudes Towards Fish

Fish is a food-stuff towards which people have definite attitudes. Despite the fact that fresh fish is rather a bland product, many people express dislike for it, possibly because of bad experiences with off flavours or bones. These attitudes are also reflected in the small number of species which are consumed in the United Kingdom, where considerable reluctance is shown towards experimenting with alternative species. There is no evidence to show whether the buying habits of the consumer have any objective basis at all and the aim of this study was therefore to determine some fundamental facts in this area, in particular to study whether people can distinguish between various species of fish, and if so whether

their objective preferences correlate with their more subjective purchasing habits.

1.2 Fish Supply

Fish is the last major source of hunted food. It is mainly caught at sea in the wild state with only 10% of the world catch of vertebrate species coming from fresh water where the highest proportion is farmed or cultivated.

The world catch of fish is approximately 70 million tons of which 50 million is used for human food. The world production of meat and poultry is more than double that of fish and in affluent countries fish tends to be eaten as a variety food (Howgate 1977). Unlike meat and poultry, where only a few species are utilised to any extent, there are several hundred species of fish used for human consumption. In the United Kingdom some 30 species or groups of related species are landed (Scottish Sea Fisheries Statistical Tables, 1978) although of these only around 6 species are consumed in any quantity (Table 1).

The last decade has seen dramatic changes in the fishing industry which have seriously affected the present and future fish supply situation. Two factors in particular have affected fish resources, these are the serious depletion of supplies of many familiar types of fish as a result of over exploitation, and the establishment by many coastal states of exclusive fishing zones (Lucas, 1980).

Until recent years most varieties of fish were cheaper than meat products other than poultry, but declining catches and increased fuel and wage costs have resulted in fish prices rising to a level which is now comparable with other flesh products. Recent years have also seen a marked change in the pattern of fish consumption, with a considerable decline in fresh fish from 3.11 oz per head per week in 1960 to 1.42 oz per head per week in 1978. There has been a significant increase in the

	1976	1978
COD	2,607	1,689
DOGFISH	168	181
HADDOCK	1,306	876
HAKE	18	18
LEMON SOLES	46	52
PLAICE	344	355
SAITHE	413	372
WHITING	493	582
HERRING	972	165
MACKEREL	873	3,223
SPRATS	985	1,050
TOTAL - Wet fish	9,241	9,593

TABLE 1 : The quantity of principal species (in hundred metric tons) landed in the United Kingdom in 1976 and 1978.
Source : Scottish Sea Fisheries Statistical Tables 1978.

consumption of fish products so that net fish consumption has remained at a reasonably steady level, 5.86 oz per person per week in 1960 compared with 4.25 oz per head per week in 1978 (Household Food Consumption and Expenditure, 1960, 1978). Reference was made earlier to the conservative nature of the consumer in selecting fish species for purchase. Until comparatively recently, the traditional familiar species of Cod, Haddock and Herring, made up a high percentage of total fish sales in both fresh and processed forms. The situation has changed slightly in the last two to three years because the traditional species, especially Herring, have, for the reasons mentioned above, been in short supply. However, in spite of the fact that traditional species are consistently more expensive than closely related alternative species such as Ling, Whiting and Mackerel, consumers seem reluctant to depart from tradition and continue to buy the more expensive types.

1.3 Sensory Attributes of Meat Products

The modern consumer appears to have sufficient nutritional knowledge to recognise that certain food-stuffs contain protein and that protein is an essential component of the diet. Regardless of this fact, meat products are largely eaten for enjoyment and would certainly not be consumed in the quantities they are unless they appealed to the palate. Palatability of all animal flesh is dependent on qualities such as aroma, flavour, colour, appearance, tenderness and juiciness. Studies have shown that tenderness is the most important factor in the acceptance of beef and other meats by consumers. Beef shows the widest range of tenderness qualities, followed by pork, lamb and finally veal. Fish species are mainly small bodied with fine textured muscles and are inherently tender due to the easily solubilised composition of the collagen connective tissue and the lack of the more resistant elastin and reticulin which is found in other types of meat. For these reasons there are few marked differences in structure and properties between

different types of fish fillets.

Flavour whether from meat or any other food, embraces sensations of taste and smell and these two responses are normally considered together. It is generally accepted that man can recognise four basic tastes (sweet, sour, bitter and salt), and innumerable odours, which are derived from volatile chemical substances, can be distinguished by the olfactory receptors. The odour and taste of cooked meat arise from water-and fat-soluble precursors and by the liberation of volatile substances pre-existent in the meat. The majority of research work into the flavour components of cooked meat has been concerned with identifying the volatile flavour. In addition over 100 compounds of at least 10 chemical classes have been identified as non-volatile flavour components. It appears that lean meat flavour originates in the water-soluble fraction of muscle and that the elements which characterise the species flavour reside in the fat and give the individual species distinctive and characteristic aroma and taste. In fish such precursors are not apparent and most species which are used commercially have a similar and bland flavour. The more obvious 'fishy' flavour and aroma is not present in fresh fish and is a product of post mortem autolysis and microbial activity. The two chemicals commonly associated with fish flavours are trimethylamine and hypoxanthine. The precursor trimethylamine oxide is found in small quantities in marine fish; its function is unknown and it is odourless and tasteless in this form. The fishy smelling trimethylamine is a result of reduction of trimethylamine oxide by bacterial action, normally eight or nine days post-rigor. Hypoxanthine is formed enzymatically from A T P through inosine monophosphate and inosine and its appearance correlates with the disappearance of the pleasant 'seaweedy' taste of very fresh fish to the almost tasteless product five to six days after death (Love, 1980a).

The foregoing general observations are widely applicable to most commonly eaten fish species and most species have similar

values for the important attributes of eating quality such as texture, tenderness, aroma and taste, even though the consumer has strong preferences for particular types, as judged by their purchasing habits.

1.4 Quality of Food Products

The perception of quality by the consumer particularly as applied to food-stuffs is a highly complex process. It is largely subjective and many factors, e.g. physiological and hygienic are relevant. The judgement is largely based on the experience of the consumer with that or similar food-stuffs, and the concept of quality often has quite different meanings for different people.

The judgement of quality in food-stuffs differs from most other items in that it is a two-stage process. An initial judgement is made when a decision is made to purchase, and a further quite distinct judgement is made when it is eaten. There are of course highly complex interactions and feed back responses between these two judgements. This study is concerned with eating quality which is a rather ill-defined term which depends on four main factors - appearance, texture, flavour and odour. Quality can be considered as the relative excellence of food based on sensory estimates of the four factors acting in combination. A broad consideration of quality would also encompass wholesomeness, (microbial or chemical safety and nutritional value), economy and convenience (cost, quantity, preparation and packaging), and the market appearance. The definition of quality is imprecise because the different factors vary in importance in different circumstances. Fish is particularly complex in this respect and a later chapter has been devoted to discussion of variations in fish quality. It will suffice at this point simply to observe that the majority of consumers rarely taste really fresh fish due to the time lag between catching and consumption. Some consumers may even prefer fish which might be regarded as of poorer quality since deterioration can produce a more fishy flavour which may be

liked even though it is in fact a product of deterioration.

There has been very little research work carried out on the ability of consumers to distinguish between fish species at the point of eating them or to establish why preferences are formed. This data seems to be absolutely fundamental for any understanding of purchasing decisions and it was accordingly decided to investigate the problem, using a range of sensory evaluation techniques, which are described in detail in a later chapter. Discussions were held with Torry Research Laboratories, Aberdeen, who readily agreed to collaborate in the project, particularly with the supply of fish of known quality.

1.5 Aims and Methods of Implementation

The purpose of this introduction has been to outline the general complexity of any work involving consumers and food-stuffs and the particular problems of working with fish. There is clearly a vast area of work to be carried out and the aim of this study was simply to establish a limited number of basic facts as objectively as possible.

In order to achieve this aim it has been necessary to control the preparation and presentation of samples rigidly in ways which differ significantly from those normally encountered by consumers when cooking and eating fish. It was necessary to work with assessors who were available regularly; namely students and staff of the School of Home Economics, who are not necessarily a typical population. Despite these reservations it was considered that the baseline established, and the methods developed, would be valuable for future studies. A preliminary account of some of this work has been published (Hamilton, 1980).

It was decided to carry out this investigation using eight species of white fish. These were Cod (Gadus morhua), Saithe (Pollachius virens), Ling (Molva molva), Plaice (Pleuronectes

platessa), Lemon Sole (Microstomus kitt), Dab (Limanda limanda), Whiting (Gadus merlangus), and Haddock (Gadus aeglefinus). These fish were a representative selection of different types of white fish which would be available throughout the duration of the project. The differences in cost between species can be seen in Table 2. In later tests it was considered worthwhile adding a ninth species, Blue Whiting (Micromesistius poutassou) since there is a great deal of interest currently focused on this particular species. It was also considered useful to gain some insight into the responses of people to fish when presented in forms other than plain steamed. A series of tests were therefore carried out, in which two fish species (Whiting and Blue Whiting) were compared after incorporation into various products. The results of this work have been accepted for publication (Hamilton and Bennett, 1981).

FISH	COST PER lb. (P)
COD	90 - 125
LING	60 - 70
SAITHE	40 - 50
HADDOCK	100 - 120
WHITING	60 - 80
LEMON SOLE	120 - 140
PLAICE	95 - 100
DAB	40 - 60

TABLE 2 : The types of fish used in sensory evaluation tests, with approximate prices in September 1979.

CHAPTER 2

A Review of the Investigation of Fish Quality by Sensory Evaluation Techniques

2.1 Sensory Evaluation of Quality

The term food quality has been referred to in the introduction to this study. The definition of food quality is wide and has different meanings for different people, depending on which of several aspects is of most importance in a particular circumstance or country. The quality concept for the same product can vary markedly in different countries and this has been shown to apply particularly to fish quality (Jellinek, 1964). The assessment of food quality is difficult and the search for accurate and precise test methods is a continuous one. Because food is eaten, it is inevitable that organoleptic properties are prominent among those factors which contribute to overall quality and for this reason sensory tests are the most widely used methods in the food industry for judging food quality. Sensory tests use individuals to make some type of assessment or to express a preference for a food. The Sensory Division of the Institute of Food Technologists defines sensory evaluation as "a scientific discipline used to evoke, measure, analyse and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, taste, touch and hearing" (Prell, 1976).

Many types of sensory tests have been devised to fulfil a number of specific objectives. The types range from simple preference tests to complex descriptive tests where judges assess samples against quality points on a scale for several factors. Sensory tests can be of two basic types, subjective and objective (B S I 1975). Subjective tests "pertain to individual experience which can be observed or reported only by the person involved and subject to influence of temperament, personal bias

and emotional background" (Amerine, Pangborn and Roessler 1965). In objective sensory testing, biases are deliberately minimised by the use of specially trained assessors who concentrate on particular well-defined attributes of a food product.

2.2 Instrumental Evaluation of Quality

Instrumental or analytical tests can be used to assess some aspects of food quality. Since changes in levels of certain chemicals or in physical properties can sometimes be related to changes in sensory quality factors, such tests may also be used as indices of quality. Instrumental tests have the advantage that the results are independent of personal bias and they are easier and more economical to carry out than taste panels which can be inconvenient to organise and expensive in terms of manpower and time.

The major disadvantage of instrumental tests is that the ultimate criterion for eating quality of food is the human response to it, and no non-sensory test can give a complete picture of the eating quality of a food. The results from an instrumental test must always be shown to correlate well with results from an established sensory method before the former can be accepted as a measure of quality.

2.3 The Use of Sensory Evaluation Tests

Many people have reservations about the validity of sensory tests, and regard the methods as simplistic and the conclusions as 'unscientifically' based. This reputation possibly lingers from the time when the subject of sensory evaluation was in its infancy, when many publications included misleading information based on the misinterpretation of results from inadequately controlled experiments carried out using inappropriate facilities. The methodology has now advanced considerably and there is a large and increasing body of background knowledge and research available to enable tests

to be carried out in a sound scientific manner. Providing that sufficient attention is paid to the selection of the most appropriate test method and to the control and standardisation of each stage in the preparation and presentation of samples, the results obtained provide reliable and valuable information about food quality.

The experimenter must be familiar with the various psychological and physiological effects which occur (Amerine, Pangborn and Roessler, 1965) and must use an appropriate experimental design to minimise these effects. The limitations and variations which are inevitable when using these techniques must be taken fully into account when results are being interpreted.

2.4 Types of Sensory Evaluation Test

The various sensory test methods can be divided into three groups on the basis of the type of information they provide (Hamilton, 1979; Campbell, Penfield and Griswold, 1980).

2.4.1 Difference or Discrimination Tests

This group is used to find out if there is a difference between two similar samples. The commonly used methods of difference testing are the paired comparison, the triangle and the duo-trio tests.

2.4.2 Quality or Descriptive Tests

These tests are used to characterise or compare more than two samples on the basis of one or more specific organoleptic characteristic. Tests in this group include ranking, rating or scoring, texture or flavour profiling, quantitative descriptive analysis and magnitude estimation.

2.4.3 Preference or Acceptance Tests

These tests are used to evaluate consumer opinions about food products. Acceptance tests determine whether or not a product will be used by consumers and preference tests are carried out to find whether or not assessors like food samples. These tests are often referred to as consumer tests, because large panels of untrained, inexperienced judges are normally used. The specific tests which have been used during the experimental research for this study are described in more detail in Chapter 4. A fuller treatment of the subject, including physiological and psychological aspects can be found in 'Principles of Sensory Evaluation of Food' (Amerine, Pangborn and Roessler, 1965). The general requirements and basic procedures of sensory evaluation are outlined in 'The Manual of Sensory Testing Methods' (ASTM, 1968) and in 'Methods for Sensory Analysis of Food' (BS 5929: Part 1 : 1980).

2.5 Consumer Evaluation of Fish Quality

The aim of this project has been to compare similar types of white fish in terms of the important attributes of eating quality i.e. appearance, texture and flavour. The methods used were designed to find if consumers could detect significant differences between similar types of fish and if so if they could identify which particular attributes of eating quality contributed to the ability to discriminate. It was also of interest to attempt to determine if there was a relationship between preferences for fish presented in identical unidentified form and the established consumer preferences.

There has been very little research of this type carried out on fish products and there are few papers in the literature which deal specifically with the underlying basis of consumer choice of fish. A number of speakers at International Symposia on fish research (O'Sullivan, 1971; Connell and Howgate, 1971; Shewan and Connell, 1980) have stressed the importance and need

for research to find out why consumers are motivated to buy certain types of fish and what attributes of fish quality are regarded as being important to consumers. There is also a need to gain insight into the ways in which consumers judge quality of fish and how its acceptability is affected over a range of freshness.

The published papers which deal specifically with consumer responses to fish and fish products have been concerned largely with the perception of fish quality. Rasekh and Kramer (1970) using samples of canned Tuna found that consumer preference was dependent approximately equally (40%) on appearance and flavour and to a much lesser extent (20%) on textural characteristics. Consumers were not able to discriminate the well-defined quality attributes of canned Tuna as well as an expert trained panel were able to do.

In a similar type of investigation Connell and Howgate (1971) using a nine point hedonic scale, measured the acceptability of unfrozen and frozen Cod and Haddock over a range of freshness. They concluded that, contrary to previous findings, panellists found that within the range of qualities presented, flavour was a more important criterion than texture in determining quality.

An investigation of the ability of an inland population to recognise fish quality and to determine factors which influenced their perception of quality, concluded that consumers could recognise moderate and extreme quality differences in fish products caused by changes in flavour, colour and texture (Wesson, Lindsay and Stuiber, 1979). Consumers were also able to discriminate between the quality of different fish species after it had been incorporated into various products. A strongly oxidised flavour was the most important reason for rejecting samples, although regional differences were found between panellists. When samples with blander flavours were tested, texture was found to be more important in determining

preferences. These results differ from those found by most workers and are possibly a result of there being very little intrinsic flavour in the samples.

The ability of consumers to differentiate between white fish species was investigated by Thompson et al (1980) in a fish matching experiment. This test was carried out as a preliminary part of a large project aimed at identifying the components responsible for the flavour of cooked fresh fish. The test was devised to find a white fish with a strong recognisable flavour for use in later analytical tests. Sixty untrained panellists were asked to match one reference sample of cooked white fish with one, more, or none of five coded samples of similarly cooked white fish. The five types of fish used in the test were Cod, Haddock, Whiting, Sole and Plaice. A substantial proportion of the panel were unable to match the species correctly, indicating that to most of the panellists, the flavour of the fish were very similar. Haddock, with the highest number of correct matches was used in subsequent tests. (The matching test method was adapted for use in this investigation and the results which we obtained were completely different. This was due possibly to the fact that the experimental design devised by us was less confusing for panellists).

2.6 Objective Sensory Evaluation of Fish Quality

Subjective tests on fish quality using large panels are difficult and expensive to organise, but the results are extremely important since the view of the consumer who ultimately eats the fish is gained. Most of the reported sensory tests on fish or fish products are of the objective type and use small panels of trained assessors, where biases of individual members are minimal. The most frequently used tests are the paired comparison, triangle and ranking or scoring, with the latter being the most common. Sensory tests have been used mainly to assess the freshness of chilled fish or to determine changes

in quality which occur during chill or frozen storage.

2.6.1 Scoring Tests

The aim of many of the sensory projects relating to fish quality has been to construct practical scales by which the fish could be scored numerically. Shewan et al. (1953) developed scales representing distinguishable characteristics that appear during the spoilage of fish. Seven quality factors were identified and scored for wet white fish; four for the raw fish and three for the cooked fish (Appendix A.). Using this scoring system a trained panel can differentiate between fish stored in ice under standard conditions to within a day or two of its storage time. This scale is in regular use at The Torry Research Station, Aberdeen and has also been used by several other research groups (Burt et al. 1975).

A similar scoring scheme was later constructed for frozen Cod (Baines and Shewan, 1965; Baines et al., 1969) which details the organoleptic changes occuring during freezing and frozen storage. A nine point hedonic rating scale was also included so that preferences of panel members could be correlated with changes in the sensory attributes of the frozen fish. The scoring system developed by Baines et al. (1969) was used by Connell and Howgate (1968) for evaluating the eating quality of frozen Cod of different initial freshness. Deterioration prior to freezing was assessed by the eleven point scale for freshness odour and freshness flavour proposed by Shewan et al. (1953). After frozen storage the cooked fish was scored for four quality attributes on separate numerical scales (Baines et al. 1969). A six point scale was used for cold storage odour and flavour (0 = absent, 5 = very strong), a seven point scale for firmness (0 = very soft, 6 = extremely tough) and a five point scale for dryness (0 = sloppy, watery, 4 = extremely dry). In addition, overall acceptability was assessed using a nine point hedonic scale.

A similar experiment was carried out on Haddock by Connell and Howgate (1969). The system for scoring Haddock was similar in principle to that used for Cod, but modifications were made to suit the different type of fish. Since the assessors used for this test had previous training in scoring unfrozen Cod, the scales for firmness and dryness were anchored with points indicating the normal firmness and dryness of unfrozen North Sea Cod of average pH, to allow for easier transposition of scores by the assessors. In both sets of experiments the taste panel was readily able to detect changes in sensory attributes produced by frozen storage at different temperatures for different lengths of time.

Several other workers have used scoring tests in various studies of fish quality. Scoring has been used for measuring the texture of fish by Kelly et al., (1966), Kelly, K.O. (1969) and Kelly, T.R. (1969). Cowie and Little (1966 & 1967) used a two dimensional scoring system for toughness/softness and wetness/dryness and Love (1969) and Love et al. (1974a) used a five point toughness scale. Bremner, Laslett and Olley (1978) when assessing textural properties of fish minces from Australian species used a nine point score sheet for texture, divided into two components, toughness and moisture content. They also included a nine point hedonic scale to assess overall acceptability.

2.6.2 Difference Tests

Love (1966) attempted to use a ten point scale with reference standards at each end in a scoring test to determine texture changes in cold-stored Cod, but the results were found to show too much scatter and a simpler paired comparison test was subsequently substituted. Considerable success was found using untrained panellists in this test, and small differences between samples were detected.

Triangle tests although in common use in fish research are

usually used as a preliminary to scoring tests or are used in informal information gathering projects and the results are often not published. Triangle tests have been used at the Torry Research Station to determine if there are detectable differences between different parts of the same fish fillet, and between fish fingers with varying levels of fish mince or bone content. Hume, Farmer and Burt (1972) used a triangle test to compare the flavours of farmed and trawled Plaice. Small untrained panels of 6 - 12 members were able to detect flavour differences between some treatments, but they were not consistent enough for a firm conclusion to be reached.

2.6.3 Flavour Profiles

In the last few years there has been increasing interest in the application of flavour and texture profile techniques to fish research. The flavour profile method was developed in the Arthur D. Little Company by Cairncross and Sjöström (1957). The flavour components of foods are analysed and described in terms of flavour-note identity, order of perception, relative intensity, amplitude and aftertaste.

Many attempts have been made to isolate the volatile and non-volatile components which contribute to the smell or flavour of fish. These tests have been either instrumental or chemical, but several groups are now attempting to use the flavour profile technique to identify and describe the flavour notes of fish or extracts. It is thought that the results from this method will help with the identification of the individual chemical components. The results of flavour profile tests have not yet been published in full, but reference is made to their use by Jellinek (1962), Thompson et al. (1980) and King et al. (1980).

Jellinek (1962) has reported a preliminary profile of descriptive terms which characterise the aroma and flavour components of four quality grades of Cod, Coalfish and Norway Haddock.

The gills and fillets of raw and cooked samples of fish were analysed by a trained panel and a number of reference standards were worked out using aromatic chemicals, essential oils and compositions of aromatic materials.

The flavour profile used at The Torry Research Station, described by Thompson et al. (1980) contains a list of twenty four terms which describe the flavour of cooked fish muscle and free cooked fish liquors. Five of these notes have been found to be of importance both in the muscle and in the free liquors, although in varying proportions, these are salty, sweet, meaty (boiled), chicken-like and boiled cabbage. A flavour profile is also being used as part of a project at The National Marine Fisheries Service to develop and implement a new system for establishing market names for fishery products. Little detail has been published about the results from the flavour profile but King et al. (1980) show a sample profile for one species of fillet containing nine flavour notes of which three, namely sweet, sour and fishy-fresh are the most prominent.

2.6.4 Texture Profiles

The texture profile was developed in 1963, following the principles of the flavour profile, by researchers at The General Foods Corporation (Brandt, Skinner and Coleman, 1963; Szczesniak, 1963). The procedure involves the evaluation of the mechanical, geometrical, fat and moisture properties of food. Unlike flavour notes, whose order cannot be predicted, textural characteristics are perceived in an ordered sequence at the three stages of ingestion; initial, masticatory, and residual. Texture profiles have been used for beef and chicken (Harries, Rhodes and Chrystall 1972; Frijters 1976) and it is hoped that the technique will be applied successfully to fish and fish products. It should enable researchers to obtain a more detailed picture of the complex textural characteristics of fish than is possible with the simpler scoring systems used at present. Textural comparisons between different fish and products should

become more discriminating and illuminating. The technique should prove particularly valuable in the development of comminuted products of acceptable texture using fish mince.

Howgate (1977) described the use of a provisional texture profile scheme for fish and fish products. Six variables were used, with three initial characteristics of wetness, firmness and springiness, and three secondary characteristics of fibrousness, toughness and succulence (The definitions of these terms were as proposed by Jowitt (1974). Three sets of data from seventeen different species of fish, extruded Cod minces and frozen Cod and Haddock were treated by factor analysis where the six original variables were reduced to two new factors.

A texture profile technique, modified by Horsfield and Taylor (1976) has been used to describe and compare the textures of different types of fresh and frozen, whole and comminuted fish (Weddle, 1980). Eleven attributes of texture and appearance have been defined and used in this profile. Allowance is also made for an acceptability score. Panel scores are processed by multi- factor analysis of variance to produce adjusted mean scores for each attribute for each sample. If two or three profiles have to be compared, principle components analysis is used to form three new variables, (structure, juiciness and toughness) which are linear combinations of the eleven original variables. Three dimensional maps of the principle textural components can be produced so that relationships between samples can be seen clearly.

These two profile techniques are still in the initial stages of development and will be improved as knowledge of the complexity of fish texture increases.

From this brief review of the types of sensory evaluation test which have been used in fish research, it should be clear that the state of knowledge concerning consumer reaction to fish

and fish products is still limited. Most of the tests referred to have been concerned with assessing intrinsic quality of fish samples rather than their acceptability. The aim of this project has been to use samples, all of the same initial intrinsic quality to assess the relative contribution made by the individual sensory attributes in relation to the overall acceptability of the fish as perceived by untrained panellists.

CHAPTER 3

The Variation of Fish Quality and its Causes

In contrast with other flesh products, such as beef, fish has a relatively homogeneous structure and exhibits few differences between fillets. In beef, connective tissue is an important factor in toughness, the collagen becoming more insoluble in well- exercised muscles and in older animals. In all types of flesh production, with the exception of fish, producers control the age of slaughter and animals are reared to reach a certain size and quality at a specified age. Fish is harvested irrespective of age and size, although it is then graded by size for marketing. The age of fish has been shown to influence the texture of fish slightly, older ones being tougher, but the effect is small (Love, 1980). Female fish seem to show the effect more strongly than males, but fish caught at certain times of the year do not show the effect at all or even show it in reverse.

Fish is caught in the wild state and is a highly perishable commodity. During storage and processing individual fish show variations in the pattern and rate of spoilage or in other quality attributes, thus suppliers and processors have limited control over its intrinsic quality. It is important to appreciate at the outset that there can be significant variation between individual fish at the time of catching. This variation may have its origin in the species, in the fishing ground or even within the same species from the same ground. An awareness of the sources and effects of variation is essential to fish processors as they are very relevant to the production of good quality fish for the consumer.

When carrying out research into any aspect of fish quality, natural variability is an important consideration both in designing experiments and in drawing conclusions from results.

3.1 Biological Condition

Biological variation has been shown to cause a marked degree of difference in all attributes of the eating quality of fish as perceived by the consumer (Love, 1980b).

The surface appearance, colour of flesh and skin, the texture and flavour of fresh, cold-stored and frozen fish all vary according to the fishing ground and some of them also vary with season. Love, in a number of investigations conducted over a ten year period on Cod from different fishing grounds (1965, 1969, Love et al, 1974a) found that there were variations in appearance, shape, colour and biological condition. Cod varied from good condition with firm and clear translucent fillets, to poor condition with soft milky white flesh. These variations were at first thought to be caused by genetic differences between fish from different grounds, or by differing environmental features. No evidence has been found to support the genetic theory although differences in the skin colour of fish from different grounds, while mainly governed by the colour of the sea bottom, might also contain a genetic factor (Love et al, 1974a). The main differences in the quality attributes mentioned previously are now known to be caused by differences in the eating or swimming behaviour of the fish and to seasonal variability.

3.2 Nutritional Status

The nutritional status of the fish at the time of death has been shown to affect the texture of cooked muscle. The texture of cooked fish muscle is influenced mainly by post-mortem pH (Kelly et al., 1966; Cowie and Little, 1966; Love, 1980b) which is itself related to the glycogen content in the muscle at the time of catching. The pH of live fish is close to neutral and after catching, the residual glycogen in the muscle can be converted anaerobically to lactic acid. A greater amount of glycogen is converted to lactic acid if there

is excessive struggling before death. The pH usually falls after death to around 6.8 and is proportional to the amount of lactic acid present (MacCallum et al., 1968).

There is not a straightforward relationship between changes in pH and nutritional status since the circumstances of catching, killing and storing the fish complicate the picture. The only exact relationship is that the pH of the muscle of starving fish in poor condition is always raised.

There is an unusual effect on post-mortem pH for a short period when fish start refeeding after their winter starvation. This lasts for between 3 - 8 weeks depending on the fishing ground. High glycogen reserves are built up in this period and lead to a post-mortem pH as low as 6.0. Another short period of low post-mortem pH has been regularly recorded in fish caught in the June-August period in most grounds and this correlates with a rise in muscle glycogen (Love, 1979). This rise in muscle glycogen falls after about three weeks regardless of food supply and is thought to be a type of built-in mechanism of over compensation and a spontaneous redistribution of energy reserves. Further variations between fish caused by differences in their eating behavior will be considered later when seasonal variation is discussed.

3.3 Body Length

Love (1969) showed that different batches of Cod of the same pH sometimes differed in texture and suggested that the body length might have influenced the results. Love et al. (1974b) pursued this idea and found that large fish are slightly tougher than small fish of the same pH. In addition, the pH of large fish is often lower than that of small fish, so the relative toughness of large fish is enhanced. This 'size-pH' relationship however is only clearly defined in well fed fish at certain times of the year. At other times when food is scarcer, the post-mortem pH of the muscle of all sizes of Cod

varies within wide limits so that size no longer appears to influence texture.

3.4 Influences of Post Mortem pH

Although no fresh fish is ever too tough to eat, small changes in post-mortem pH can cause marked differences in texture. If the pH a day after death is above 6.6 then the texture will be reasonably soft. If the pH is 7.0 or above, the texture becomes very soft and mushy and unattractive to consumers. Fish of certain pH can become unacceptably tough if frozen or cold stored. It has been concluded that fish which is to be frozen should have a pH greater than 6.6 (Kelly T.R., 1969) or 6.7 (Kelly K.O., 1969). Soft fish of high pH will actually improve during cold storage or freezing since it will become firmer (Kelly T.R., 1969).

3.5 Swimming Behaviour

Another factor which particularly causes differences between fish from different grounds is swimming behaviour. Variations in the intensity of colour of the dark muscle which lies under the skin along the lank of white fish result from differences in swimming activity. Migratory stocks of Cod have darker dark muscle than fish from other grounds and a seasonal cycle in dark muscle colour follows the activity involved in obtaining food which again varies from one ground to another. This means that a processor who wants a particularly white product e.g. for fish fingers, has to avoid migratory fish. In the case of Cod the darkest dark muscle is found in the Spitzbergen, Bear Island, Lofoten stock which are known to swim hundreds of miles in each year.

3.6 Seasonal Variations

Seasonal variations in the condition and composition of fish have been observed in all species and the changes have been

well documented, (Idler et al. 1965; Connell 1975; Burt et al. 1975). Poor condition occurs during the spawning period which takes place in spring, but the exact timing varies between fishing grounds and occurs later as one moves north. In some fisheries spawning extends over several months.

Fish are in poor condition just before, during and for some time after spawning. They do not feed during this time. Food reserves are used for the development of the gonads and thus the flesh becomes depleted of protein, glycogen and fat and the fish becomes thin, flabby and less active. The cooked flesh from fish in poor condition is soft, sloppy and gelatinous. A complicating factor however when discussing condition is that similar poor condition is also caused at other times of the year by poor nutritional status resulting from the fish not feeding or feeding at lower levels than normal. Good condition is recovered when normal feeding commences. It is possible therefore that throughout the year, fish which is landed from vessels which have visited several grounds will vary from good to bad condition. This, coupled with the fact that a lot of fish caught today is frozen before sale, means that for the fish consumer, the old certainties of fixed seasons when fish was in prime condition are no longer entirely valid.

3.7 Spoilage Rates

Differences in composition and condition of fish can give rise to complicating secondary influences on quality. Fish is a perishable commodity and soon after harvesting natural spoilage reactions commence. One of the major problems in marketing fish is the prevention or amelioration of deterioration since these result in major losses in the industry. Lean fish in poor condition spoil more rapidly than the same species in good condition. Fish is normally gutted immediately after capture and is chilled promptly by stowing in melting ice or in chilled fresh sea water. Fish with white flesh of normal size in good condition from temperate or cold water, keep for 12 - 18 days

if properly chilled and stored. The fish will be of excellent quality for the first four days, then there will be a slow but steady decline in freshness, until the flesh eventually becomes inedible. Fish of poor condition have a high pH and bacteria which cause spoilage are more active at higher pH. Differences in spoilage rates, defined by deterioration in sensory qualities and increase in volatile base content have been found between catches from the same grounds and between catches from different grounds (Burt et al. 1975). Spoilage rates of fish packed in melting ice have also been found to vary according to the place and the time of catching. Connell and Howgate (1971) found that fish of different species deteriorate at different rates; for example Haddock deteriorated more rapidly than Cod under all conditions of storage. It is also well established that iced fish from different catches spoil at different rates (Shewan and Ehrenberg, 1957).

3.8 Variation Between Catching and Marketing

The period between catching the fish and marketing it, is subject to variation which although unavoidable is still a factor leading to differences in quality. The type of fishing technique, the distance of the fishing ground and the speed of the boat all determine the time taken to market the fish. Fish caught at the beginning of a long trip will undergo greater spoilage than fish caught at the end of the same trip. Fish must also be transported to inland markets and more spoilage may occur during this time.

Loss of quality also results from the nature of the techniques used for catching, handling and storing fish. The conditions of harvesting fish cannot be compared with any other forms of flesh production. Carelessness in the initial stages of processing can seriously affect the quality of the end product.

3.9 Colour and Flavour Variation

Variability in the colour of the white muscle of Cod is

caused by inadequate bleeding at death or by freezing at sea too soon after death. Poor hygienic practices during gutting, cleaning or washing can lead to contamination, and the reluctance of many fishermen to apply enough ice for the chilling and storage of fish leads to variations in the rates of spoilage (Connell, 1975).

Variations in the taste of fish may result from small quantities of material being absorbed directly from the surrounding water or from the diet, thus there is likely to be seasonal or ground to ground variation in this respect between fish. An example noted by Torry staff who taste fish in both Aberdeen and Hull is that Cod from grounds near Aberdeen has distinctly sweet flavour notes while Cod landed at Scarborough has more 'cabbagy' flavour notes. This makes comparisons of spoilage changes between fish from different grounds particularly difficult.

3.1.0 Variation Within Fillets

As well as these possible variations between whole fish there can also be slight variations between different parts of fish fillets. An awareness of these differences is important when using fish in taste panel tests.

At certain times of the year a difference in pH along the length of a fish fillet has been measured. The pH increases towards the tail, with the result that softer flesh is found nearer the tail end. There is also a slightly higher proportion of brown muscle to white at the tail end of a fillet and this has an influence on the flavour of that part. There is a noticeable variation in the appearance of the top and bottom fillets of flat fish. The fillets taken from the upper dark skinned side are darker in colour with slight veining on some parts of the flesh which affects appearance and acceptability. Fillets from the bottom white skin side are whiter and thus more acceptable to the consumer.

It was necessary in this study to control many variables and the methods adopted for this are discussed later. All the fish studied were selected and treated similarly, so although they may differ in relative quality from those normally encountered by the consumer, the comparisons between species should be meaningful.

CHAPTER 4

Methods of Sensory Assessment and Their Analysis

The first two test methods described in this chapter, (the triangle and matching tests), were selected in order to determine whether or not assessors could discriminate between similar samples of white fish. The ability of assessors to identify differences was investigated using unmasked samples of steamed fish and fish which was similarly cooked, but masked by either eliminating appearance, or textural characteristics. The aim of these tests was to find if there was a perceptible difference between the sensory characteristics of samples and was not intended to establish the amount, type, or direction of the difference.

The other two tests, (paired preferences and the hedonic rating tests), were used to measure relative preferences or liking for samples of steamed white fish, and fish products made with two different types of white fish. The term preference, as used in sensory evaluation, has been defined as follows by Amerine, Pangborn and Roessler, (1965);

1. An expression of higher degree of liking;
2. The choice of one object over others;
3. A psychological continuum of affectivity (pleasantness) (unpleasantness) on which such choices are based.
   This continuum is also referred to as that of degree of liking or disliking.

This definition is quoted, because the term preference is often considered to be synonymous with acceptance. The interchangeable use of the two terms can lead to the misinterpretation of results. The definition of acceptance given by Amerine, Pangborn and Roessler, (1965), is as follows;

1. An experience, or feature of experience, characterised by a positive attitude;
2. Actual utilisation (purchase, eating).

Preference is only one of many factors involved in acceptability, but it is an important factor. Peryam et al. (1960) estimated that preference accounts for 35 - 60% of the variation in consumption of foods, and they thought it unlikely that any other single variable would be found as effective in predicting acceptability. However, the fact that certain products are found to be preferred over others does not establish that the other samples are unacceptable. It is of course possible to express a relative preference for unacceptable samples.

The four sensory test methods which were used in this investigation are each described separately in terms of the experimental design and procedures used. The statistical techniques which were used to analyse the results are described at the end of the chapter.

4.1 Triangle Test

The triangle test is a method of sensory evaluation which is designed to determine whether or not there is a perceptible difference between two similar samples. Three samples are presented simultaneously to the assessor of which two are the same and the third is different. The assessor is required to identify the different sample.

For additional information, refer to Peryam (1958), Dawson Brogdon and McManus (1963), Amerine, Pangborn and Roessler (1965), ASTM (1968) and B.S.I. (1980).

4.1.1 Experimental Design

Both samples were used as the 'odd' sample an equal number of times, since we had no knowledge about the possible differences between samples.

The design was balanced so that each of the six possible permutations of order (AAB, ABA, BAA, BBA, BAB, and ABB) were used, as far as possible, an equal number of times. Each permutation block was completed and was then repeated in random order. Each combination must be equally presented to the panel to avoid the possible effects of positional bias, contrast and convergence. (These are discussed further in Chapter 5 at 5.6.3). Where the size of panel was not a multiple of six, the design was balanced as far as possible and the remaining permutations selected at random.

Assessors completed three sets of triangle test at each tasting session, thus allocation of each of the six possible permutations of samples within a block was done randomly for each set, to control for possible expectation effects. Subjects sometimes expect the positioning of samples in the second and third sets to have some logical relationship to those in earlier sets. This was discouraged by informing assessors of the random positioning of permutations, before starting each test.

Two samples only can be compared in a triangle test; thus when several samples are being studied, each sample should be paired with every other sample in a separate test.

Triangle tests are considered to be very sensitive methods for detecting small differences between similar samples, and are unsuitable for samples which have obvious differences. In this investigation, it was decided only to use the triangle test to compare fish which had similar characteristics, i.e. the same type and size of fillet. It was considered to be unnecessary to compare samples which have obvious large differences in the size and structure of muscle flakes, such as Cod and Lemon Sole.

The sample pairs which were used for the triangle tests were;

Haddock and Whiting
Haddock and Cod.
Whiting and Blue Whiting
Cod and Ling
Cod and Saithe
Cod and Whiting
Plaice and Lemon Sole
Plaice and Dab
Lemon Sole and Dab.

4.1.2. Procedure

The assessors were given clear instructions about the test method. At each tasting session they were presented with three sets of samples as follows;

Set 1. - The samples of steamed fish were unmasked.

Set 2. - Visible textural differences between samples of steamed fish were masked by forking the cooked samples to the same consistency, (as judged visually).

Set 3. - The appearance of samples of steamed fish was masked by the combined use of reduced illumination and coloured lights.

The assessors were asked to rinse their mouths between each set of samples with water at room temperature.

4.2 Matching Test

The matching test was specifically devised for this project as a means of determining whether assessors could match correctly unidentified coded samples of fish with named fish samples. The method is a variation of one described previously by Thompson et al. (1980).

Assessors were presented with three named and different samples of cooked white fish, which they were asked to taste. They then received two coded samples of fish which had to be matched with the named samples, (which were left with the assessor so that direct comparisons could be made). The coded samples could be two different species or two samples of one species.

4.2.1 Experimental Design

At each tasting session, assessors received three sets of three named samples of cooked fish, with an interval of at least ten minutes between sets. The three types of fish in each set were chosen on the basis of similarities in the size and type of fillet, and in the structure of the muscle flakes. The three sets of samples were;

Set 1. - Cod, Saithe and Ling.
Set 2. - Whiting, Haddock and Blue Whiting.
Set 3. - Lemon Sole, Plaice and Dab.

From the three named samples in each set, there were nine possible permutations for sample pairs, (AB, AC, AA, BC, BA, BB, CA, and CC). These permutations were presented equally to the panel, to avoid bias. When the size of panel was not a multiple of nine, the presentations were balanced as far as possible, and the remaining permutations selected at random. The panellists were informed in advance about the possibility of both coded samples being the same type of fish.

4.2.2 Procedure

The assessors were given clear instructions about the test method. They were asked to rinse their mouths thoroughly between each set of samples with water at room temperature. The samples used in all the matching tests were unmasked.

4.3 Paired Preference Tests

The paired preference test is designed to determine which, if any, of two products is liked most. Two samples are presented simultaneously to the assessor who is asked to state which, if any, sample is preferred. The test is basically a ranking test with two samples.

For additional information, refer to Amerine, Pangborn and Roessler (1965), Ellis (1968) and ASTM (1968).

4.3.1 Experimental Design

There are only two possible combination of the samples (AB and BA). These permutations were presented to assessors an equal number of times. The order of presenting the two permutations was randomised.

The conventional method for the paired preference test, recommends that when more than two treatments are involved in an experiment, all possible combinations of pairs should be used in separate tests. In this investigation a compromise was made regarding this recommendation. The comparatively large number of nine samples of fish, was considered to be too many for each combination to be tested. The pairs of fish used previously in triangle tests were therefore also used in the paired preference tests.

4.3.2 Procedure

Assessors were given clear instructions on how to carry out the test. When more than one set of samples was presented during a tasting session, assessors were asked to rinse their mouths thoroughly between each set with water at room temperature. There was an interval of several minutes between sets. The assessors were permitted to make a 'no-choice' response, when they found they liked the samples equally.

4.4 Hedonic Rating Test

The rating test methods provide subjects with a numerical scale with descriptions showing progressive degrees of magnitude. Amerine, Pangborn and Roessler (1965) define a hedonic scale as "a calibrated continuum, upon which degree of like and dislike is recorded".

This type of scale is suitable for use by untrained panellists, and measures the level of liking for foods.

There are many different forms of hedonic scales, all with the same feature of having verbal anchoring of clearly successive categories. The classical hedonic scale devised by Peryam and Girardot (1952) has nine such categories, and this length of scale is sometimes recommended for greater discrimination, although seven and five point hedonic scales are in frequent use.

The scale used in the first two sets of hedonic rating tests in this investigation, carried out with plain steamed fish, had five points, (the minimum recommended length for scalar tests). The five point hedonic scale was considered initially to be the most suitable length of scale for inexperienced assessors, who could then be expected to make use of the full scale. A problem found with longer scales is that assessors are often reluctant to use the extreme points on the scale.

The normal convention is for the greatest degree of liking to have the highest numerical rating, but in the first two rating tests in this project, this scale was reversed to use the implied grading of 1 = the most liked sample, 5 = the least liked sample. This was considered to be less confusing for untrained assessors. In a subsequent hedonic rating test, using two types of white fish in five different fish products, it was decided that a longer scale might be more discriminating. Thus the seven point hedonic scale was used and the convention

of having the highest score as the most liked was adopted, 7 = the most liked sample, 1 = the least liked sample.

For additional information refer to Peryam and Girardot (1952), Peryam and Pilgrim (1957), Amerine, Pangborn and Roessler (1965), Ellis, (1968) and ASTM (1968).

4.4.1 Experimental Design

In each hedonic rating test, the samples were presented and rated individually. A maximum of six samples were tested and rated at each session. The order for presenting samples to each assessor was determined randomly to reduce, as far as possible, the effects of bias. In the rating test on fish products, samples of each product were presented successively in random order (i.e. the pairs of each product were presented randomly). No attempt was made to treat the five pairs of products as ten individual samples.

4.4.2 Procedure

The assessors were given instructions on how to carry out the test.

In the first two sets of hedonic rating tests, using plain unmasked samples of cooked fish, ratings were first assigned to the three organoleptic properties, appearance, texture and flavour (in that order), then assessors awarded a final rating for overall acceptability. In the rating test on fish products, each sample was given a hedonic rating for overall acceptability. In all three tests, only unit marks were allowed. Assessors were asked to rinse their mouths well between tasting each sample. There was an interval of one to two minutes between samples.

4.5 The Statistical Analysis of Results

For additional information, refer to BSI (1980); ASTM (1968); Smith (1973) and Howgate (1978).

The results of the first three tests used in this investigation, (triangle, matching and paired preference) are expressed in terms of levels of significance. The significance of a result is the probability (usually expressed as a percentage) that a given result, rejects the null hypothesis. This hypothesis states that there is no real difference between two treatments and that assessors make their choice between samples at random. The most frequently used levels of probability, and the common expressions used to describe these levels are:-

5% level of probability, 'P$\leq$0.05,' '*', 'significant.'
1% level of probability, 'P$\leq$0.01,' '**,' 'highly significant'.
0.1% level of probability, 'P$\leq$0.001' '***,' 'very highly significant.'

5% is the conventionally accepted cut-off point between a 'real' difference (which rejects the null hypothesis) and one which can only be accepted with reservations.

The Expanded Statistical Tables of Roessler, et al. (1978), which supply the critical number of responses in one direction necessary to establish significance at different levels, have been used for the analysis of results of the triangle, matching and paired preference test. These tables are based on various levels of chance probability appropriate to the different test designs.

4.5.1 Triangle Test

The rationale behind the triangle test is that if a detectable difference does exist between samples, many assessors will correctly select the odd one. If there is no detectable difference, then the number who pick the correct one will not

be much more than the number which would be expected if the judges chose a sample at random.

The null hypothesis asserts that each judge makes his own choice at random, so that he is equally likely to choose each of the three samples as the odd one. To determine the significance level of results from triangle tests, tables for One - Tailed Tests for 33⅓% Chance Probability are used. A statistically significant result implies that there is a perceptible difference, but the test gives no indication of the nature of the difference, its direction or degree. The size of the difference can be inferred from the proportion of the panel making the correct choice, the higher it is, the larger the difference.

4.5.2 Matching Test

The null hypothesis asserts that there is no difference between the three types of named fish and that the assessor matches the coded samples with the named samples at random. As in the triangle test, there is a 33⅓% chance of the correct match being made by chance alone, thus the hypothesis is tested by comparing the number of correct responses for each sample with tables for 33⅓% Chance Probability in a One - Tailed Test. The comments made on the significance of the results from triangle tests, also apply to matching tests.

4.5.3 Paired Preference Test

Two different samples were presented to assessors with no prior expectation being made as to which one the assessor would prefer. This hypothesis is tested using a Two - Tailed Test for 50% Chance Probability. A statistically significant result implies that there is a perceptible difference, as does the triangle test, and gives the additional information about its direction. The test does not give a direct measure of the size of the preference

but this can be inferred from the proportion choosing a particular sample. It can often be more informative to note the proportion than to test for statistical significance.

The paired preference test described in this thesis allowed for a 'no preference' response. There are various methods available for evaluating 'no preference' data and considerable debate has occurred concerning the most appropriate technique to use. The three possible alternatives are, to ignore the 'no preference' responses, to split them equally between the two test samples, or to split them in the same ratio as the positive responses. The most recent recommendations (BSI 1980) allow the use of either of the first two alternatives, and the procedure used in these tests was to ignore the 'no preference' responses when analysing the results. The number of 'no preference' responses was subtracted from the total number of assessors in the panel. This procedure increases the chance of producing a significant result.

4.5.4 Hedonic Rating Tests

The data for each fish for each sensory characteristic were averaged to give mean scores. The data were thus treated as scoring data by using the numerical values of the ratings. (Since hedonic rating scales cannot be considered as true interval scales, there are reservations about treating the data as such for statistical analysis. This practice is however generally accepted, providing that caution is exercised in the interpretation of results).

The results for each sample were summarised as a mean, and the standard deviation is shown to indicate the amount of spread of ratings from the mean. The distribution of ratings is illustrated in the form of histograms which show the number of panellists giving each rating to each sample.

The data were examined in various other ways. Since multiple

comparisons were being made, Analysis of Variance was carried out. This technique determines whether significant differences exist in these circumstances.

t Tests were used to determine the significance of differences between samples. The t statistic involves a family of distributions which vary as a function of degrees of freedom. (the number of values which are free to vary). Standard tables are available which show t values as critical values, i.e. those values which bound the critical rejection regions corresponding to varying levels of significance. The t values are defined as the difference divided by the standard error of the difference. The two methods used on the hedonic rating data were :-
a) Student's t Test, used for testing the significance of the difference between the means from the plain steamed fish samples.
b) t - by - Difference, used for the pairs of ratings from the fish products made from Whiting and Blue Whiting, this is a more sensitive test but can only be applied when each assessor has rated all samples.

Duncan's Multiple Range Test involves ranking the mean scores in order of magnitude and testing whether all samples are significantly different or whether some differ while others do not. This test is more sensitive than the application of t tests to multiple comparisons.

In this test, the standard error of the mean is calculated and tables are used to determine the shortest significant range values for the number of means in the sub-group and the degrees of freedom available. Each range figure is multiplied by the standard error to give a numerical value for the shortest significant range. Comparison of the differences in numerical values of the ranked means establishes whether or not the differences are significant.

In addition, scatter diagrams were drawn to give a pictorial representation of the degree of correlation between acceptability

and the sensory characteristics of flavour, texture and appearance. Correlation coefficients were calculated to provide a numerical measure of the closeness with which these pairs of values fitted a straight line. 'Partial' correlations were also calculated in which the linearity of the relation with one factor was estimated after eliminating that of the relation with another factor or factors.

CHAPTER 5

The Preparation and Presentation of Samples

One of the most important considerations when planning and conducting sensory evaluation tests is to eliminate as many factors of external bias as possible. It is particularly important to ensure that all possible variability between replicates is removed since variations between samples or between methods of preparation can affect both the interpretation of results and the ability to reproduce the results in future experiments.

Fish, as discussed previously in Chapter 3, is a product which can exhibit considerable variation in both extrinsic and intrinsic quality and every possible effort must be taken to reduce the effect of variability when using fish in taste panels. The following section discusses the measures which have been taken to prepare and present samples with the elimination of as many variables as possible.

5.1 Initial Quality - Freshness

A number of preliminary experiments were carried out using fresh fish of known history. This was fish which had been stored for three to four days on ice. The results from these tests indicated that the variation between fish samples in terms of freshness and fillet size was too great for the results to be meaningful. It was thus established that much stricter controls in selection of fish samples would be necessary.

The most favoured method for selecting fresh fish is on the basis of its raw odour (Baines and Shewan, 1965). A scale for scoring the odour of raw fish was devised by Shewan et al. (1953) and has been referred to previously. The scale is used for assessing the spoilage of wet white fish stored on ice (Appendix A).

This scale is a fast, sensitive and reliable method of judging freshness and is in regular use by quality assessors in fish markets. The Raw Odour Scale goes from 10, (fresh seaweedy odours) for fish recently caught, to 0, (nauseating, putrid, faecal odours; indole, ammonia etc.) for fish in advanced stages of deterioration. All the fish used in the tests described in this thesis, (other than the Blue Whiting) were individually selected at the Aberdeen Fish Market, and had a raw odour score of between 8 and 9. At this stage, rigor has resolved and no bacterial spoilage has occurred. The Blue Whiting was caught and handled under experimental rather than commercial conditions. It was frozen at sea as 50kg blocks within hours of catching, and stored at - 30°C until required. At temperatures at or below - 30°C, frozen storage deterioration is found not to occur to any significant extent (Howgate, 1977).

These controls over the supply of fish ensured that all comparisons were between fish of excellent quality, for all species.

5.2 Initial Quality - Size

The size variation identified in the preliminary tests was controlled by specifying the length of fillet for each type of fish. These lengths were based on the length of an average sized fillet for each fish species. By controlling this aspect of variation, all similar types of fish used in the tests were known to have approximately the same size of muscle flakes. It was obviously not possible to control the natural variations in size found between different species of fish such as Cod and Plaice, which vary markedly in the appearance and size of the myotomes. In tests where these obvious but unavoidable differences were judged to be undesirable, all types of cooked fish were finely mashed with a fork to disguise differences.

5.3 Storage of Samples

The sensory evaluation tests were carried out at different times of the year, and each series of tests took a period of weeks to complete. The original intention was to use only wet fish for the tests, but it was decided subsequently that the variation in quality over a period of weeks or months would be too great.

All fish used in the tests (other than Blue Whiting) was bought in large batches from the fish market, filleted and then stored in shatter packs at - 30°C.

The selection of all fish samples on the basis of freshness and size, and the storage of sufficient fish for each series of tests, ensured that variations between the samples were as small as possible.

5.4 Preparation of Samples

A sufficient number of fillets of each fish species were removed from the freezer twenty four hours before each test and allowed to thaw at ambient temperature. The thawed Blue Whiting were hand filleted immediately before being used in the experiments.

To reduce variations in the appearance of samples, only the middle part of each fillet was used. The head and tail ends of the fillet and the side edges were removed and 5 cm. squares of fish were cut from the middle portion. As well as producing standard sized samples, this procedure also reduced the possibility of pH differences within samples resulting from variation along the length of the fillet. The sample size chosen was considered to be an adequately representative portion and was sufficient for the assessor to retaste if necessary.

Large fillets of fish like Cod, and Ling were 'V' cut to remove

the large pin bones and ensure a bone-free fillet as far as possible.

In a separate series of tests, two species, Whiting and Blue Whiting, were incorporated in five different recipes. Both species were prepared by identical methods for cooking. After thawing, the top and tail ends and the side edges of the fillets were removed. For fish cakes and fish pies, the whole middle section was cooked. The samples for steaming in sauce and frying in batter and crumbs were trimmed down from the centre section to produce two samples of identical size from each fillet.

5.5 Cooking Method

Shewan et al. (1953) made preliminary studies of a variety of different cooking methods. Baking was not recommended as too many of the volatile flavour components were lost in the high oven temperature, and the flavour of fried samples was found to be affected too much by the fat. The final preferred method of cooking was steaming the middle section of fish fillets in covered glass casseroles over a boiling water bath. The fish were maintained at a temperature of 60°C for tasting. Baldwin, Hussemann-Strong, and Torrie (1963) found that the acceptability of cooked fish was not affected by the presence of skin or bone during baking and frying. They also found that fried samples were preferred to baked samples but since the fish was in different forms for the two methods of cooking this cannot be regarded as conclusive evidence.

In an attempt to clarify the position regarding the effect of cooking procedure on the quality of cooked fish, Dyer et al. (1964) carried out a series of taste panels using Cod of various qualities at different stages of frozen storage deterioration. The fish were either baked, steamed, or fried by standard methods. It was found that all methods gave high scores for acceptability with good quality fish, but on samples

with frozen storage deterioration much better discrimination between quality levels was shown by using baked or steamed samples, than fried samples. Texture showed greater differences than flavour. Baking was found to be the method of cooking which provided the greater degree of discrimination. Steaming was slightly less effective in distinguishing very good from medium quality fish, while frying was found to obscure some of the characteristic frozen storage quality changes. The conclusion therefore was that baking or possibly steaming were suitable methods for detection and comparison of quality changes in fish. Frying, the most popular method used by consumers, was a suitable method for poorer quality fish where off-flavours needed to be disguised. All methods were regarded as being suitable for high quality products.

Further comments on cooking methods were made by Connell and Howgate (1971), who disputed the findings of Dyer et al. (1964) concerning frying. Rather than disguising off-flavours in cooked fish, frying was found to accentuate them in their experiments. Steaming was recommended by them as the most satisfactory method for taste panel work.

The decision was taken to cook all the samples used in this series of experiments by steaming over boiling water, since the relatively small sample size was considered to be unsuitable for baking, due to the dangers of the fish drying out and losing flavour.

Samples were steamed on covered pyrex plates over boiling water. A specific cooking time for each type of fish was calculated in preliminary tests. The fish samples were all cooked to the same stage of 'doneness' rather than for the same length of time, the large fish like Cod taking longer to cook than the finer textured Lemon Sole.

It is probable that the use of seasonings or sauces will affect the discriminatory powers of consumers and it is also virtually

impossible to standardise their application. It was therefore decided to exclude both the addition of any type of condiment during cooking and the free use of condiment by panellists.

This very plain method of cooking samples of fish was considered to provide the optimum circumstances for enabling assessors to discriminate between different species. In order to find out the effects of introducing fish into more complex products, two species (Whiting and Blue Whiting) were selected and incorporated in five different recipes, chosen as being those most frequently used in the home when serving fish, (steamed with parsley sauce, deep fried with batter or with crumbs, fish cakes and fish pies). Both species were prepared and cooked by identical methods. The trimmed middle sections of fillets for fish cakes and fish pies were steamed for the same time and flaked with a fork to the same degree. Steamed samples were cooked by the method described above. Frying was carried out for the same time at the same temperature (185°C) in thermostatically controlled deep fat friers. The fish pies were baked in the same fan-assisted oven at 150°C for the same length of time.

Standard recipes were used for incorporating the fish into products (Hammond, 1975). Where samples included sauce, batter or mashed potato, one quantity was prepared and was divided between the two types of fish. Assessors were not provided with extra seasoning for use during tasting.

5.6 Presentation of Samples

Cooked samples were usually served immediately in identical, coded, disposable, white polystyrene containers which did not impart odour or taste to the food. The fish pies were presented in the individual 5cm. foil containers in which they had been cooked. In some of the tests, samples had to be kept hot for short periods. This was done by covering the samples with cling film and placing them in pre-heated warming cabinets.

The methods of presenting samples were kept uniform in each of the tests conducted, (the quantity and temperature of samples, the containers and the eating utensils were the same in each test). This was in keeping with the principle that samples should be presented in such a manner that subjects will only respond on the basis of factors which are intrinsic to the material being tested (ASTM, 1968).

The number of samples presented at one tasting session followed the general recommendations of the American Society for Testing and Materials (1968); a maximum of three pairs in paired preference test, four sets of three samples in triangle and matching tests, and six samples in hedonic rating tests.

5.6.1 Masking

For some of the tests it was necessary to mask the appearance and texture of fish samples from assessors.

The appearance of cooked fish samples was disguised by reducing the overall illumination and using a combination of red and blue coloured lights. Texture differences caused by differences in flake size of plain steamed samples of fish were eliminated by mashing the samples to an equal extent with a fork.

5.6.2 Coding

The method used to code samples in sensory evaluation tests should give the assessor no clue or information (real or imaginary) about the samples being tested. Successive alphabetical letters or numbers are not recommended as they have often acquired meanings which can influence decisions. In our tests samples were coded with two digit random numbers chosen from random numbers tables (Kmietowicz and Yannoulis, 1976).

5.6.3 Presentation Sequence

It is well established that there can be psychological or physiological effects on assessors brought about by the order of presentation of samples. There can be a 'time error' effect where response to samples is affected by the order of presentation and 'contrast' or 'convergence' effects can occur which are related to the qualities of other samples served in the same test. When a number of samples are served simultaneously 'positional bias' can occur for example there is a tendency to choose the middle sample in a triangle test as the odd sample. It has been established that these effects occur regardless of instructions or training and therefore it is important that measures are taken to neutralise the effects by using appropriate experimental designs (Amerine, Pangborn and Roessler, 1965).

In the experiments described in this thesis the experimental designs used for the paired preference, triangle and matching tests were balanced so that the possible permutations of order of presentation were used an equal number of times. In the hedonic rating test, a randomised experimental design was used where each panellist received one replication of each treatment in random order. This method is theoretically less satisfactory than are balanced designs because each sample does not appear in each test position an equal number of times and therefore does not neutralise the interactive effects of judge, product and time. However, in experiments with large numbers of samples, randomising is the only practicable method which can be used, and very little bias is introduced (ASTM, 1968; Sidel and Stone, 1976). The experimental designs used for each test have been discussed in more detail in Chapter 4.

5.7 The Tasting Environment

When conducting sensory evaluation tests, every effort must be

made to eliminate the effect of the environment on judgements. The factors governing choice and control of the tasting environment are described fully in the literature (Larmond, 1973; ASTM, 1968; Amerine, Pangborn and Roessler, 1965). Taste panels carried out at Robert Gordon's Institute of Technology, took place in a room separate from, but adjacent to, the kitchen where samples were prepared. This is an important requirement when testing fish products since strong cooking odours can affect judgements (Larmond, 1969). The room is equipped with seven individual purpose-built tasting booths. Separate booths are recommended for sensory testing as they eliminate distraction and prevent communication between assessors and encourage them to make independent judgements. The booths can be screened from daylight so that uniform lighting can be used. Various combinations and intensities of coloured lights can be used in each booth when it is desirable to mask the appearance of samples.

Panellists were supplied with water at room temperature for rinsing their mouths, and instructions regarding rinsing were given before each test.

Panels were normally conducted mid-morning or mid-afternoon since these are generally regarded as being the times when people are most sensitive to tasting, (although this can vary considerably between individuals).

5.8 Panellists

The panellists were usually female Home Economics students aged from 19 - 21 years. Some staff or mature students from the School of Home Economics occasionally took part.

No one taking part in the tests had any previous experience of assessing fish. The third year Home Economics students who participated in the tests had a reasonable knowledge of sensory evaluation techniques and had some basic taste training. All other panellists had no such experience.

CHAPTER 6

Results and Discussion

6.1 Triangle Tests

A preliminary investigation was performed using triangle tests with 14 assessors, the object of which was to establish whether panellists were able to detect differences between samples of different species of fish. Nine species were tested in pairs in each of three types of presentation (plain steamed, steamed then mashed, and steamed with the appearance masked by dim coloured lighting) and the results are shown in Table 3. It can be seen that most assessors were able to detect significant differences between all the pairs of fish. Masking of texture and appearance had no effect on this ability to discriminate.

6.2 Matching Tests

Table 4 shows the results obtained by means of matching tests carried out by 34 assessors and it can be seen clearly that assessors were able to match coded samples of fish with the appropriate named samples with a high degree of accuracy. This test is probably more exacting than the triangle test since assessors have to make positive matches rather than simply pick out the different sample, however both tests have the same probability ($\frac{1}{3}$) of achieving the result by chance.

The proportion of correct matches was somewhat lower for the flat fish, indicating that the differences although significant at the 5% level were less well defined.

The introduction to this study commented on the apparent similarity and blandness of fish flesh from various species and it was by no means a foregone conclusion that differences would be detectable even with the optimal conditions for

FISH PAIRS	TEST TYPE	Number of Correct Responses	Percentage of Correct Responses	Significance
HADDOCK	No Masking	9	64	*
	Masked Texture	10	71	**
WHITING	Masked Appearance	11	79	***
COD	No Masking	11	79	***
	Masked Texture	10	71	**
HADDOCK	Masked Appearance	13	93	***
COD	No Masking	7	50	N.S.
	Masked Texture	7	50	N.S.
WHITING	Masked Appearance	11	79	***
COD	No Masking	11	79	***
	Masked Texture	13	93	***
LING	Masked Appearance	11	79	***
COD	No Masking	13	93	***
	Masked Texture	13	93	***
SAITHE	Masked Appearance	13	93	***
BLUE/	No Masking	9	64	*
WHITING	Masked Texture	11	79	***
WHITING	Masked Appearance	7	50	N.S.
PLAICE	No Masking	13	93	***
	Masked Texture	9	64	*
LEMON SOLE	Masked Appearance	11	79	***
DAB	No Masking	10	71	**
	Masked Texture	11	79	***
LEMON SOLE	Masked Appearance	10	71	**
DAB	No Masking	10	71	**
	Masked Texture	11	79	***
PLAICE	Masked Appearance	8	57	N.S.

Table 3 : The results of a Triangle Test, where 9 fish species were evaluated by 14 assessors.

N.S. = No Significant Difference.
* = Significant at the 5% level.
** = Significant at the 1% level.
*** = Significant at the 0.1% level.

NAMED FISH SPECIES	NUMBER OF CODED SAMPLES	NUMBER OF CORRECT MATCHES	PERCENTAGE OF CORRECT MATCHES	SIGNIFICANCE
COD	24	18	75	***
SAITHE	22	22	100	***
LING	22	18	82	***
WHITING	20	17	85	***
HADDOCK	28	25	89	***
BLUE WHITING	20	17	85	***
LEMON SOLE	26	17	65	**
PLAICE	19	12	63	*
DAB	23	13	56	*

Table 4 : The results of a Matching Test, where 9 fish species were evaluated by 34 assessors.

* = Significant at the 5% level.
** = Significant at the 1% level.
*** = Significant at the 0.1% level.

discrimination (plain steamed without condiment) used in these tests. These two initial investigations, however, established quite conclusively that there were significant differences in the sensory characteristics of the various white fish species tested. There was also a preliminary indication that flavour could be a major influence on discrimination, since masking appearance and texture had not prevented assessors from perceiving differences between species.

6.3 Paired Preference Tests

The fact that assessors were able to discriminate between species did not of course give any indications of the direction of preference and this aspect was therefore examined by means of a series of paired preference tests. Table 5 shows the results obtained when the nine species pairs used previously were presented to panellists who were asked either to state a preference for one of the pair, or to indicate if they had no preference. The results show that for most pairs there was a clear preference though not enough for statistical significance at the 5% significance level, except for the Lemon Sole/Plaice, and Plaice/Dab pairs. Approximately two thirds of the panel members preferred one sample more than the other, except for the Cod and Haddock which were preferred equally. (These tests were performed in summer 1979 and the data on seasonal variation which is discussed later, has some bearing on these findings),

The statistical significance of this set of data was determined by excluding the 'no preference' responses and calculating significance on the total number of panellists who expressed positive preference. Many authorities feel that although the 'no preference' responses are awkward to treat statistically it is nevertheless valuable information which can be illuminating if kept in mind. For example there seems to be an overwhelming preference for Lemon Sole over Plaice by 13 to 1 but this fact takes on a new dimension when the additional fact that 7

FISH PAIRS	NUMBERS PREFERRING EACH SAMPLE	NUMBERS PREFERRING NEITHER SAMPLE	PERCENTAGE OF POSITIVE RESPONSES	SIGNIFICANCE
HADDOCK	12	3	67	N.S.
WHITING	6		33	
COD	9	3	50	N.S.
HADDOCK	9		50	
COD	10	5	63	N.S.
WHITING	6		38	
COD	11	5	69	N.S.
LING	5		31	
COD	12	4	71	N.S.
SAITHE	5		29	
WHITING	11	3	61	N.S.
BLUE WHITING	7		39	
LEMON SOLE	13	7	93	**
PLAICE	1		7	
LEMON SOLE	12	4	71	N.S.
DAB	5		29	
PLAICE	14	3	82	*
DAB	3		18	

Table 5 : The results of a Paired Preference Test, where 9 fish species were evaluated by 21 assessors.

N.S. = No Significant Difference.
* = Significant at the 5% level.
** = Significant at the 1% level.

assessors preferred neither is considered. This example is simply put forward as an additional dimension since there would clearly not be too much profit in speculating substantially on results gained from 21 panellists.

In eight out of the nine pairs of samples the more frequently eaten and expensive fish of the pair had the greater number of preference responses, which suggests that traditional buying patterns may have some basis in the sensory characteristics of the fish species. On the other hand, there is good evidence that the less preferred species are perfectly acceptable to consumers, since in most cases the less preferred vote plus the no preference vote is very similar to the score of the preferred species. Informal discussions were held with some panellists who usually indicated that their choices were not often based on very strong feelings about the samples. The only exceptions to this were fairly definite reactions of dislike for the grey coloured appearance of Saithe and, to a lesser extent, Blue Whiting.

6.4 Hedonic Rating Tests

The nature of the differences between species was investigated in detail by means of a series of hedonic rating tests. Two series of rating tests were carried out on eight and then nine fish species, one series in the summer of 1979 and one in the winter of the same year. The mean panel ratings for the summer tests are shown in Table 6, and those of the winter tests in Table 7.

The standard deviations are included to show the amount of spread within the ratings. The assessors awarded ratings using a 5 point hedonic rating scale (1, like very much; 2, like; 3, neither like nor dislike; 4, dislike; 5, dislike very much). This is the coarsest useful rating scale but in practice the scale proved to be sufficiently discriminating for the purpose of ranking the species in terms of sensory characteristics.

	COD	SAITHE	LING	WHITING	HADDOCK	LEMON SOLE	PLAICE	DAB
APPEARANCE								
Mean	2.4	4.5	2.7	2.0	2.2	1.7	2.4	2.0
S.D.	1.1	0.8	0.9	1.0	0.8	0.7	0.9	0.8
TEXTURE								
Mean	2.7	2.6	3.0	1.7	1.8	1.9	2.8	2.0
S.D.	1.1	1.1	1.2	0.8	0.6	0.9	0.8	0.9
FLAVOUR								
Mean	2.4	2.7	2.7	2.3	1.8	1.4	2.6	2.0
S.D.	1.2	1.1	1.3	1.0	0.7	0.7	0.9	1.0
ACCEPTABILITY								
Mean	2.5	3.2	2.9	2.1	1.9	1.6	2.5	2.0
S.D.	1.1	1.1	1.2	1.0	0.6	0.7	0.7	0.9

TABLE 6 : The mean scores obtained in a summer rating test, with 21 assessors using a 5 point hedonic scale, (1 = like very much, 5 = dislike very much).

	COD	SAITHE	LING	WHITING	HADDOCK	LEMON SOLE	PLAICE	DAB	BLUE WHITING
APPEARANCE									
Mean	1.5	3.8	2.1	1.9	1.8	2.0	1.4	1.6	2.8
S.D.	0 6	1.1	1.0	0.8	0.8	0.8	0.6	0.8	1.0
TEXTURE									
Mean	2.2	2.7	2.6	1.9	2.4	2.9	2.1	2.3	2.7
S.D.	1.1	1.0	1.0	0.9	0.9	1.3	1.0	1.0	1.1
FLAVOUR									
Mean	2.2	3.0	2.5	1.8	2.4	3.4	2.3	2.8	2.5
S.D.	1.0	1.0	1.1	0.7	1.1	1.2	1.1	1.2	1.3
ACCEPTABILITY									
Mean	2.1	3.2	2.5	1.8	2.2	3.3	2.2	2.6	2.7
S.D.	1.0	1.0	1.1	0.6	0.9	1.1	1.0	1.2	1.1

TABLE 7 : The mean scores obtained in a winter rating test, with 34 - 36 assessors using a 5 point hedonic scale, (1 = like very much, 5 = dislike very much).

The results from the summer and winter rating tests were reorganised to produce a rank order for all the fish species for each characteristic, and these data are presented in Tables 8 and 9. Examination of Tables 8 and 9 leads to a number of very significant observations. Firstly there is an exact relationship between the rank order for flavour and for overall acceptability in both tables, a close relationship for texture, and a more variable relationship for appearance. Secondly Lemon Sole which rates highly in the summer results is rated very badly in the winter set. Thirdly for most fish species the scores for all characteristics are on the 'like' side of neutrality. The series of tests carried out in the winter had originally been intended as additional results for the summer set, but it was clear that there was too much seasonal variation to justify combining the two sets of data and they were therefore considered separately.

The fish used in the rating tests had been selected for high quality and freshness, and large differences between sample scores would not be expected. In the summer results the maximum spread in mean ratings between most liked and least liked was 1.3 for both texture and flavour, 1.6 for acceptability and 2.8 for appearance. The larger range for appearance was primarily due to the very low rating given to Saithe which has a greyish coloured fillet. If the Saithe score is excluded, the spread is only 1.0 which tends to indicate that appearance is neutral in determining positive acceptability, but is significant in eliciting negative reactions. This pattern is seen again in the winter results which also included Blue Whiting which has a slightly grey coloured flesh, although less so than Saithe.

6.4.1 Analysis of Variance

A computer analysis of the separate ratings for each sensory characteristic was carried out in which the experiments were treated as a randomised block with each judge constituting a

Rank Order / Sensory Characteristic	1	2	3	4	5	6	7	8
APPEARANCE	Lemon Sole	Dab	Whiting	Haddock	Cod	Plaice	Ling	Saithe
	1.7	2.0		2.2	2.4		2.7	4.5
TEXTURE	Whiting	Haddock	Lemon Sole	Dab	Saithe	Cod	Plaice	Ling
	1.7	1.8	1.9	2.0	2.6	2.7	2.8	3.0
FLAVOUR	Lemon Sole	Haddock	Dab	Whiting	Cod	Plaice	Ling	Saithe
	1.4	1.8	2.0	2.3	2.4	2.6	2.7	
ACCEPTABILITY	Lemon Sole	Haddock	Dab	Whiting	Cod	Plaice	Ling	Saithe
	1.6	1.9	2.0	2.1	2.5		2.9	3.2

Table 8 : The mean scores from Table 6, arranged in rank order.

Rank Order / Sensory Characteristic	1	2	3	4	5	6	7	8	9
APPEARANCE	Plaice	Cod	Dab	Haddock	Whiting	Lemon Sole	Ling	Blue Whiting	Saithe
	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.8	3.8
TEXTURE	Whiting	Plaice	Cod	Dab	Haddock	Ling	Blue Whiting	Saithe	Lemon Sole
	1.9	2.1	2.2	2.3	2.4	2.6	2.7		2.9
FLAVOUR	Whiting	Cod	Plaice	Haddock	Ling	Blue Whiting	Dab	Saithe	Lemon Sole
	1.8	2.2	2.3	2.4	2.5		2.8	3.0	3.4
ACCEPTABILITY	Whiting	Cod	Plaice	Haddock	Ling	Dab	Blue Whiting	Saithe	Lemon Sole
	1.8	2.1	2.2		2.5	2.6	2.7	3.2	3.3

Table 9 : The mean scores from Table 7, arranged in rank order.

single block. A two-way analysis of variance was performed in which it was possible to remove the block effect from the estimation of error variance. This made subsequent analysis more sensitive. The analysis of variance tables for each organoleptic property appear in the top half of Tables 10 to 17, and show that the variation among species in both the summer and winter tests was significant at the 1% level for all four attributes.

While looking at the analysis of variance tables it is also interesting to note that in the summer test there was no significant difference between the ratings given by judges, whereas in the winter results there was a significant difference between judges for all attributes at either the 5% or 1% levels. The panels used in these two sets of tests were different, and it is unusual to have a panel exhibit the insignificant amount of variation shown in the summer results. The winter panel variation is much more normal.

6.4.2 Student's t Test

Further analysis using Student's t Test and Duncan's Multiple Range Test was carried out to identify the sources of the variation betweeen different species. The computer programme was used to apply Students' t Test in comparing each species with each other species. The purpose of this multiple comparison was to identify the fish which were significantly different statistically from the others in the test.

The t value applied, was arrived at by dividing the significance level by the number of comparisons. This had the effect of slightly reducing the sensitivity of the test, but allowed the flexible multiple comparisons to be made with more confidence, since the most conservative assessment of significance was used at each stage.

The data from Student's t Test is summarised in Tables 18 and 19.

Key to Tables 10 - 19

The following abbreviations have been used in the above tables.

DF. = Degrees of Freedom.

SS. = Sum of Squares.

MS. = Mean Squares.

F = F - Ratio.

NS = No Significant Difference.

* = Significant at the 5% level.

** = Significant at the 1% level.

LS = Lemon Sole.

D = Dab.

P = Plaice.

W = Whiting.

H = Haddock.

BW = Blue Whiting.

C = Cod.

S = Saithe.

L = Ling.

In the tables of results from the Duncan's Multiple Range Test, the fish which are not underscored by the same line are significantly different at the levels shown.

All the data in the above tables is obtained from 5 point Hedonic Rating Tests where 1 = like very much, 2 = like, 3 = neither like nor dislike, 4 = dislike, 5 = dislike very much.

a) ANALYSIS OF VARIANCE

	D.F.	S.S	M.S.	F.	SIGNIFICANCE.
FISH	7	112.56	16.08	19.74	**
JUDGES	20	13.37	0.69	0.82	N.S.
ERROR	140	114.06	0.81		
TOTAL	167	239.99			

b) DUNCAN'S MULTIPLE RANGE TEST

FISH	L.S.	D.	W	H	C	P	L	S
RANKED MEANS	1.7	2.0	2.0	2.2	2.4	2.4	2.7	4.5
5% SIGNIFICANT RANGE								
1% SIGNIFICANT RANGE								

Table 10: Appearance (Summer series).

a) Analysis of Variance of all ratings.

b) The Duncan's Multiple Range Test applied to mean ratings for 8 species.

(see page64 for the key of abbreviations).

a) ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.	F.	SIGNIFICANCE.
FISH	7	41.31	5.91	6.25	**
JUDGES	20	17.14	0.86	0.91	N.S.
ERROR	140	132.19	0.94		
TOTAL	167	190.64			

b) DUNCAN'S MULTIPLE RANGE TEST

FISH	W	H	L.S.	D	S	C	P	L
RANKED MEANS	1.7	1.8	1.9	2.0	2.6	2.7	2.8	3.0
5% SIGNIFICANT RANGE	———			———	———			———
1% SIGNIFICANT RANGE	———		———	———	———	———	———	———

Table 11 : Texture (Summer series).

a) Analysis of Variance of all ratings.

b) The Duncan's Multiple Range Test applied to mean ratings for 8 species.

(See page 64 for the key of abbreviations).

a) ANALYSIS OF VARIANCE

	D.F.	S.S	M.S.	F.	SIGNIFICANCE.
FISH	7	30.83	4.40	4.33	**
JUDGES	20	24.25	1.21	1.19	N.S.
ERROR	140	142.42	1.02		
TOTAL	167	197.50			

b) DUNCAN'S MULTIPLE RANGE TEST

FISH	L.S.	H	D	W	C	P	L	S
RANKED MEANS	1.4	1.8	2.0	2.3	2.4	2.6	2.7	2.7
5% SIGNIFICANT RANGE								
1% SIGNIFICANT RANGE								

Table 12 : Flavour (Summer series).

a) Analysis of Variance of all ratings.

b) The Duncan's Multiple Range Test applied to mean ratings for 8 species.

(See page 64 for the key of abbreviations).

a) ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.	F.	SIGNIFICANCE.
FISH	7	45.40	6.49	7.58	**
JUDGES	20	22.73	1.14	1.33	N.S.
ERROR	140	119.85	0.86		
TOTAL	167	187.98			

b) DUNCAN'S MULTIPLE RANGE TEST

FISH	L.S.	H	D	W	C	P	L	S
RANKED MEANS	1.6	1.9	2.0	2.1	2.5	2.5	2.9	3.2
5% SIGNIFICANT RANGE								
1% SIGNIFICANT RANGE								

Table 13 : Acceptability (Summer series).

a) Analysis of Variance of all ratings.

b) The Duncan's Multiple Range Test applied to mean ratings for 8 species.

(See page 64 for the key of abbreviations).

a) ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.	F.	SIGNIFICANCE
FISH	8	166.60	20.83	31.73	**
JUDGES	35	44.42	1.27	1.93	**
ERROR	274	179.82	0.66		
TOTAL	317	390.85			

b) DUNCAN'S MULTIPLE RANGE TEST

FISH	P	C	D	H	W	L.S.	L	B.W.	S
RANKED MEANS	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.8	3.8
5% SIGNIFICANT RANGE									
1% SIGNIFICANT RANGE									

Table 14 : Appearance (Winter series).

a) Analysis of Variance of all ratings

b) The Duncan's Multiple Range Test applied to mean ratings for 9 species.

(See page 64 for the key of abbreviations).

a) ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.	F.	SIGNIFICANCE.
FISH	8	31.08	3.89	4.12	**
JUDGES	35	94.02	2.69	2.85	**
ERROR	274	258.13	0.94		
TOTAL	317	383.23			

b) DUNCAN'S MULTIPLE RANGE TEST.

FISH	W	P	C	D	H	L	B.W.	S	L.S.
RANKED MEANS	1.9	2.1	2.2	2.3	2.4	2.6	2.7	2.7	2.9
5% SIGNIFICANT RANGE									
1% SIGNIFICANT RANGE									

Table 15 : Texture (Winter series).

a) Analysis of Variance of all ratings.

b) The Duncan's Multiple Range Test applied to mean ratings for 9 species.

(See page 64 for the key of abbreviations).

a) ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.	F.	SIGNIFICANCE.
FISH	8	63.89	7.99	7.18	**
JUDGES	35	60.33	1.72	1.55	*
ERROR	274	304.60	1.11		
TOTAL	317	428.83			

b) DUNCAN'S MULTIPLE RANGE TEST

FISH	W	C	P	H	L	B.W.	D	S	L.S.
RANKED MEANS	1.8	2.2	2.3	2.4	2.5	2.5	2.8	3.0	3.4
5% SIGNIFICANT RANGE									
1% SIGNIFICANT RANGE									

Table 16 : Flavour (Winter series).

a) Analysis of Variance of all ratings.

b) The Duncan's Multiple Range Test applied to mean ratings for 9 species.

(See page 64 for the key of abbreviations).

a) ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.	F.	SIGNIFICANCE
FISH	8	72.19	9.02	10.06	**
JUDGES	35	70.71	2.02	2.25	*
ERROR	274	245.69	0.90		
TOTAL	317	388.60			

b) DUNCAN'S MULTIPLE RANGE TEST

FISH	W	C	P	H	L	D	B.W.	S	L.S.
RANKED MEANS	1.8	2.1	2.2	2.2	2.5	2.6	2.7	3.2	3.3
5% SIGNIFICANT RANGE									
1% SIGNIFICANT RANGE									

Table 17 : Acceptability (Winter series)

a) Analysis of Variance of all ratings.

b) The Duncan's Multiple Range Test applied to mean ratings for 9 species.

(See page 64 for the key of abbreviations).

	C	S	L	W	H	LS	P	D
C		**						
S			**	**	**	**	**	**
L						**		
W								
H								
LS								
P								
D								

APPEARANCE

	C	S	L	W	H	LS	P	D
C				*				
S								
L				**	**	*		*
W							**	
H							*	
LS								
P								
D								

TEXTURE

	C	S	L	W	H	LS	P	D
C						*		
S						**		
L						**		
W								
H								
LS							**	
P								
D								

FLAVOUR

	C	S	L	W	H	LS	P	D
C						*		
S				**	**	**		**
L					**	**		
W								
H								
LS							*	
P								
D								

ACCEPTABILITY

Table 18 : Matrix of significant differences between species in summer results for four sensory characteristics found on application of Student's t - Test.

	C	S	L	W	H	BW	LS	P	D
C		**	*			**			
S			**	**	**	**	**	**	**
L						*		**	
W						**			
H						**			
BW							**	**	**
LS								*	
P									
D									

APPEARANCE

	C	S	L	W	H	BW	LS	P	D
C									
S				**					
L				*					
W						**		**	
H									
BW									
LS									
P									
D									

TEXTURE

	C	S	L	W	H	BW	LS	P	D
C		*					**		
S				**					
L							*		
W							**		**
H							**		
BW							*		
LS								**	
P									
D									

FLAVOUR

	C	S	L	W	H	BW	LS	P	D
C		**					**		
S				**	**				
L									
W						**	**		*
H							**		
BW									
LS								**	
P									
D									

ACCEPTABILITY

Table 19: Matrix of significant differences between species in winter results for four sensory characteristics found on application of Student's t - Test.

The anticipated pattern where the differences in acceptability can be explained mainly by flavour or appearance can be seen. Saithe is significantly different at the 1% level for appearance from all other species in the summer and winter tests. Blue Whiting follows a similar pattern in the winter test. Ling and Plaice (summer) and Whiting (winter) show significant differences in texture between other species which are explained by their bottom or top (respectively) rank order positions for mean scores (Tables 8 and 9). Sole differs significantly from other samples in both sets because of its position at the top (summer) or bottom (winter), of the rank order of mean scores for flavour.

6.4.3 Duncan's Multiple Range Test

For a more sensitive analysis of the differences between fish species, Duncan's Multiple Range Test was carried out on the ranked means, and these results are summarised in the lower half of Tables 10 to 17. Since there is no significant difference between the degree of liking for the species underscored by the same line, the conclusion must be that any species which is underscored by the same line or which lies to the left of it in the table of ranked means would be a satisfactory substitute for other species in the same group. The implications of this finding will be considered in more detail at the end of the discussion.

6.4.4 'Halo' Effects

The rating tests had been performed by assessors who were asked to rate separately all four characteristics at the same sitting. Given these conditions it is clearly possible for assessors to be unconsciously influenced by one characteristic when scoring another, and it is not possible with the experimental design used in these tests to rule out the possibility that a carry-over effect was occurring. These influences are sometimes referred to as 'halo' effects even though the influences can be negative as well as positive. The organoleptic properties

of texture, flavour, and appearance are generally considered to be independent of each other, but this assumption may not be entirely valid in the case of fish. For example the intensity of the particular chemical properties which produce good flavour may be pH related, and there is also an established relationship between pH and texture. The translucency and degree of whiteness of fish fillets could also be related to pH. These possible interactions might have an effect on the results of the rating test but the experimental design which was used was not able to exclude them with certainty.

Despite these reservations there is some evidence within the results that panellists were rating the different sensory parameters independently. Blue Whiting and Saithe, for example, score badly for appearance, but their scores for flavour and texture were not significantly different from other species. The poor ratings for appearance did however affect the acceptability scores. This effect is seen very clearly in the Student's t Test results, Tables 18 and 19.

The computer analysis of ratings which is discussed later provides various regression models for describing acceptability in terms of other properties. It demonstrates a highly significant extra contribution from appearance when the flavour factor has been fitted, and vice versa. This result would again tend to indicate that assessors were scoring the three organoleptic properties independently.

6.4.5 Texture - Sensory and Instrumental Results

The smallest range of scores in both the summer and the winter tests was for texture, a result which is not unexpected since, as mentioned previously, all types of fresh white fish are tender. The two lowest scores (Ling 3.0 and Lemon Sole 2.9), were probably awarded for quite different reasons, the Ling having a relatively coarse structure and the Lemon Sole in the winter tests having a rather loose and sloppy structure.

(It is important to keep in mind that these scores relate only to degree of liking and not to any specific textural property).

Cooked samples of each of the nine species rated in the winter series were tested for hardness on a purpose-built fish Texturometer to which Unilever Research laboratories allowed access, (Main, Ross and Sutton, 1972). Tests carried out by staff there had established that machine readings equated well with assessments made by taste panels on the 'hardness' of Cod (Sutton and Main, 1967). The principle of the apparatus is that mashed fish is packed into a small stainless steel cup and a plunger which has a very loose fit is driven into the sample a predetermined distance and the maximum resistance recorded. The movement of the plunger has a twofold action, it compresses the fish and also extrudes some of it, and the final measure depends both on the difficulty of compression (resistance) and the ease of extrusion (shear and slipperiness). These two factors are of course, encountered when biting into samples.

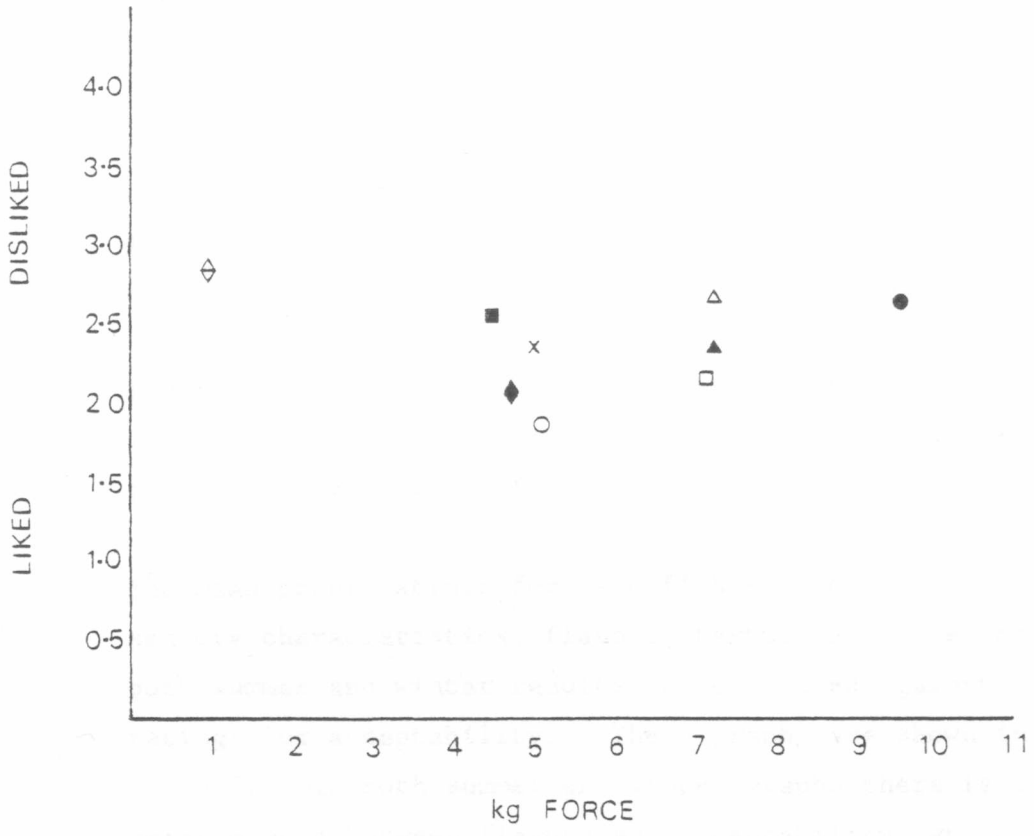
The apparatus had an attachment for assisting the packing of samples into the test cup which was basically a well-fitting piston attached to a torsion wrench. Despite this apparatus, packing could not be absolutely standardised and the recommended procedure was always to carry out at least seven tests on each fish and to average the middle five. The mean readings in kg force obtained from the machine tests are shown alongside the mean panel scores for texture in Table 20, and graphically in Figure 1. It can be seen that the machine scores vary considerably from hard (9.7kg force) for Blue Whiting to very soft (0.9 kg force) for Lemon Sole, while the panel scores varied by 1 point from like (1.9) for Whiting to neither like nor dislike (2.9) for Lemon Sole. The shape of the graph in Figure 1 tends to indicate that liking is not really influenced significantly by texture as measured by the Texurometer. These results therefore establish that a wide range of fish textures are acceptable to consumers and that texture alone is unlikely to be a major

FISH TYPE	MEAN SCORES	
	PANEL (1)	ABERDEEN (2) TEXTUROMETER
WHITING	1.9	5.1
PLAICE	2.1	4.7
COD	2.2	7.2
DAB	2.4	5.0
HADDOCK	2.4	7.3
LING	2.6	4.5
SAITHE	2.7	7.3
BLUE WHITING	2.7	9.7
LEMON SOLE	2.9	0.9

Table 20 : A comparison of the mean scores obtained for Texture from a Hedonic Rating panel and the Aberdeen Texturometer using the same samples of 9 fish species.

(1) = Panel ratings using a 5 point hedonic scale (1 = like very much, 5 = dislike very much).

(2) = Texturometer readings in kg force.



KEY - □ Cod
■ Ling
△ Saithe
▲ Haddock
○ Whiting
● Blue Whiting
⟠ Lemon Sole
♦ Plaice
x Dab

Figure 1 : The relationship between the mean hedonic ratings for texture and the readings from the Aberdeen Fish Texturometer, for the same samples of nine fish species.

Panel - 1 = like very much, 5 = dislike very much

kg force - 1 = very soft, 11 = very hard.

factor in determining overall acceptability. This result is in contrast to that found with most other types of flesh product where texture, particularly tenderness, is regarded as the major factor in determining preference.

6.5 The Correlation Between Acceptability and Flavour, Texture and Appearance

The relationship between the acceptability of fish species and the three sensory characteristics was discussed briefly earlier. This data is shown in detail in Figures 2 to 5 as histograms where the number of assessors awarding each score is plotted for each characteristic. The general similarity in profile for flavour and acceptability is fairly marked in most cases, the exceptions being where a negative effect of appearance on acceptability is identifiable.

The mean panel ratings for each fish species for the three sensory characteristics, flavour, texture and appearance, from both summer and winter results, were plotted against the mean ratings for acceptability. These graphs are shown in Figures 6 and 7. In both summer and winter graphs there is a clear relationship between flavour and acceptability, which is further emphasised by the high correlation coefficient (r) between flavour and acceptability (obtained from the correlation matrix from the computer Regression Analysis Programme).

Matrices of correlation coefficients for the four characteristics rated in the hedonic rating tests were calculated for the summer results (8 species), the winter results (9 species), the combined results (17 species), and the combined results with the data for Saithe and Blue Whiting removed 14 species). The matrices for 17 and 14 species are shown in Table 21. From this table it can be seen once more that flavour correlates best with acceptability. Texture apparently has a reasonably high correlation with acceptability, but is also highly

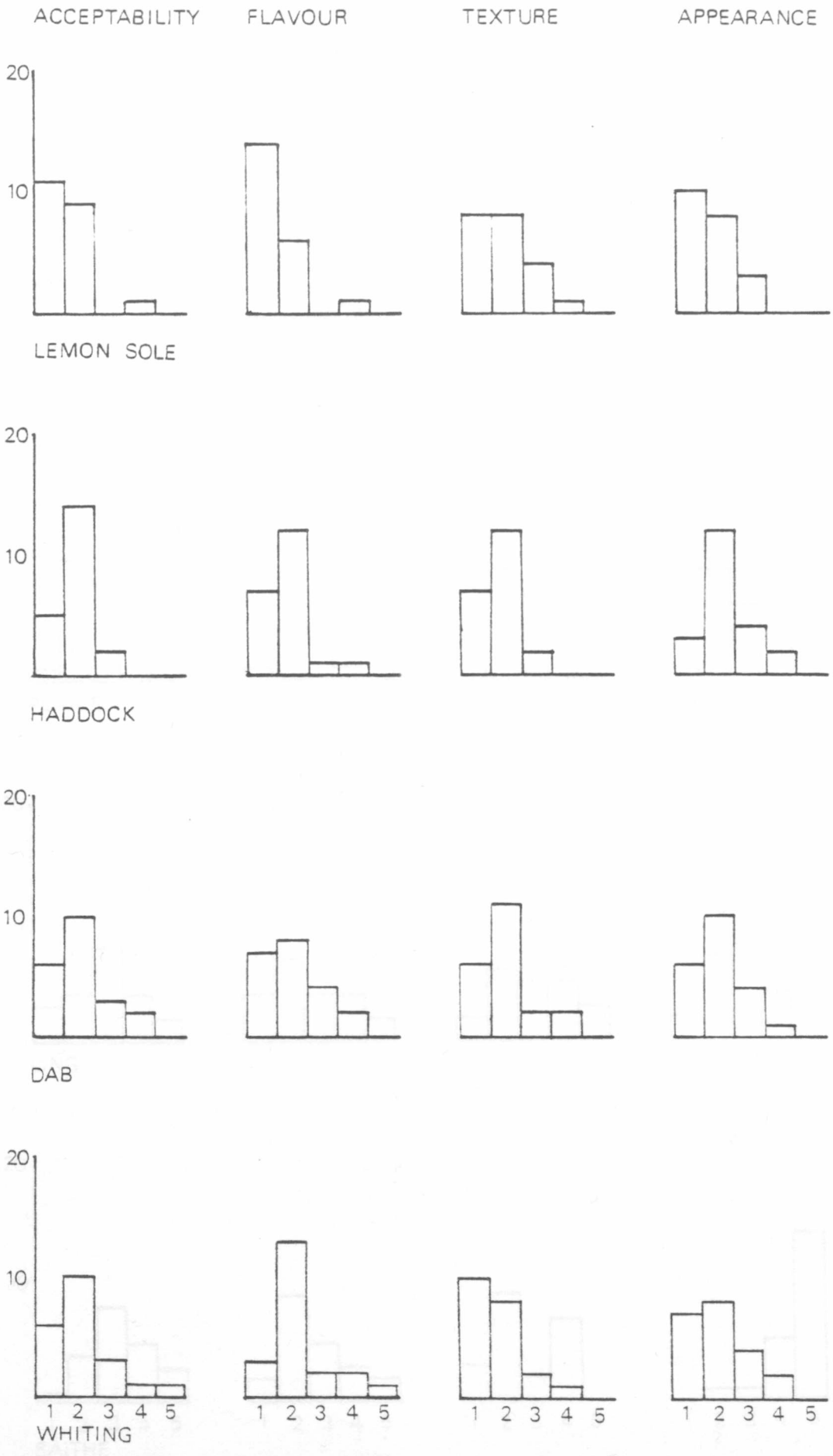


Figure 2 : The distribution of ratings for four sensory characteristics from the summer series of hedonic rating tests with 21 assessors. (1 = like very much, 5 = dislike very much).

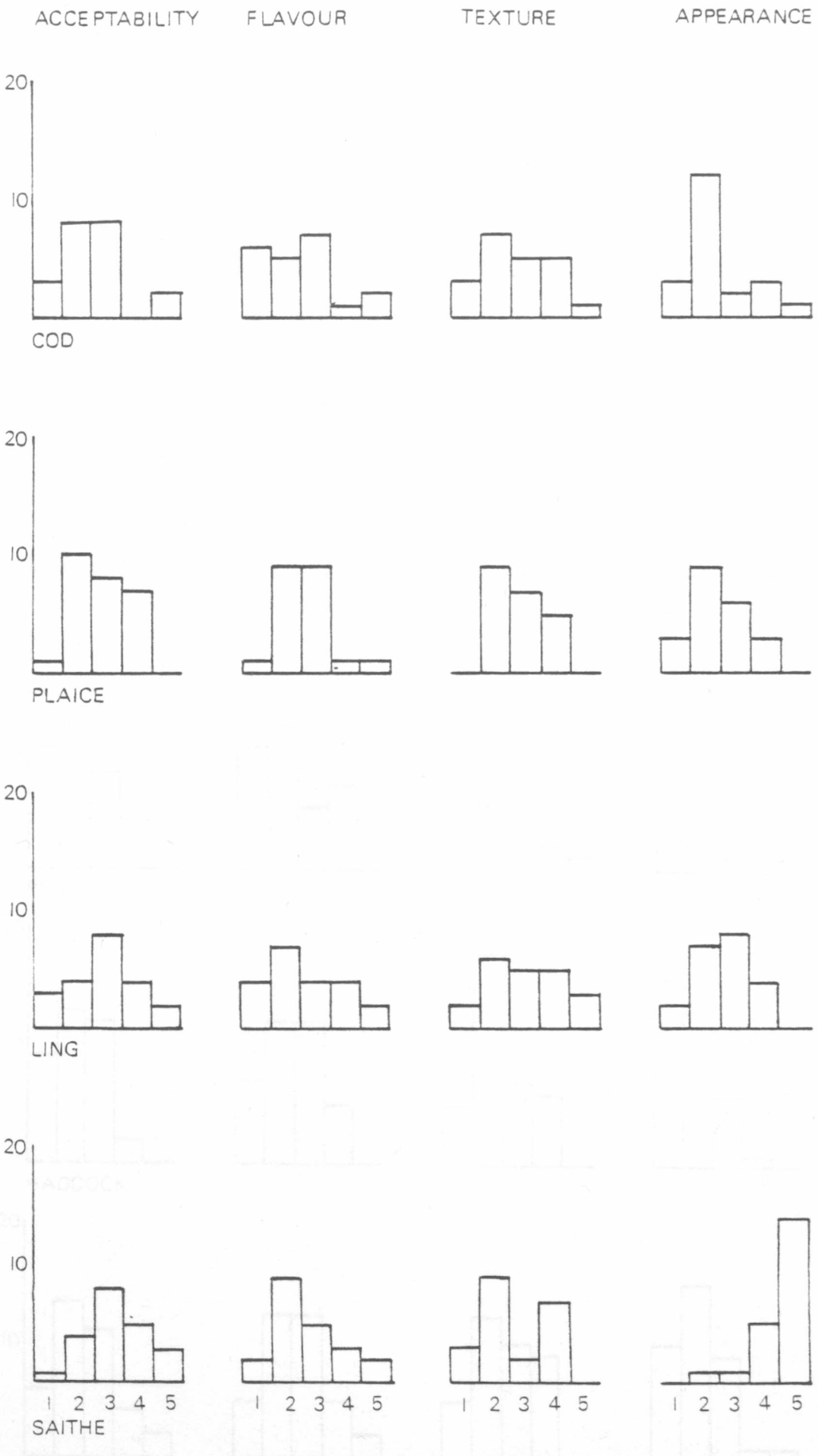


Figure 3 : The distribution of ratings for four sensory characteristics from the summer series of hedonic rating tests with 21 assessors. (1 = like very much, 5 = dislike very much).

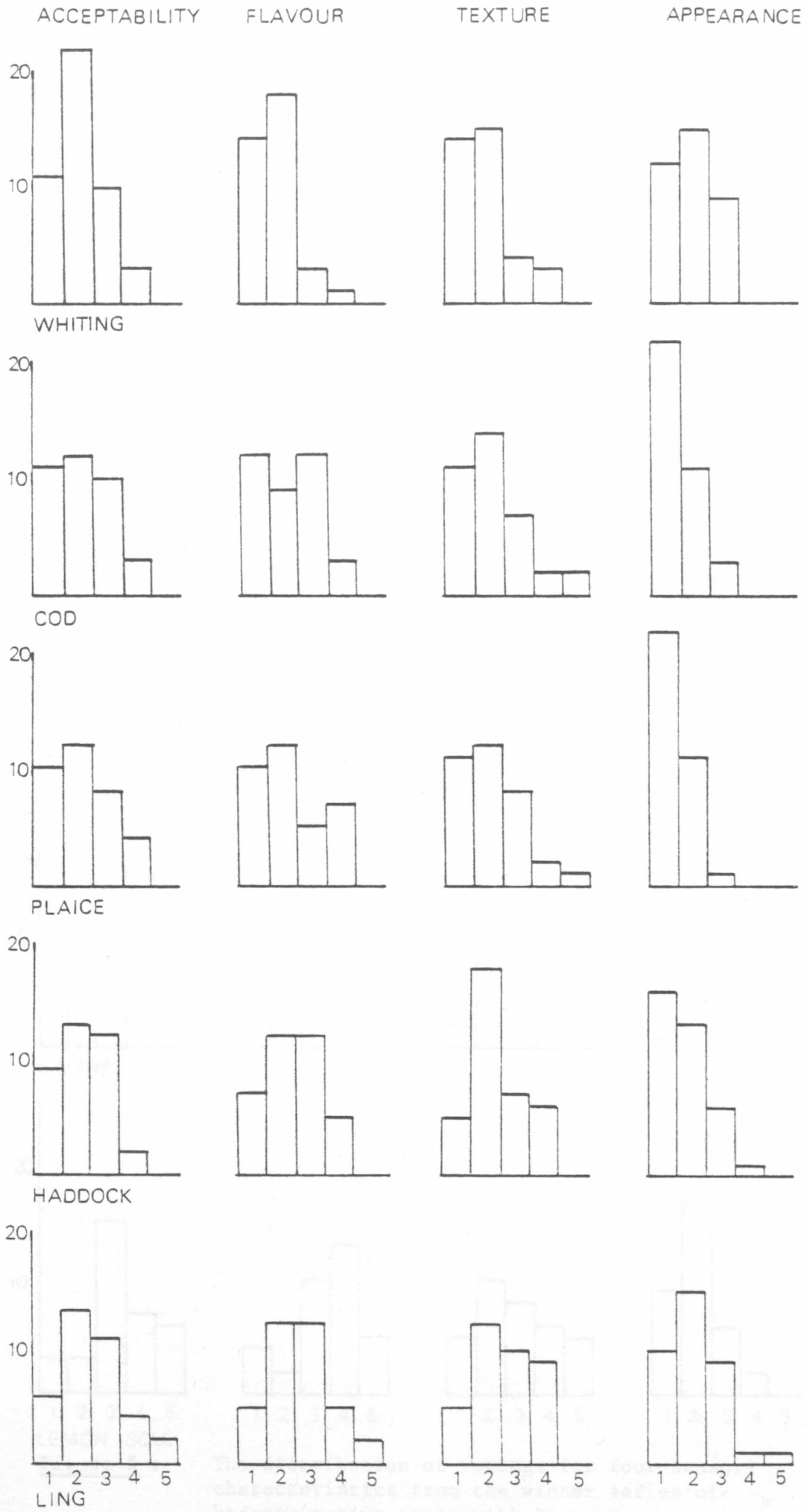


Figure 4 : The distribution of ratings for four sensory characteristics from the winter series of hedonic rating tests with 36 assessors. (1 = like very much, 5 = dislike very much).

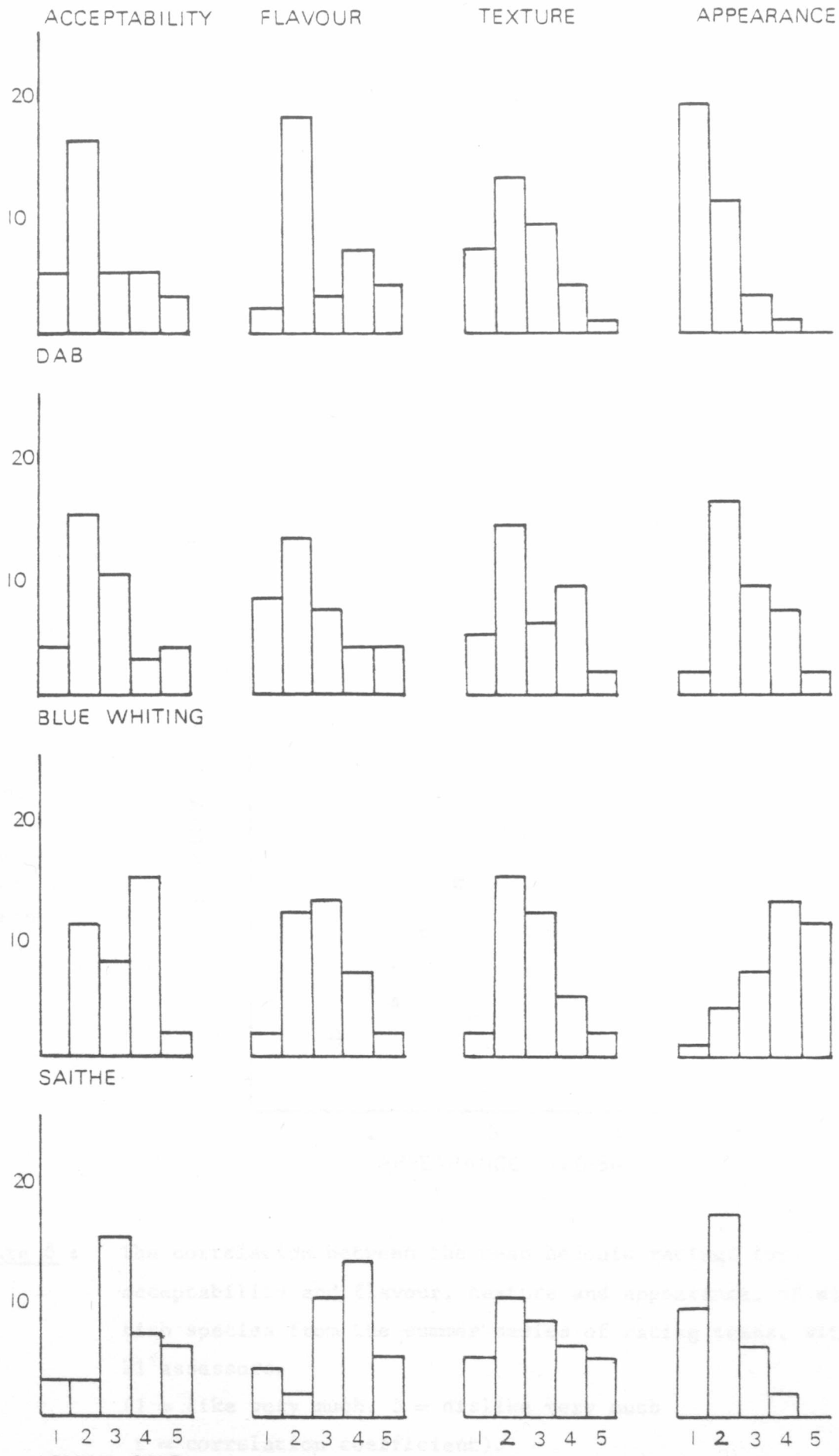


Figure 5 : The distribution of ratings for four sensory characteristics from the winter series of hedonic rating tests with 36 assessors. (1 = like very much, 5 = dislike very much).

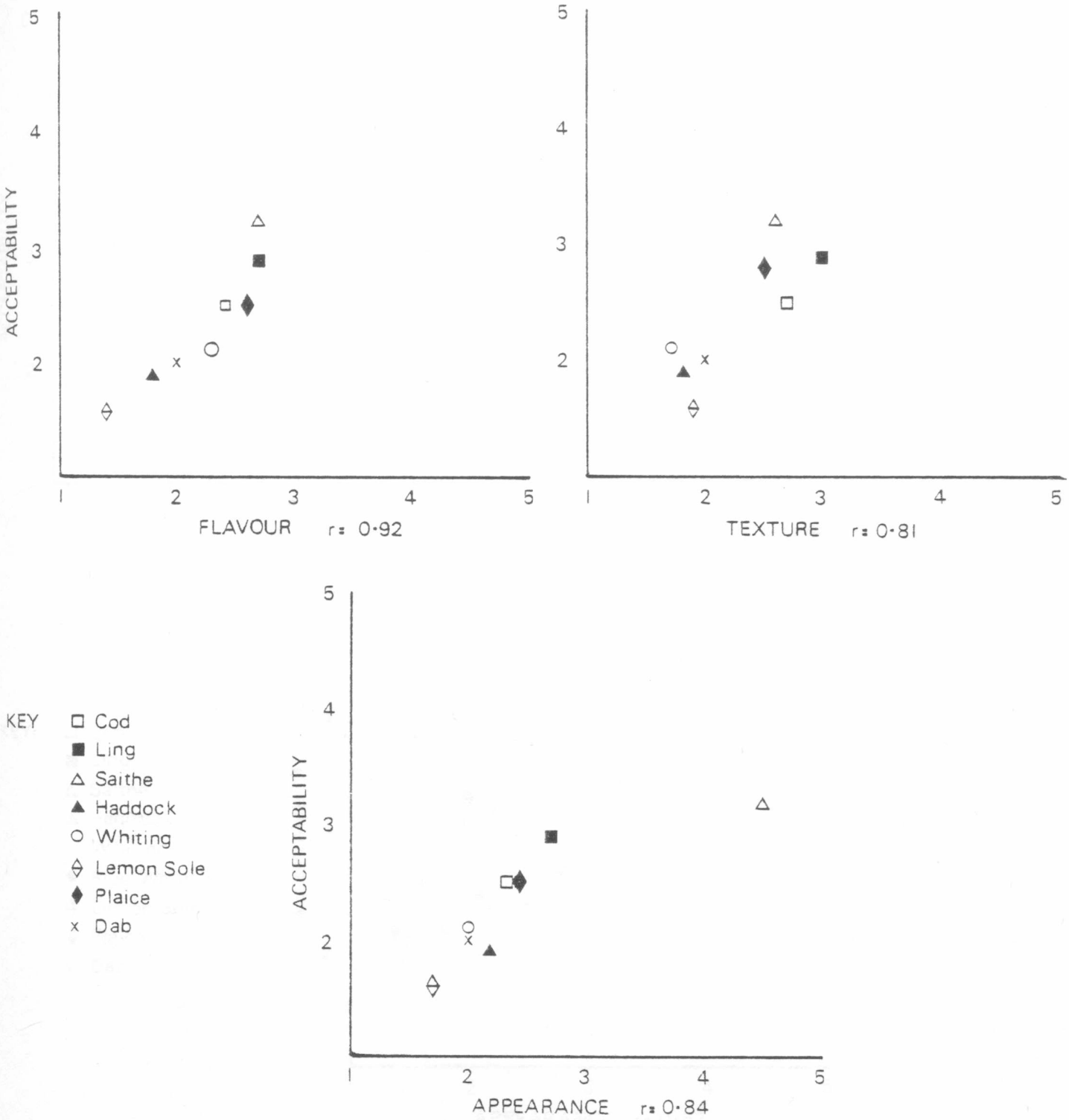


Figure 6 : The correlation between the mean hedonic ratings for acceptability and flavour, texture and appearance, of eight fish species from the summer series of rating tests, with 21 assessors.
(1 = like very much, 5 = dislike very much
r = correlation coefficient).

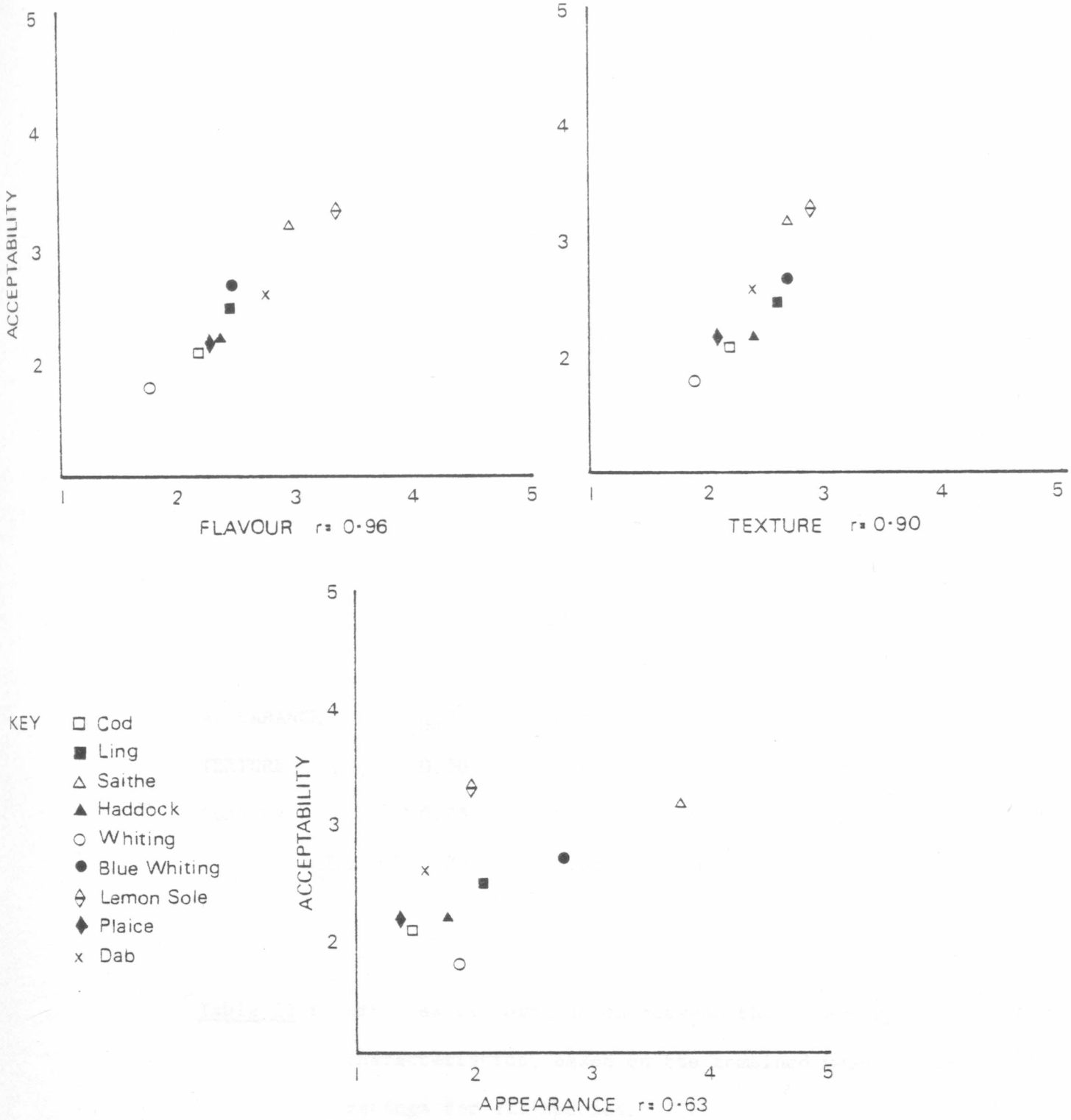


Figure 7: The correlation between the mean hedonic ratings for acceptability and flavour, texture and appearance, of nine fish species from the winter series of rating tests with 36 assessors.
(1 = like very much, 5 = dislike very much
r = correlation coefficient).

CORRELATION MATRIX A.

	APPEARANCE	TEXTURE	FLAVOUR	ACCEPTABILITY
APPEARANCE	1.00	0.47	0.42	0.67
TEXTURE	0.47	1.00	0.78	0.83
FLAVOUR	0.42	0.78	1.00	0.93
ACCEPTABILITY	0.67	0.83	0.93	1.00

CORRELATION MATRIX B.

	APPEARANCE	TEXTURE	FLAVOUR	ACCEPTABILITY
APPEARANCE	1.00	0.51	0.25	0.38
TEXTURE	0.50	1.00	0.76	0.86
FLAVOUR	0.25	0.76	1.00	0.96
ACCEPTABILITY	0.38	0.86	0.96	1.00

Table 21 : Matrices of correlation between the 4 sensory characteristics, based on the combined mean ratings for all species.

Matrix A - For 17 species combining the Summer and Winter results.

Matrix B - For 14 species combining the Summer and Winter results, but omitting all ratings for Saithe and Blue Whiting.

correlated with flavour.

The multiple regression analysis carried out on the data allowed various regression models to be tested for the purpose of describing acceptability in terms of the other characteristics. The best model for describing the acceptability of white fish species which was identified did not require texture scores to be included in the equation and showed that:

Acceptability = 0.8 Flavour + 0.2 Appearance (approximately).

Using this model it would be possible to predict the acceptability of a sample of any fresh white fish by using the individual attribute ratings from a hedonic rating test. The figures in the model can also be regarded as weightings, which indicate that, using this model, flavour is four times as important as appearance in determining acceptability.

If the partial scores for each species are considered it is found that fish such as Saithe and Blue Whiting which have a poor appearance, show some divergence from this model, and for this reason the multiple regression analysis was performed again, with omission of all the data from these two fish. In this separate analysis it was found that appearance now made no significant contribution to overall acceptability, which was now best described purely in terms of flavour. These findings reinforce the previous conclusions that in terms of their contribution to the overall acceptability of fish species, texture is usually neutral and appearance is either neutral or negative.

From the results and discussion from tests using plain steamed fish samples, there is therefore a strong indication that consumers are likely to be satisfied with fresh samples of most white fish species. People are certainly able to distinguish between different species mainly on the basis of flavour and will express a measurable preference, but the intensity or strength of the preference is not great. The Duncan's Multiple Range Test

results show that there is a large number of species which could be satisfactorily interchanged with one another without causing adverse consumer reaction. In general the more traditional species were marginally preferred to others but on the basis of this evidence consumers could be advised strongly to choose the cheapest alternative species when presented with a choice in the fishmonger's shop.

6.6 Evaluation of Fish Species in Product Form

From the foregoing analysis on data from plain steamed samples, it seemed probable that the use of alternative cooking methods or disguise of the appearance of samples by incorporation into products, would cause some modification to the picture. A further series of tests was thus made, using only two of the nine species, which were incorporated in five types of fish dish, thought to be representative of those normally encountered in homes.

The species chosen for comparison were Whiting and Blue Whiting, the former because of its good ratings in the previous hedonic test, and the latter because it is a relatively new species which is often advocated as a possible solution to some of the problems presently facing the fishing industry (Burgess, 1977). Blue Whiting had also been found to be less acceptable to assessors than other species due to its grey appearance, and for this reason it was chosen for use in products to find out whether or not this effect remained.

Table 22 summarises the results obtained from a seven point hedonic rating test, where 58 assessors tasted five products into which Whiting and Blue Whiting had been incorporated. In the hedonic rating test on plain steamed samples (Table 7), Whiting scored approximately 1 unit higher than Blue Whiting for all four characteristics (texture, flavour, appearance and acceptability). (Samples were rated on a seven-point hedonic scale, 7, like very much 1, dislike very much). Table 22 shows

Product	Species	Mean Score	Standard Deviation	Paired t-test	Significance	Mean Product Score
Steamed in Parsley Sauce	Whiting	5.9	1.2	1.92	N.S.	5.7
	Blue Whiting	5.5	1.2			
Deep fried in batter	Whiting	5.5	1.4	1.69	N.S.	5.35
	Blue Whiting	5.2	1.4			
Deep fried in crumbs	Whiting	5.8	1.1	1.16	N.S.	5.7
	Blue Whiting	5.6	1.3			
Fish Cakes	Whiting	5.4	1.4	1.37	N.S.	5.5
	Blue Whiting	5.6	1.2			
Fish Pie	Whiting	5.6	1.5	1.02	N.S.	5.5
	Blue Whiting	5.4	1.7			

(N.S. = Not significant at 5% level)

Table 22 : Results of a rating test carried out by 58 assessors on 5 products using a 7 point hedonic rating scale.

that after the incorporation of fish into products, the ratings became quite similar and the products made with both types of fish are well liked.

It is interesting that this is not a progressive effect which is being influenced by the extent of treatment (e.g. frying in batter), or volume of other material (e.g. potato in fish cakes). There is an indication that in the simplest product (coating plain steamed fish with parsley sauce) Whiting is preferred to Blue Whiting, since the t - by difference test is significant at about the 6% level.

All products made with both types of fish were liked by the assessors. Since there is no significant difference in the products made with either species, it is possible to calculate a product rating by halving the combined means, and this rating is also shown in Table 22. It can be seen that all the products rated very similarly, which is an interesting result, since it would not have been unreasonable to expect assessors to like some products more than others.

An analysis of variance carried out on the results confirmed that there were no significant species differences within or between products. Significant differences were found between assessors, which, as mentioned previously, is the normal finding.

It is thus evident from the results of this test that when two different fish species are incorporated in cooked products, whether simple or complex, the three sensory properties of flavour, texture and appearance, become increasingly irrelevant in determining overall acceptability. The Blue Whiting which had been found to be less acceptable than Whiting in plain steamed form, because of its greyish cooked appearance, was well liked by assessors when incorporated in products, and would appear to be a satisfactory alternative to products made with more traditional species.

6.7 Conclusions

The investigations which have been carried out allow a number of definite conclusions to be drawn with respect to white fish of good quality.

1. People are able to distinguish between the various species on the basis of their sensory properties.

2. People will express relative preferences for the various species which have a reasonable correlation with traditional buying habits.

3. The major determinant of preference is flavour.

4. The expressed preferences were relative and even the least preferred species were very acceptable in more absolute terms.

5. Most consumers would be perfectly satisfied by most species and could well be advised to base their selection on price rather than name.

6. Highly acceptable products could probably be made from any good quality fish. The investigation was only on two species, but the data strongly indicates that mixing fish with other materials and flavours will produce satisfactory products from most species.

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APPENDIX A

SCORE SHEET FOR THE ORGANOLEPTIC CHARACTERISTICS OF WHITE FISH. (Shewan et al. 1953).

RAW FISH

GENERAL APPEARANCE	Score
Eyes perfectly fresh, convex black pupil, translucent cornea; bright red gills (colour depending on species); no bacterial slime, outer slime water-white or transparent; bright opalescent sheen, no bleaching.	5
Eyes slightly sunken, grey pupil, slight opalescence of cornea; some discoloration of gills and some mucus; outer slime opaque and somewhat milky; loss of bright opalescence and some bleaching.	3
Eyes sunken; milky white pupil, opaque cornea; thick knotted outer slime with some bacterial discoloration.	2
Eyes completely sunken; shrunken head covered with thick yellow bacterial slime; gills showing bleaching or dark brown discoloration and covered with thick bacterial mucus; outer slime thick yellow-brown; bloom completely gone; marked bleaching and shrinkage.	0

FLESH INCLUDING BELLY FLAPS	
Bluish translucent flesh, no reddening along the backbone and no discoloration of the belly flaps; kidney blood bright red.	5
Waxy appearance, no reddening along backbone, loss in original brilliance of kidney blood, some discoloration of belly flaps.	3
Some opacity, some reddening along backbone, brownish kidney blood and some discoloration of the flaps.	2
Opaque flesh, very marked red or brown discolouration along backbone, very brown to earthy brown kidney blood, and marked discoloration of the flaps.	0

ODOURS	
Fresh seaweedy odours	10
Loss of fresh seaweediness, shellfish odours	9
No odours, neutral odours	8
Slight musty, mousey, milky or caprylic acid like odours, garlic, peppery,	7
Bready, malty, beery, yeasty odours	6

Lactic acid, sour milk, or oily odours.	5
Some lower fatty acid odours (eg acetic or butyric acids) grassy, 'old boots', slightly sweet, fruity or chloroform-like odours.	4
Stale cabbage water, turnipy, 'sour sink', wet matches, phosphene-like odours.	3
Ammoniacal (trimethylamine and other lower amines) with strong 'byre-like' ('o-toluidine') odours.	2
H_2S and other sulphide odours, strong ammoniacal	1
Indole, ammonia, faecal, nauseating, putrid odours	0

TEXTURE

Firm, elastic to the finger touch	5
Softening of the flesh, some grittiness near tail	3
Softer flesh, definite grittiness and scales easily rubbed off the skin	2
Very soft and flabby, retains the finger indentations, grittiness quite marked and flesh easily torn from the backbone.	2

COOKED FISH

ODOUR

Strong seaweedy odours	10
Some loss of seaweediness	9
Lack of odour or neutral odours	8
Slight strengthening of the odour but no sour or stale odour - wood shavings, woodsap, vanillin or terpene-like odours	7
Condensed milk, caramel or toffee-like odours	6
Milk jug odours, or boiled potato or boiled clothes-like odours	5
Lactic acid and sour milk, or 'byre-like' odours	4
Lower fatty acids (eg acetic or butyric acids) some grassiness or soapiness, turnipy or tallowy odours	3
Ammoniacal (trimethylamine) and some sulphide odours	2
Strong ammoniacal (trimethylamine) and some sulphide odours	1
Strong ammonia and faecal, indole and putrid odours	0

FLAVOUR

Fresh, sweet flavours characteristic of the species	10
Some loss of sweetness	9
Slight sweetness and loss of the flavours characteristic of the species	8
Neutral flavour, definite loss of flavour but no 'off' flavours	7
Absolutely no flavour, as if chewing cotton wool	6
Trace of 'off' flavours, some sourness but no bitterness	5
Some 'off' flavours, and some bitterness	4
Strong bitter flavours, rubber-like flavour, slight sulphide-like flavours	3
Strong bitterness, but not nauseating	1
Strong 'off' flavours of sulphides, putrid, tasted with difficulty	0