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Sensory Evaluation of the Texture and Appearance of 17 Species of North Atlantic Fish

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ABSTRACT

A standardized sensory methodology for evaluating the texture and appearance of fin fish was developed as part of a new retail marketing strategy for fisheries products proposed by the National Marine Fisheries Service of the U.S. Department of Commerce. This methodology is based on the evaluation of eight texture and appearance attributes of fish, using a 7-point category scale. The method was applied to an evaluation of 17 species of North Atlantic fish to provide a data base for grouping species according to similarities and dissimilarities in their sensory characteristics. The obtained data were analyzed by cluster analytic procedures and revealed several distinct groupings of fish. Multidimensional unfolding of the data resulted in a two-dimensional "fish map" that can be used to schematically represent the sensory relationships among species.

INTRODUCTION

ALTHOUGH IT HAS BEEN STATED that the acceptability of cooked fish is more dependent on its flavor than on its texture (Rasekh et al., 1970; Connell and Howgate, 1971; Howgate, 1977), texture has also been shown to be an important determinant of preference, especially for fish with mild flavor character (Wesson et al., 1979). Szczesniak (1972) has also reported that texture is cited 25% more often than flavor among teenagers as the reason for disliking fish and seafood. Unfortunately, most of the sensory research on the texture of fish muscle has focussed on differences in texture within a single species resulting from biological, preparation, or storage variables (e.g., Kelly et al., 1966; Cowie and Little, 1966; Love, 1969; Love et al., 1974; Gill et al., 1979). Comparative studies of the texture of different species have been few in number, originating primarily from research at Torry Research Station in Aberdeen, Scotland.

The National Marine Fisheries Service (NMFS) of the U.S. Department of Commerce (USDC) has recently been involved in developing a new seafood nomenclature system that is to be based on the sensory or "edibility" properties of fish. The goal of this new system is to enable consumers to make educated choices among novel species by providing the comparative sensory data necessary to select a desired texture, flavor, etc. of fish. As part of this work, our laboratory has been involved with the development of standardized methodology for evaluating the sensory properties of cooked fish (King et al., 1980; Kapsalis and Maller, 1980; Cardello et al., 1981). The present report details this methodology as it applies specifically to the evaluation of the texture and appearance of fish and presents descriptive/quantitative data on the texture and appearance of 17 species of North Atlantic fish.

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MATERIALS & METHODS

Development of methodology

Samples and preparation. All samples tested in the present study were from fish harvested by "day boats" (dock-to-dock time was approximately 24 hr). Fish were landed the night before or early in the morning of the day that they were filleted. Two firms performed most of the filleting: Amoriggi Sea Foods, Inc., Johnston, R.I., and Legal Sea Foods, Inc., Chestnut Hill, MA (no endorsement implied). Boxes of fillets were packed with ice in insulated shipping containers and brought to NLABS on the same day on which the fish were filleted. If fillets arrived "skin on" they were skinned at this time. Preparation of samples was done in a 10°C chill room. The quality of the fish was checked by Military Veterinary Personnel and by Dr. Frederick J. King of NMFS/USDC, using visual and odor criteria for freshness. Fillets were trimmed by removing the belly flap, the edge of the nape, and the tip of the tail. The rest of each fillet was cut into 56g pieces.

Portions of the fillet trimmings, representing at least six different fillets, were taken to the Gloucester Laboratory, Northeast Fisheries Center, for species identification using thin-layer isoelectric focusing. Most of the identifications were based on an official first action method of the Association of Official Analytical Chemists (Lundstrom, 1980). However, over the course of the two years during which these data were collected, a similar but more rapid method was also used (Lundstrom, 1981).

In order to ensure uniform heating and to minimize distortion of the "innate" texture and appearance characteristics of the fish, a boil-in-pouch method of cooking was used. All fish samples were cooked by placing the samples in cooking pouches specially fabricated by the Food Packaging Group/NLABS. The cooking pouch was a laminate of 5.1×10^{-2}nm polyethylene and 2.5×10^{-2}nm polyester. The pouches allowed drainage of drippings from the fish by gravity through interconnecting perforations into a lower compartment of the pouch. This prevented the steam-cooking of the fish in its own liquids. Once heat-sealed, the pouches were immersed in 71°C water. The time required for cooking was determined by placing thermocouples at the center of samples of different thickness and then performing heat penetration studies. Cooking times were established for various thicknesses and all fish samples were cooked uniformly to an internal temperature of 71°C.

Texture profile panel. Development of the sensory methodology for evaluating fish texture was based on the use of a trained texture profile panel. This panel, operating within the Behavioral Sciences Division of the Science and Advanced Technology Laboratory (SATL) at NLABS, was formed in June of 1977 and consisted of six members. Each panelist had extensive prior training and experience in the texture analysis of a wide variety of solid and semi-solid food products.

The methods used by the texture panel were modeled after the General Foods Texture Profile Method (Szczesniak, 1963; Szczesniak et al., 1963; Brandt et al., 1963), and as such, the descriptive terminology described herein was developed within a framework that recognizes three general classes of texture attributes. These are: (1) mechanical – those characteristics that are related to the responses of food materials to applied forces; (2) geometrical – those characteristics that are related to the geometrical arrangement of the constituents of food, e.g., size, shape and orientation of particles; and (3) moisture and fat-related – those characteristics that are associated with the water and fat content of foods. Moreover, each attribute was evaluated at a specific time during the masticatory cycle, since most textural attributes are perceived in a specific temporal order.

Throughout the duration of these studies, the Texture Profile Panel convened on an average of twice per week. All sessions were conducted in the preparation area of the Food Acceptance Laboratory SATL/NLABS or in an adjoining panel room. During test sessions hot samples were removed from their cooking pouches and placed on individual plastic-coated serving plates. Each sample was evaluated by cutting standard-sized pieces of flesh (approximately 1.3 cm square) from the cooked section of fillet using a conventional serrated steak knife. Distilled water and unsalted crackers were available for cleansing the mouth of residual flavor, oil, and particulate matter. All samples were coded to conceal the identity of the species. A maximum of three species were evaluated at any one session.

Development of descriptive terminology. Initial research was focused on the development of a comprehensive list of sensory texture attributes to include the broad range of fish muscle texture that was likely to be encountered in testing. For this purpose, a wide variety of fish species (≈25) was examined, so that all relevant textural attributes could be identified and appropriate definition given to each. The resulting set of textural attributes included those of "hardness," "flakiness," "chewiness," "fibrousness," "moisture/oil release," "cohesiveness of the mass," "adhesiveness," "oily mouthcoating," and "astringent mouthfeel."

Due to the consumer-oriented nature of the NMFS/USDC project, this initial set of attributes was analyzed for its usefulness to consumers for discriminating among species of fish. Details of this multi-phased evaluation, using stepwise multiple discriminant analysis, can be found in Sawyer et al. (1982). For the purpose of this report it can be stated that, during repeated testing, consumers could not use effectively the textural attributes of "adhesiveness," "cohesiveness of the mass," "astringent mouthfeel," or "moisture-oil release" to differentiate species of fish. Based on these data, as well as the texture profile panel's assessment of the relative importance of these terms, it was decided that the terms "adhesiveness," "cohesiveness of the mass," and "astringent mouthfeel" could be eliminated and that the term "moistness" could be substituted for "moisture-oil release." Thus, the six textural attributes listed and defined in Table 1 were adopted for subsequent use.

In addition to the attributes shown in Table 1, two appearance attributes were evaluated. These were "darkness" and "visual flakiness." "Darkness" was chosen instead of "whiteness" since it does not imply a particular hue. Although some fish possess a pinkish hue, their frequency of occurrence did not warrant a complete analysis of the hues present in fish muscle. "Visual flakiness" was selected because of its important contribution to the overall appearance of cooked fish muscle, and because it would enable assessment of the relationship between flakiness as it is perceived visually and flakiness as it is perceived in the mouth.

Identification of a reliable scalar method. In order to select a reliable rating scale for evaluating the sensory properties of fish, a two-phase reliability test was carried out. In the first phase, four different scaling techniques were evaluated. These included a 5-point category scale, a 9-point category scale, a 9-point difference-from-control scale (Mahoney et al., 1957), and a magnitude estimation scale (Stevens, 1957). Fig. 1 (A, B, and C) show the first three scales.

Fig. 1A shows the 5-point category scale, with end-points labeled "slight" (1) and "extreme" (5) and the mid-point labeled "moderate" (3). Fig. 1B shows the 9-point category scale with end-points labeled the same as on the 5-point scale and category (5) labeled "moderate." Fig. 1C shows the difference-from-control scale, in which each sample was compared to a constant control sample and in which the magnitude of difference was evaluated on a 9-point category scale. Zero indicated no difference, (1) reflected "slight" difference, (5) reflected "moderate" difference, and (9) reflected "extreme" difference. The direction of difference between the test and control sample was indicated separately by checking one of two boxes labeled "more" or "less". For the magnitude estimation method, each sample was compared to a control sample that was assigned a modulus of 10.0 on all attributes. Test samples were judged relative to the control, so that, if a sample was perceived to be twice as chewy as the control it was assigned the number 20.0, whereas, if it was perceived to be one third as chewy, it was assigned the number 3.33, etc.

Three species of fish (cod, white hake and monkfish) were used in the first reliability test. Each scale type was used once on each of four consecutive weeks to assess the intensity of the six attributes listed in Table 1, as well as those of "adhesiveness," "cohesiveness of the mass" and "astringent mouthfeel," cited previously. The order of testing of each scale was randomized. During the morning, panelists rated each sample on one scale, followed by a 10 min rest period, and then rated a new set of the same samples using the second scale. Panelists then reconvened in the afternoon to evaluate the samples using the other two scales. After ratings had been obtained on each scale type on each of the four weeks, Pearson product-moment correlation coefficients were calculated between the ratings of individual panelists on each fish for each attribute and for all possible pairs of sessions. The mean correlation coefficient across attributes and session pairs was calculated for each scale type and used as an index of session-to-session reliability. The top section of Table 2 shows these average coefficients.

The scale types fell into two categories. Both the 5-point category scale and the magnitude estimation scale had poor average correlation coefficients ($r = 0.51$). The 9-point category scale and difference-from-control scale had much higher average correlation coefficients ($r = 0.82$ and 0.86, respectively). Of the two scale types that produced good reliability, it was decided that the 9-point scale was more practical, since the difference from control method required an unchanging control species at each session.

Although the 9-point category scale had high session-to-session reliability, it was subsequently tested against a 7-point category scale to determine if similar reliability could be achieved with fewer categories. In order to accomplish this, both the 9-point category scale and a 7-point category scale (Fig. 1D) were used during two test sessions to evaluate three different sizes of cod (whale, market and scrod) and during two separate sessions, to evaluate cod (market size) and wolffish (market size). The Pearson product-moment correlations between sessions for all attributes and both scale types were calculated and the mean correlation coefficients are shown in the bottom section of Table 2. Since the reliability of the 7-point scale was higher than that of the 9-point scale, the 7-pt scale was chosen for further use.

Following the identification of the important texture and appearance attributes and a reliable scalar method, an 8-wk training/practice phase was initiated to give the panel experience in using the

Table 1—Sensory texture attributes of cooked fish muscle as defined by the texture profile panel

Hardness	— The perceived force required to compress the sample using the molar teeth.
Flakiness	— The perceived degree of separation of the sample into individual flakes when manipulated with the tongue against the palate.
Chewiness	— The total perceived effort required to prepare the sample to a state ready for swallowing.
Fibrousness	— The perceived degree (number x size) of fibers evident during mastication.
Moistness	— The perceived degree of oil and/or water in the sample during chewing.
Oily Mouthcoating	— The perceived degree of oil left on the teeth, tongue and palate after swallowing.

		NONE 0	
	SLIGHT 1	SLIGHT 1	
	2	2	SLIGHT 1
SLIGHT 1	3	3	2
2	4	4	3
MODERATE 3	MODERATE 5	MODERATE 5	MODERATE 4
4	6	6	5
EXTREME 5	7	7	6
	8	8	EXTREME 7
	EXTREME 9	EXTREME 9	
		MORE	
		LESS	
1A	1B	1C	1D

Fig. 1—The 5-point category scale (1A), 9-point category scale (1B), difference-from-control scale (1C) and 7-point category scale (1D), used in the tests of scalar reliability.

attributes and to insure repeatable panel performance. During any one training/practice session, only one attribute was evaluated. A wide variety of species of fish were examined in order to identify reference samples, i.e., species that were readily available and that were consistently rated as being on one or the other extreme of the scale for that attribute. Fish selected for this purpose and their modal scale values are shown in Table 3. Identification of these reference species enabled panelists to be recalibrated on each attribute so that no "perceptual drift" occurred over time. In addition, the continual refinement of such reference species lists are indispensable to the expedient training of new panels at other laboratories, as would be required upon adoption of the methodology by NMFS/USDC.

Table 2—Session to session reliability measures for the various scalar methods examined in the two series of reliability tests. The reliability measure is the mean Pearson product-moment correlation among all pairs of sessions and across all attributes

First Reliability Test Series[a]	
SCALAR METHOD	$\bar{r}$
5-point category scale	0.51
Magnitude Estimation	0.51
9-point category scale	0.82
Difference from control	0.86
Second Reliability Test Series[b]	
SCALAR METHOD	$\bar{r}$
7-point category scale	0.72
9-point category scale	0.64

[a] $\bar{r}$ is the mean of the 54 r values (9 attributes x 6 session pairs)
[b] $\bar{r}$ is the mean of the 12 r values (6 attributes x 2 session pairs)

Table 3—Reference species and associated modal scale values for the texture attributes. Species and scale values were identified by the texture profile panel and used in subsequent training practice sessions

Attribute	Reference species	Reference scale value
Hardness	Flounder, blackback	1
	Cusk	6–7
Flakiness (oral)	Bluefish	1
	White Hake	6–7
Chewiness	Flounder, blackback	2
	Cusk	6–7
Fibrousness	Flounder, blackback	1–2
	Cusk	6
Moistness	Swordfish	1–2
	Pollock	5–6
	Menhaden (due to oil)	5–6
Oily mouthcoating	Flounder, blackback	1
	Mackerel	5–6
	Menhaden	7

Application of methodology to 17 species

Samples, preparation and evaluation. The following 17 species of fish were evaluated: Whiting (*Merluccius bilinearis*), Mackerel (*Scomber scombrus*), White Hake (*Urophycis tenuis*), Cusk (*Brosme brosme*), Monkfish (*Lophius americanus*), Pollock (*Pollachius virens*), Tilefish (*Lopholatilus chamaeleonticeps*), Wolffish (*Anarhichas lupus*), Blackback Flounder (*Pseudopleuronectes americanus*), Weakfish (*Cynoscion regalis*), Grouper (*Mycteroperca microlepis*), Haddock (*Malanogrammus aeglefinus*), Halibut (*Hippoglossus hippoglossus*), Swordfish (*Xiphias gladius*), Cod (*Gadus morhua*) – both scrod and market size, Bluefish (*Pomatomus saltatrix*) and Striped Bass (*Morone saxatilis*).

All samples were harvested, prepared and cooked as described under 'Development of methodology.'

Samples were evaluated by the texture profile panel using the same general methods as described previously. Panelists judged the six texture attributes of Table 1, as well as the darkness and visual flakiness of the samples, using the 7-point category scale (Fig. 1D). A maximum of three species were evaluated at any one session and each species was evaluated on three separate occasions during the period of testing (approx. 12 months).

RESULTS

Mean panel ratings and correlations among attributes

Table 4 shows the mean panel ratings on each attribute for each species of fish.

A comparison of the initial scale values assigned to the reference species (Table 3) with the actual mean values obtained for these species after 12 months of testing (Table 4), reveals that several modifications and refinements can be made in the reference list. As a result, a modified set of reference species and values are being prepared for future panel training purposes.

In order to assess the relationships among judged attributes, Pearson product-moment correlations were calculated among all pairs of sensory attributes. Table 5 shows these correlation coefficients (r). Significant ($p < 0.01$) correla-

Table 4—Mean ratings (7-pt scale) for the texture and appearance attributes judged by the texture profile panel for each species of fish. Each entry is the mean of three panel means. The standard error of the mean appears in parentheses after each entry.

Species	Darkness	Flakiness (Visual)	Hardness	Flakiness (Oral)	Chewiness	Fibrousness	Moistness	Oily mouthcoating
Blue fish	4.9 (0.14)	2.1 (0.42)	3.4 (0.40)	1.4 (0.15)	3.9 (0.23)	3.2 (0.06)	4.5 (0.64)	4.1 (0.64)
Cod, Market	1.7 (0.10)	6.2 (0.15)	5.4 (0.75)	5.6 (0.40)	5.9 (0.64)	4.6 (0.51)	4.2 (0.47)	0.4 (0.17)
Cod, Scrod	1.6 (0.40)	5.7 (0.60)	3.1 (0.80)	5.2 (0.53)	4.6 (0.92)	3.8 (0.44)	3.9 (0.31)	0.7 (0.31)
Cusk	1.7 (0.12)	2.5 (0.26)	5.2 (1.04)	2.8 (0.35)	5.5 (0.62)	5.4 (0.40)	3.4 (0.53)	0.5 (0.58)
Flounder Blackback	1.6 (0.07)	1.8 (0.20)	2.0 (0.20)	1.8 (0.25)	2.2 (0.00)	2.2 (0.53)	3.2 (0.69)	0.8 (0.45)
Grouper	3.1 (0.64)	3.4 (0.92)	5.7 (0.23)	2.9 (0.92)	5.8 (0.35)	4.0 (1.42)	2.8 (0.53)	0.9 (0.31)
Haddock, Scrod	2.0 (0.44)	4.9 (1.42)	3.8 (0.62)	4.5 (1.26)	4.8 (0.06)	4.3 (0.81)	3.4 (0.40)	0.8 (0.71)
Hake, White	2.8 (0.25)	5.9 (0.17)	2.5 (0.58)	6.0 (0.40)	3.0 (0.45)	2.6 (0.85)	3.8 (0.71)	0.3 (0.23)
Halibut	1.5 (0.19)	2.2 (0.38)	3.7 (0.63)	2.0 (0.53)	3.6 (0.75)	2.7 (0.64)	2.8 (0.37)	0.8 (0.84)
Mackerel	5.1 (0.23)	3.2 (1.11)	4.2 (0.21)	2.5 (0.46)	4.4 (0.35)	3.7 (0.95)	5.1 (0.61)	4.9 (0.70)
Monkfish	2.6 (0.40)	2.0 (0.93)	3.1 (0.52)	3.0 (1.20)	3.8 (0.20)	4.8 (0.45)	4.8 (0.47)	1.1 (0.31)
Pollock	2.6 (0.53)	5.1 (1.09)	3.6 (0.61)	4.3 (0.92)	4.4 (0.60)	3.5 (0.28)	3.4 (0.50)	0.9 (0.64)
Striped Bass	3.6 (0.07)	2.3 (0.31)	5.2 (0.55)	2.9 (0.61)	5.4 (0.85)	4.3 (0.76)	3.7 (0.36)	1.7 (0.42)
Swordfish	3.7 (0.78)	1.6 (0.51)	4.0 (1.45)	1.4 (0.40)	4.5 (1.15)	3.4 (1.78)	3.2 (0.80)	2.4 (1.29)
Tilefish	3.0 (0.35)	3.9 (0.23)	4.2 (0.69)	3.7 (0.12)	4.6 (0.53)	3.5 (0.30)	4.0 (0.35)	1.3 (0.64)
Weakfish	4.2 (0.44)	3.2 (0.35)	2.6 (0.53)	2.6 (0.51)	3.2 (0.53)	3.4 (0.35)	4.3 (0.42)	2.9 (0.29)
Whiting	3.2 (0.20)	5.9 (0.42)	1.7 (0.31)	6.1 (0.70)	2.1 (0.42)	1.0 (0.00)	4.4 (0.20)	1.2 (0.60)
Wolfish	1.5 (0.40)	3.1 (0.68)	3.3 (1.74)	2.8 (0.17)	4.3 (1.36)	3.8 (1.22)	4.8 (0.80)	1.0 (0.35)

tions were found (1) among the triad of attributes consisting of "hardness," "chewiness," and "fibrousness," (2) between "visual flakiness" and "flakiness as judged in the mouth" and (3) between "darkness" and "oily mouthcoating."

Cluster analysis to identify species with similar and dissimilar texture and appearance

In order to identify groups of similar and dissimilar species, based on judgments of their sensory texture and appearance, the data were analyzed via cluster analysis. The method used in these studies was hierarchical and used the BMDP-P2M "Cluster Analysis of Cases" computer program (Engelman, 1977). The measure of distances among clusters was based on a standard Euclidean distance formula and the program normalized the data to give equal weight to all attributes. The latter procedure was used since there is no available empirical data on the relative perceptual importance of different texture and appearance attributes in fish.

Fig. 2 shows the tree-diagram of clusters from the cluster anlaysis applied to the sensory texture data. Note that "visual flakiness" was not used as a variable in this analysis (or in the subsequent multidimensional unfolding), due to its high correlation with oral "flakiness" (Table 5).

The numbers to the left and corresponding to individual branches of the tree reflect the order of amalgamation (combination) of species. Thus, the number 1 located opposite the branch connecting pollock and tilefish, indicates that these two species were the most similar of all the possible pairs of fish and were clustered (amalgamated, combined) first. Similarly, haddock and scrod cod were grouped together second, monkfish and wolffish third, and the fourth amalgamation combined the pollock-tilefish and haddock-scrod cod pairs etc. Thus, as the amalgamation number gets larger and as one gets closer to the top of the tree, the groupings become weaker.

Six distinct groupings emerge from Fig. 2. The largest is that housed under amalgamation 10. Here we find eight fish species that resemble one another in their texture/appearance. They consist of pollock, tilefish, haddock, scrod cod, cusk, striped bass, grouper, and market cod. All of these species are white-fleshed, low-oil, relatively flaky fish. They are distinguished from one another primarily in terms of their firmness, chewiness, and fibrousness, as revealed by inspection of Table 4. Cusk, striped bass and grouper are very firm, chewy and fibrous, while pollock, tilefish, haddock, and scrod cod are much less so. Market size cod, while more similar to the scrod cod-haddock-tilefish-pollock group than the cusk-striped bass-grouper triad is significantly firmer and chewier than the former group (see Table 4), so that it constitutes a sub-group by itself. The second largest group in Fig. 2 is the group of dark-fleshed, highly oily fish species – bluefish, mackerel and weakfish. Weakfish appears to form a subgroup of its own within this triad, perhaps due to its less oily flesh (Table 4). Three separate groups contain only two species each. These are the flounder-halibut group, the monkfish-wolffish group and the whiting-white hake group. Of these, the flounder halibut grouping may appear peculiar. However, the halibut used in these tests was filleted, rather than steaked. This, combined with the boil-in-pouch method of cooking, produced a relatively soft and moist texture. The monkfish-wolffish group is a strong group, as reflected by its amalgamation number of 3. However, the whiting-white hake group is a weak grouping as reflected by its amalgamation number of 12. Finally, swordfish appears to form a sixth and independent group of its own.

Multidimensional unfolding of the data

As evidenced by the above description, although cluster analysis provides groupings of fish species based on sensory ratings of the species, the final output does not provide

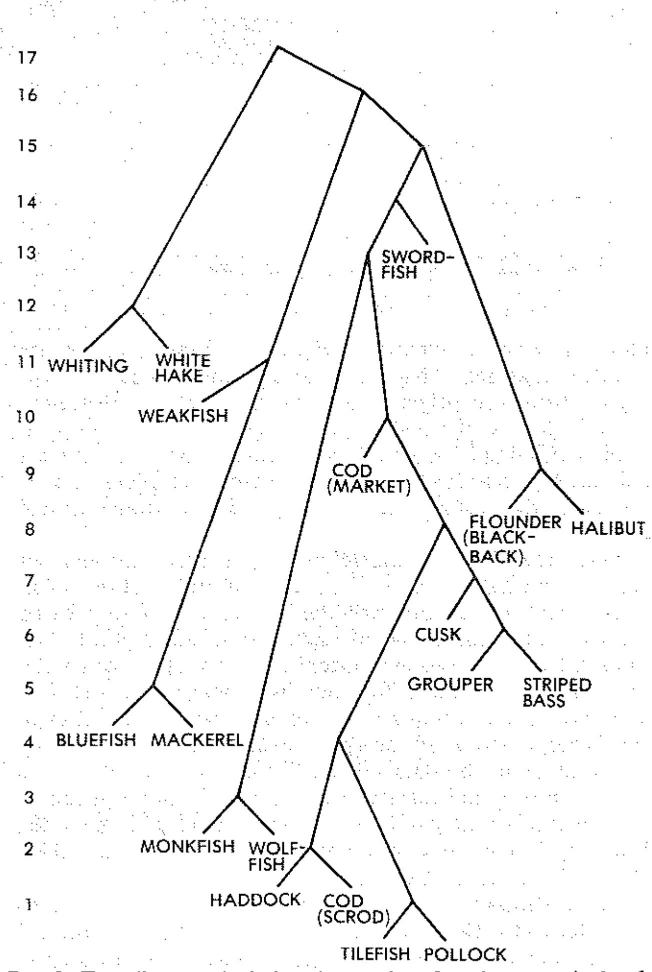

Fig. 2—Tree-diagram depicting the results of a cluster analysis of the data on the texture and appearance of 17 species of North Atlantic fish.

Table 5—Pearson product-moment correlation coefficient for relationships among sensory texture and appearance attributes of fish

	Visual flakiness	Hardness	Flakiness	Chewiness	Fibrousness	Moistness	Oily mouthcoating
Darkness	–0.23	0.0	0.30	–0.08	–0.05	0.39	0.88**
Visual flakiness	—	–0.06	0.95**	0.03	–0.29	0.11	–0.38
Hardness	—	—	–0.14	0.94**	0.72**	0.26	0.00
Flakiness	—	—	—	–0.10	–0.21	–0.02	–0.55
Chewiness	—	—	—	—	0.78**	–0.16	–0.04
Fibrousness	—	—	—	—	—	–0.04	–0.08
Moistness	—	—	—	—	—	—	0.58

$^{**}p < 0.01$

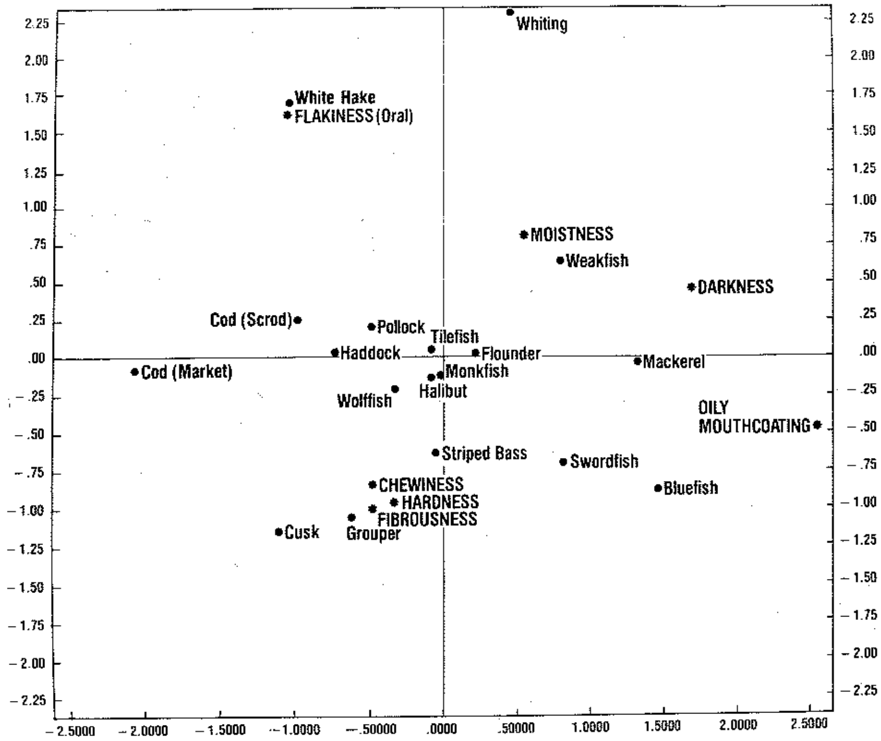

Fig. 3—Two-dimensional solution resulting from the multidimensional unfolding of the data on the texture and appearance of 17 species of North Atlantic fish.

information on the "reason" why two or more species were grouped together. This information must usually be extracted from the original data matrix (Table 4). However, through the use of the statistical procedures of multidimensional unfolding (Coombs, 1964), the relationships between and among stimulus objects and sensory variables can be schematically represented within a multidimensional geometric space.

The input for the multidimensional unfolding analysis was the matrix of ratings for each stimulus object (fish species) on each sensory variable. These ratings were treated as ratings of similarity or proximity to idealized points that represent each judged attribute. In this way, the ratings can be viewed as distances between fish species and idealized attribute points within a multidimensional space. Although the dimensionality of the space needed to account for all the variance in the data set may be equal to n, where n is the number of judged attributes, a best-fitting solution of lower dimensionality is determined by the unfolding model. The ALSCAL-4 computer program (Takane et al., 1977) was used to analyze the data.

Fig. 3 shows the best-fitting two-dimensional solution to the data set for the fish species evaluated. This solution had a stress value of 0.336 and a coefficient of determination (r^2) of 0.91, indicating that 91% of the variability in the sensory scores for fish could be accounted for by this two-dimensional solution.

Fig. 3 shows a two-dimensional space into which are embedded both the sensory texture and appearance attributes as well as the 17 species of fish. Fish in close proximity to one another in the space are perceptually similar in texture and appearance. The proximity of any fish to an idealized attribute point is an index of the perceived degree of that attribute in the fish.

As can be seen, starting on the right side of Fig. 3, mackerel and bluefish fall closest to the point labeled "oily mouthcoating," reflecting the high degree of oiliness of these fish. Swordfish also lies relatively close to this point. This triad of fish (mackerel, bluefish, and swordfish), along with weakfish, also fall close to the point labeled "darkness," reflecting the fact that all four species are dark-fleshed. On the opposite pole of the horizontal axis (left side of the plot) are found the white-colored, low oil fish, such as cod, haddock, pollock and wolffish. Between these extremes are tilefish, monkfish, flounder, and halibut. In the bottom half of the plot, a triad of sensory attributes consisting of "hardness," "chewiness" and "fibrousness" can be seen. The proximity of these attributes to one another in the space is a direct reflection of their high positive correlation wih one another (Table 5). Falling closest to this triad of sensory variables are the cusk and grouper species, both very firm, chewy and fibrous. Striped bass also falls close to this grouping, and swordfish and bluefish fall closer to this triad than do mackerel or weakfish. In the upper half of the plot are found the extremely flaky fish – white hake and whiting. Whiting is also extremely soft (Table 4) forming a polar extreme to the hardness, chewiness, fibrousness triad, and being located in the extreme upper region of the space.

DISCUSSION

THE SENSORY METHODS developed here provide a standardized methodology for comparing different species of fish on the basis of their texture and appearance. The descriptive attributes, being chosen on the basis of texture profile panel evaluations of their importance, as well as on their meaningfulness to consumers for discriminating among species (Sawyer et al., 1982a), have practical validity. Moreover, the choice of a 7-point category scale for evaluating intensity is justified on the basis of the reliability studies (Table 2) and the fact that it is an easily-applied scalar technique.

The correlation coefficients among judged sensory attributes (Table 5) provide evidence of good independence among the attributes. The relatively high correlations among the attributes of "hardness", "cohesiveness" and "chewiness" probably reflect a single underlying perceptual construct that might be described as the "toughness" of the cooked fish muscle. However, the failure to find significant correlations between members of this triad and either "flakiness," "moistness," or "oily mouth-coating," suggests a high degree of independence among the attributes. The extremely high correlation between "visual flakiness" and "flakiness" judged in the mouth suggests that only one of these attributes needs to be used in future work.

The data in Table 4 provide a starting point for the establishment of a comprehensive data bank on the texture and appearance of fish. When combined with corresponding flavor data on these species (Prell et al., 1982), and expanded to include similar data on other species of potential importance to the U.S. fishing industry, this data bank can be used as the foundation for the development of a nationwide, market-oriented nomenclature system for fish, based on sensory relationships among species (Cardello et al., 1981). The potential usefulness of this system for substituting under-utilized or non-traditional species in various types of fisheries products has already been detailed (Sawyer et al., 1981).

The cluster analysis of the 17 species of fish (Fig. 2) depicts the overall similarities and dissimilarities in texture and appearance among these species. It should be noted that these groupings would be likely to change if more species were added to the data matrix. Also, if other cooking methods were used, some changes in groupings ought to be expected due to differential cooking effects on different species. Nevertheless, the tree-diagram of Fig. 2 well represents the similarities and dissimilarities of species as reflected in Table 4. Furthermore, the groupings and sub-groupings that emerge have face validity to those who have familiarity with the species.

As mentioned previously, one short-coming of cluster analysis is that it does not provide an indication of why, in sensory terms, any two species are grouped together. For this purpose the perceptual fish map generated by the ALSCAL-4 analysis of the data (Fig. 3) is more useful. The fact that the solution accounts for over 91% of the variability in the data set suggests that this two-dimensional space well represents the relationships among fish species and attributes and that it can be used meaningfully to interpret the groupings established through cluster analysis.

The methods and data presented here mark the first steps in the development of a comprehensive data bank on the "edibility characteristics" of fin fish. Future effort will focus on expansion of the data base and development of consumer education tools to communicate these data in the market place.

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