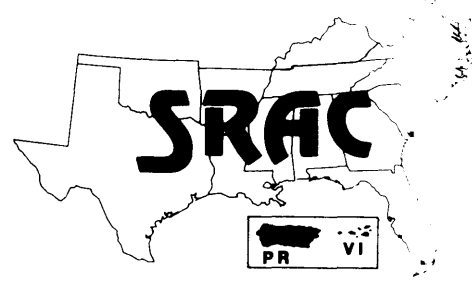


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Testing Flavor Quality of Preharvest Channel Catfish

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Farm-raised channel catfish is known for its mild flavor and lack of the “fishy” odor that is typical for marine and wild freshwater fish. This mild flavor is savored by American consumers and, together with constant product quality, is an important attribute for successful marketing of farm-raised catfish.

Unfortunately, catfish may acquire flavors perceived as unacceptable by the consumer. Such objectionable flavors are known as “off-flavors.” Marketing of off-flavor fish is likely to jeopardize consumer satisfaction and future market demand. Therefore, adequate quality control to guarantee that off-flavor fish are not marketed is essential to the catfish industry.

Reasons for “off-flavors”

Undesirable flavors may develop during grow-out or after processing of fish. Prolonged or improper storage causes processed fish products to spoil. This problem can be avoided by adherence to accepted processing and storage procedures. Odorous compounds in pond water are responsible for off-flavors that develop in the fish prior to harvesting. These com-

pounds are occasionally the result of inadvertent pollution, but in general are produced by biological processes that take place in the pond environment. Regardless of the source, the compounds are absorbed by fish through the gills and accumulate in the flesh.

Sensory analysis

To avoid marketing fish with environment-related off-flavors, fish must be screened for flavor quality before harvesting. Quantitative chemical analysis is inadequate for flavor quality control because of time constraints, costs involved, and the limited number of odorous compounds that can be detected with available methods. Sensory analysis (taste-testing), which treats trained “tasters” as analytical instruments, is the only applicable method for routine evaluation of fish flavor quality. Sensory analysis can detect odorous compounds at very low levels, and discriminates between types of off-flavors as well as flavor intensity. Variability and bias in sensory analysis can be minimized by proper selection and training of judges.

Preharvest flavor testing is practiced at all channel catfish processing plants, and flavor quality is the most important criterion for ac-

ceptability of fish to the processor. Methodology and criteria for flavor quality evaluation vary from plant to plant. When off-flavors are not pronounced, fish may be rejected for purchase by one plant but accepted at another plant. Flavor quality control does not need to be subjective. A standardized method for flavor testing can ensure maintenance of one flavor quality standard in the industry and an objective evaluation of flavor acceptability.

Most fish farmers rely exclusively on processing plant personnel for flavor analysis. Nevertheless, conducting sensory analysis of fish flavors at the catfish farm maybe quite useful. Information on the type and intensity of fish flavor may aid the farmer in managing around off-flavor episodes or in decision-making when pond treatments for off-flavor are being considered. If fish are routinely checked for flavor quality, pond harvest schedules can be adjusted to account for potential flavor problems, and the success of treatments to remove off-flavor can be monitored. On-farm taste-testing also releases some of the sample burden from processing plant quality control personnel. If fish are prescreened at the farm, only samples from ponds deemed accept-

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able need to be submitted to plant personnel for further evaluation.

This report offers a method appropriate for testing fish flavor. The method can be adapted for processing plant quality control or for use on catfish farms. Description of catfish flavors commonly found in preharvest fish, gradations in flavor intensity, sampling schedules, selection and training of judges, preparation of fish for testing and testing procedures will be explained.

Flavor perception

Flavor is a food attribute and is experienced both in the mouth (taste) and in the nose (smell). Specific flavors result from a bouquet of tastes, odors and chemical feeling factors. The four basic tastes (salty, sweet, sour and bitter) are perceived by taste buds on the tongue. Volatile odorous compounds of food are sensed by olfactory receptors at the top of the nasal cavities. The odorous compounds reach the olfactory area through the nose when sniffing or

through the pharyngeal passage when tasting (Figure 1).

Depending on the volatility of the odorous compounds, a flavor may be experienced directly after a sample is taken into the mouth or after chewing. Chemical feeling factors (astringency, spice heat, metallic flavor) are experienced in the mouth and nasal cavities. To taste a fish sample properly, the sample must be dispersed over all the surfaces of the tongue to reach the various taste buds. A sample must be chewed well to allow all aromas to reach the olfactory area. The description of fish flavor takes into account the sensory experiences of taste, smell and mouth feel, but not texture.

Flavor analysis

The fish taste-testing method described in this report is modeled after the Flavor Profile Analysis procedure used by the food and beverage industry and municipal water utilities to describe taste, odor and flavor characteristics of their products. Flavor-testing in-

volves a qualitative and a quantitative aspect: off-flavors are described with standardized terminology and the flavor intensity is rated.

Description of off-flavors is often difficult because of these factors:

- there are many chemical compounds responsible for off-flavors;
- the same chemical compound can elicit different flavor descriptions from different people;
- certain flavors may be produced by more than one chemical compound;
- variation in the concentration of an odorant may cause changes in the flavor characteristics rather than in flavor intensity.

However, the subjective nature of flavor descriptions need not interfere with the objectivity of flavor analysis, provided that a standardized terminology is used. It is possible to train judges to give the same descriptor to a particular flavor, even when the sensory experience among judges differs. When a new flavor is encountered, judges must reach consensus on an appropriate descriptor that thereafter will be used by all judges for that particular flavor.

Catfish flavor descriptors

Researchers and plant processing personnel use various descriptors to describe flavors in channel catfish. Some attempts have been made to standardize these flavor descriptors, but inconsistency and lack of distinction between different flavors still exists. Sources of odorous compounds in fish ponds include algae, microorganisms that decompose vegetation, fish waste products and pollutants such as diesel fuel or pesticides. Many of the specific compounds that cause objectionable flavors in fish have not been identified. Therefore, most flavor descriptors are standardized by and

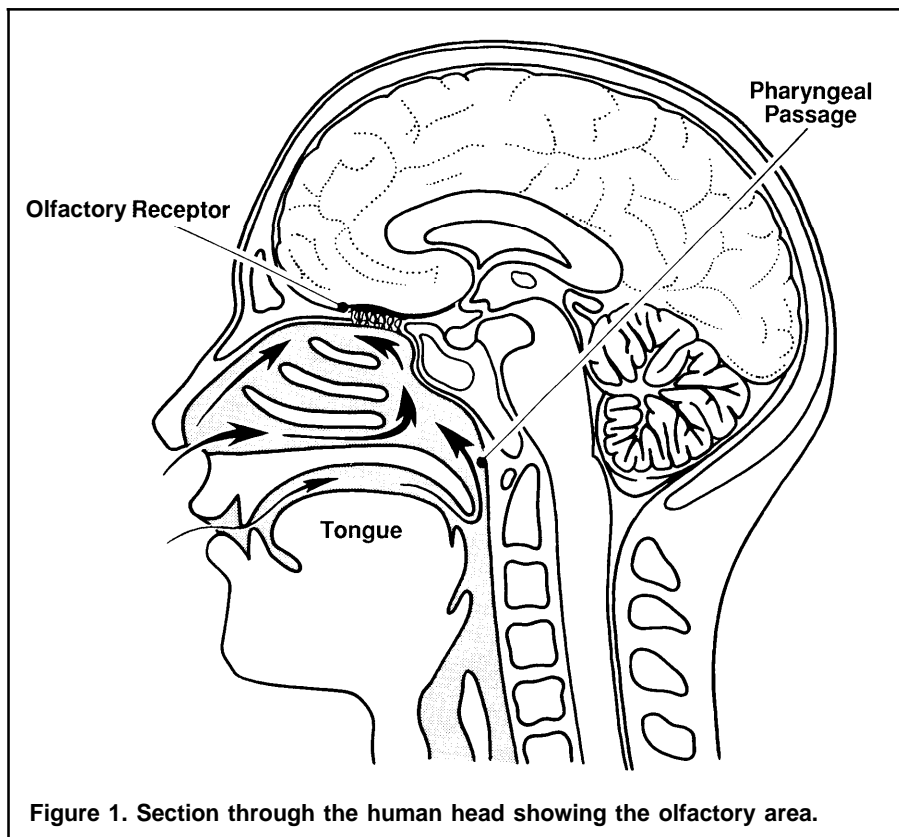


Figure 1. Section through the human head showing the olfactory area.

referenced to names of commonly known materials and scents with odor characteristics similar to the off-flavor. Examples of such descriptors are "chicken," referring to the flavor of broiled chicken meat, and "sewage" that refers to the odor of sewage lagoons.

The specific source of two common off-flavors is known, and these flavors have been named for both the odor descriptors and the causative agents: "earthy/geosmin" and "musty/methylisobornol"

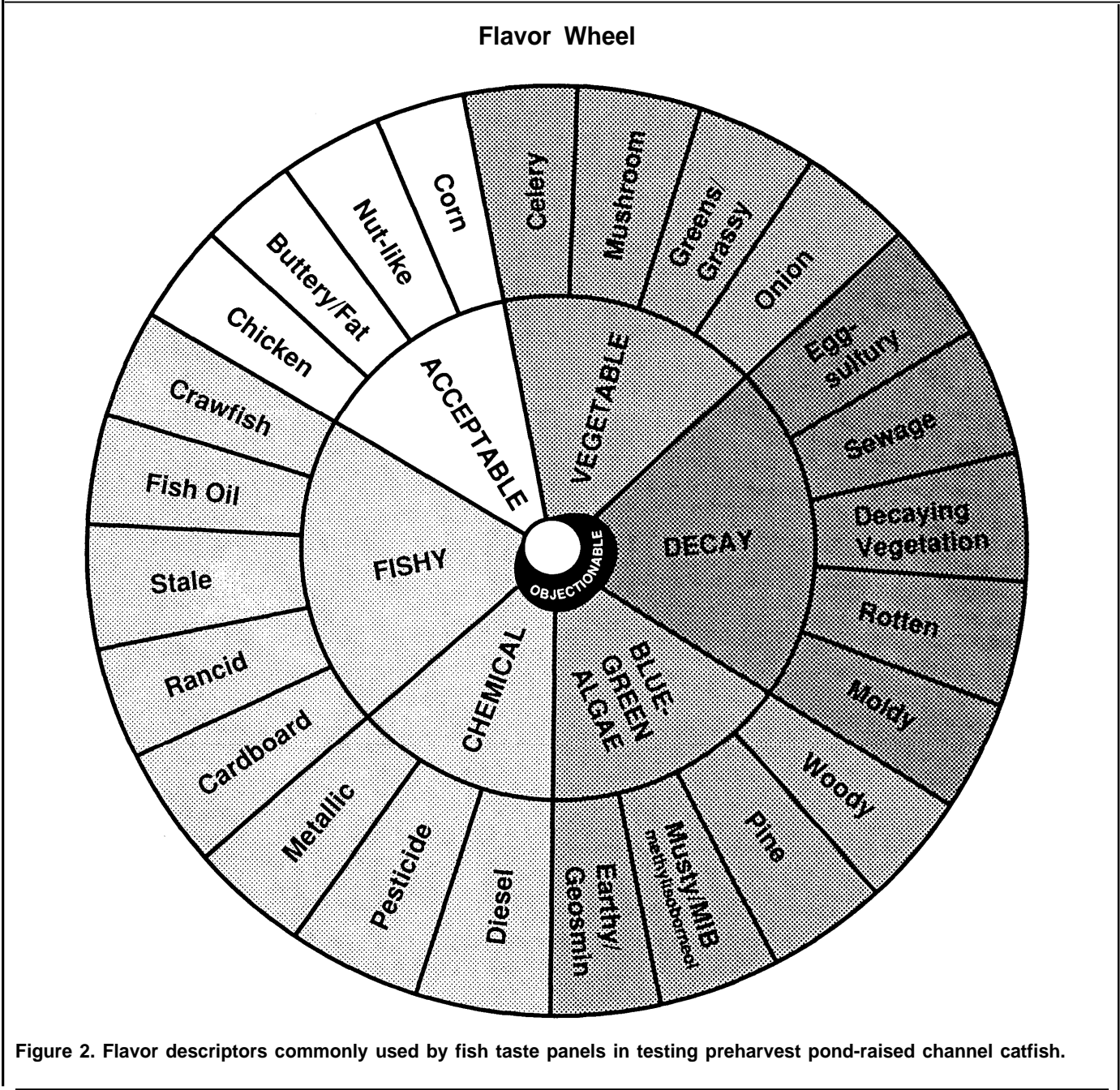
or "musty/MIB." Two other characteristic off-flavors, "diesel"

and "pesticide," are described by the general name for the cause of the flavors.

Recognizing the limitations of any flavor classification scheme, the common flavors encountered in catfish from commercial catfish ponds in the southeastern United States are depicted in a flavor wheel (Figure 2). The proposed

wheel contains those 25 descriptors that are commonly used by the fish taste panels at Auburn

University in Alabama, Delta Research and Extension Center at Stoneville, Mississippi, and Delta Pride processing plant, Indianola, Mississippi. Similar flavors are placed together within the outer wheel. Flavor descriptors have been clustered in six categories which are called Acceptable, Blue-green Algae, Chemical, Decay,



Vegetable, and Fishy. The four tastes (sweet, sour, bitter, and salty) have not been included in

the flavor wheel as they are not known to be dominant characteristics of disagreeable flavors in channel catfish.

General acceptability of fish flavors is indicated with a ribbon in the center of the wheel: fish flavor is most likely to be objectionable at the maximum width of the ribbon (e.g., musty/MIB, and diesel flavors) and, depending on flavor intensity, may be acceptable to a processor where the ribbon attenuates or is absent (e.g., celery or corn flavors).

Acceptable category

Farm-raised catfish should have a mild flavor relative to marine or wild freshwater fish. The preferred flavor is a combination of **nut-like** or pecan-like character and “sweet protein” that is reminiscent of broiled **chicken** breast meat, **corn**, or **butter**. Note that although these descriptors are considered positive flavor attributes, if chicken, corn, or buttery flavors dominate the mild catfish flavor, fish may not be acceptable to a processor.

Blue-green algae category

Flavors in this category are the most common objectionable flavors in farm-raised catfish. The category is called “blue-green algae” because these flavors are often associated with blooms of blue-green algae in aquaculture ponds. Descriptors in this group include geosmin, MIB, pine, and woody.

The **geosmin** flavor is the earthy-muddy flavor of geosmin, an odorous compound produced by certain species of the blue-green algae and actinomycetes bacteria. The flavor often is associated with the odor of freshly turned garden soil. The **musty/MIB** flavor is the musty odor of methylisoborneol, another odorous compound produced by certain species of the blue-green algae and actinomycetes bacteria. The musty/MIB fla-

vor is often referred to as “blue-green algae” but it is not the only flavor that can be attributed to blue-green algae and is better referred to by the name of the causative compound. The musty/MIB flavor is often confused with the earthy/geosmin flavor but when smelled side by side the distinction is obvious. Intense musty/MIB flavors are reminiscent of camphor. Geosmin and MIB off-flavors are most common in pond-raised fish during the warmer parts of the year.

The precise chemical causes of pine and woody off-flavors are not known with certainty, but there is some indication that metabolizes of methylisoborneol or other similar compounds are responsible. The **pine** flavor is reminiscent of the odor of pine needles and pine-scented air fresheners. The flavor is often strong and always objectionable in farm-raised catfish. Frequently musty/MIB and pine flavor occur simultaneously, with pine as the dominant flavor. Some individuals tasting fish with pine flavor have associated the flavor with oil-based paint or turpentine.

The **woody** off-flavor is one of the more difficult flavors to recognize and describe. The flavor is similar to the odor associated with wood chips or tree stumps. It is more distinct when fish are cooked without skinning. An astringent after-taste is often noted after tasting fish with woody off-flavor; this effect has not been experienced with other off-flavors. Woody off-flavors in pond-raised catfish appear to be most common in the cooler seasons. Some evidence exists that they are caused by decomposition products of 2-methylisoborneol.

Chemical category

Flavors in this category can be quite repulsive and are so different from other flavors that they can be detected and described with little difficulty. Two flavors undoubtedly result from inadvertent pollution of the culture system and, fortunately, are not found frequently. **Diesel** off-fla-

vors are easily recognized by the characteristic odors associated with diesel fuel, kerosene, lighter fluid and motor oils. **Pesticide** off-flavors vary in character depending on the source of pollution but can usually be assigned to this group based on their unique odor.

Metallic flavors are actually more of a taste sensation or mouth feel. Some indication of this type of characteristic can be experienced by placing a penny on the tongue for a few seconds. The source of metallic flavor is not known.

Decay category

Off-flavors in this category are difficult to describe because we often associate them with more than one odor characteristic of decaying matter. Off-flavors of the decay category are frequently found during the cooler months. Causes of these flavors are not known but odorous sulfur or organic nitrogen compounds resulting from decomposition processes in the pond are suspected. Consumption of rotting fish may contribute to these off-flavors as well. Descriptors in this group include: egg/ sulfury, sewage, decaying vegetation, rotten and moldy. The intensity of these off-flavors may differ considerably among fish as they maybe caused by odorous compounds in the water as well as by what the fish scavenge.

The **egg/sulfury** flavor is the flavor of (old) hard-boiled eggs. **Sewage** flavors are reminiscent of the odor of sewage lagoons. **Decaying vegetation** flavors are typified by the odor of decomposing aquatic weeds or wet hay. Sewage and decaying vegetation flavors both are considered objectionable. The flavor descriptor **rotten** is used when fish taste like spoiled (red) meat; this flavor is most offensive and can be rather strong. The **moldy** flavor does not have a sulfury character but rather suggests the odor of moldy cork.

Vegetable category

Several off-flavors are redolent of raw vegetables. The **celery** flavor

is the flavor of celery stalks. The **mushroom** flavor is the flavor of raw, white mushrooms, and has an earthy note but differs from the earthy-muddy flavor typical of geosmin. The descriptor **greens/grassy** is used for flavors that can be associated with the odors or flavors of leafy green vegetables and fresh cut grass. This flavor sometimes has an earthy note similar to the earthy note in cooked spinach. **Onion** flavor refers to the flavor of wild onion and has a sulfury note. In one particular incident, the occurrence of this flavor could be attributed to large amounts of wild onion leaves which were blown into the water when pond banks were mowed. Subtle celery, mushroom and onion flavors may be acceptable to a processor.

Fishy category

Unlike marine fish, a distinctly fishy flavor is undesirable in channel catfish. The fishy taste is often stronger in the dark muscles along the lateral line. Large fish have more dark muscles than small fish. In catfish with a large amount of fat on the surface of these dark muscles, it is difficult to judge if fish flavor is disagreeable because of a fishy off-flavor or because of high fat content. The fishy category includes rancid, stale and cardboard-like flavors that suggest prolonged storage although fish were fresh when prepared, and the crawfish and fish-oil flavors that are typical for other seafood products. Causes of these flavors are not known.

The cardboard flavor is similar to the flavor of wet cardboard or a wet brown bag; the **rancid** flavor is the odor of rancid butter or fat; and the **stale** flavor is best described as the flavor of freezer-burnt fish. These flavors are objectionable because they contradict the freshness of the product. The **crawfish** flavor is reminiscent of boiled crawfish tails and, although undesirable, it usually is not offensive in channel catfish. The **fish oil** flavor is the pungent flavor of codliver oil.

Flavor intensity

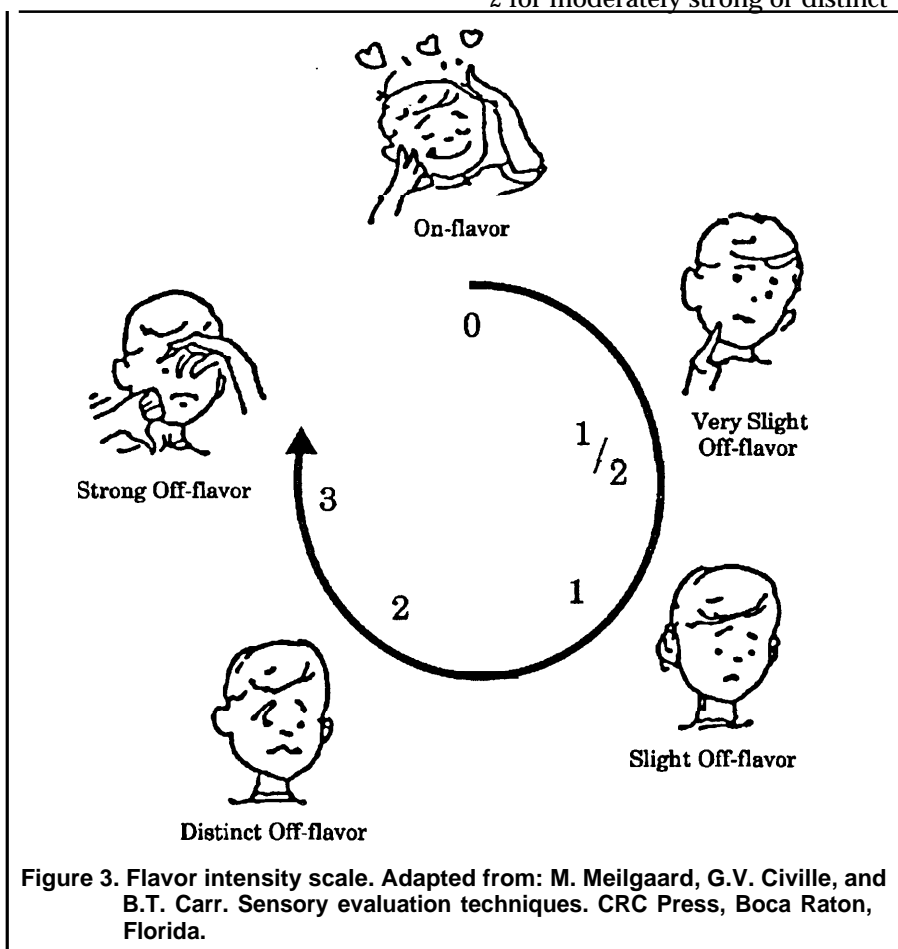
Flavor intensity is the quantitative aspect of fish flavor quality and estimates the concentration of the flavor compound(s) of interest. Flavor intensity may be quantified on a scale as presented in Table 1. The threshold concentration is the lowest level at which an odorous compound can be perceived.

Verbal Description	Intensity Scale
No off-flavors	0
Threshold	T
Very slight	0.5
Slight	1
Slight to distinct	1.5
Distinct	2
Distinct to strong	2.5
Strong	3

Threshold concentrations vary among individuals because people are not equally sensitive to odors.

Therefore, a threshold concentration of a consumer population is defined as the lowest level that 50 percent of the people can detect. Typically, people who judge flavor quality are expected to be sensitive enough to detect the compounds of interest at a concentration lower than the threshold level for the consumer population. The threshold levels for geosmin and methylisobomeol have been established and can be used to select judges for fish flavor analysis (see section on selecting judges).

The facial scale in Figure 3 is a graphic depiction of the degree of off-flavor in fish. Fish without off-flavors receive the score 0 because undesirable flavors are perceived to be absent. In off-flavor fish the intensity of a flavor is scored as 1 for a slight but recognizable flavor; 2 for moderately strong or distinct



flavors; and 3 for strong flavors. A value of "0.5" maybe assigned to fish with very slight off-flavors.

Extremely strong off-flavors may be indicated with the number 4. When off-flavor is strong enough to warrant a score of 4, it can be smelled and it is not necessary to taste the fish sample. In all other cases fish must be tasted as the odor of a fish sample can be rather different from the flavor that is perceived in the mouth.

Selection and training of judges

Individuals differ in their ability to detect odors and flavors. Some people may complain about a disagreeable flavor in fish when others cannot detect any problem. Variation in sensitivity to specific flavors among flavor quality control personnel can be reduced by proper selection and training of judges. Judges must be able to differentiate between geosmin and methylisoborneol, and they must be able to detect these compounds in water at 0.02 ppb (parts per billion), the established threshold concentration. The ability to differ-

entiate between flavor intensities can be determined by asking potential judges to rank odorous solutions of different concentrations.

After selection, judges must be familiarized with the flavor intensity scale. This can be done by tasting solutions of sugar or salt of different concentrations (Table 2) to "anchor" the intensity scale, and subsequent taste-testing of various food or beverages to evaluate the intensity of sweet and salt in those products. Through training and practice, judges can develop a consistent response to varying odor concentrations and learn to assign similar intensity scores to different flavors of equal strength. Bias towards flavors that are perceived to be more offensive than others should be minimized through training; a strong dislike of a particular flavor should not influence the flavor intensity rating. Judges must be trained in recognizing the different off-flavors and in the use of flavor descriptors according to the catfish flavor wheel. The best training is tasting fish with an experienced person.

In general, males and females are equally sensitive to odors, and

smokers are not less sensitive than non-smokers provided that they do not smoke within 1 hour of testing. Allergy symptoms, medication and a "common cold" may temporarily interfere with the ability to taste. People with 'a good nose' are generally capable of testing fish flavor quality after appropriate training. It is important that fish flavor always be checked by the same judges to maintain a certain degree of consistency in the results. If fish normally are checked by two judges it may be expected that at least one judge will be available at all times.

Fish preparation

Flavors may vary from fish to fish within a pond, but the nature of that variation is unknown. At least two fish should be analyzed from a pond at each sampling. Fish may be snagged or caught with hook and bait. Fish size should be representative for the fish population of interest. Store fish on ice until preparation because fish flavor can change as a result of decomposition. Fish should be dressed and tasted as soon as possible after they have been collected. If fish cannot be checked immediately storage of gutted fish in a freezer is recommended. Limit storage time to a week, otherwise fish may acquire extra off-flavors.

Many different materials may impart an extra flavor to fish during cleaning and preparation. Examples are the odor of waterproof markers, flavor of a wooden cutting board, odor of detergent that has not been properly removed from the work area, utensils, or hands, and the flavor of the paper bags in which fish are prepared. Such flavors imparted after harvest may mask the flavors that fish acquired in the pond. Extra flavors that are always present at the same intensity will be experienced as "background noise" and do not necessarily interfere with flavor analysis. The brown paper bags that are used to wrap fish when using a microwave do not change flavor perception if the same-brand of-bags is always used.

Table 2. Flavor intensities for different concentrations of sugar and salt.

Chemical	Concentration	Intensity	Food or beverage that corresponds
Sweet: sugar	5% (1.5 oz/quart water)	1- Slight	Peanut butter, unsweetened juice
	1 % (3 oz/quart water)	2- Distinct	Soft drinks, vanilla ice cream
	15% (4.5 oz/quart water)	3- Strong	Jellies, preserves
Salty: salt	0.4% (1/2 tsp/quart water)	1- Slight	White bread, canned peas
	0.8% (1 tsp/quart water)	2- Distinct	Canned soup, sardines
	1.0% (1 1/4 tsp/quart water)	3- Strong	Soy sauce, anchovies

Fish may be skinned before preparation but it is not required. Fish flavor is often strongest in the layer of fat just under the skin. Off-flavors are therefore easier to detect when fish are not skinned. Usually it is sufficient to sample the flesh in the portion between vent and tail.

Fish should be cooked either by microwaving or by steaming above boiling water. Never add seasonings or breading. Wrap fish samples separately so that odors released during cooking do not contaminate the other samples. When a microwave is used, wrap fish in paper or plastic bags. When fish are steamed, wrap filets separately in aluminum foil and cover the pot during steaming. Tightly folded aluminum foil allows air to expand but prevents odors from escaping the package. Cooking time depends on the method used, and size and number of fish samples that are prepared simultaneously. Avoid overcooking which may create other flavors. For example, browning of fish produces a caramelized flavor. Some trial and error may be necessary to determine the proper cooking time.

Testing fish flavor quality

Fish must be tested for off-flavors in an environment free of odors that can interfere with sensory evaluation. Perfumes, the smell of food, cigarette smoke and other strong odors must be absent before and during a taste-test. Before a taste-test, judges should wash their hands with a non-odorous soap (e.g., Ivory). Judges are advised to abstain from eating at least 15 to 30 minutes prior to testing.

Start a fish tasting session with an on-flavor fish sample as a “warm-up” to set the base line for flavor evaluation. Fish filets must be smelled and tasted while they are still warm, as flavor perception changes with temperature. Several parts of the filet should be sampled because an off-flavor may not be distributed evenly in the filet,

especially when off-flavors are subtle or belong to the Fishy or Decay categories. Greater sample-to-sample consistency in describing flavors and intensity can be obtained if more than one judge is involved in the process. Each judge tastes and grades the fish of a pond, then the findings are discussed. When a consensus is reached between judges, flavor description and flavor intensity should be recorded. Average the flavor descriptions and flavor intensity scores for each pair of fish to decide on the overall fish flavor of a pond.

The actual taste-test consists of smelling the odor with little sniffs, and tasting the flavors while slowly chewing the fish sample. It may be necessary to taste a sample twice to better judge the presence of subtle flavors. Olfactory receptors fatigue easily during sensory evaluation, especially when fish have strong off-flavors. Fish samples should not be swallowed as that may cause the senses to fatigue faster. Strong off-flavors may be judged by smelling alone or should be tasted at the end of the session. Cleanse the palate between samples with odor-free water, apple juice or water that has been slightly acidified with citric acid (0.03 percent w/v). Some people prefer to eat white bread or unsalted crackers between samples.

Judges may be provided with a small snack, like cookies, at the end of each session to assure that bad flavors do not linger in the mouth for a long time after the session. Also, it is important that the last impression of a taste session is a good one. If possible, no more than ten fish should be sampled in one session. Fish flavor is judged more objectively in several short sessions than during one long session.

Pond sampling schedules for fish flavor control

Sampling schedules for fish flavor evaluation must take into account the dynamic and unpredictable na-

ture of off-flavor episodes. Fish may acquire and purge off-flavors at different rates depending on the source, type and intensity of the flavor, water temperature, fish size, and possibly other factors. Off-flavors may develop within a matter of hours if the level of odorous compounds in the water rises suddenly, as could be the case during a chemical spill or a sudden die-off of odor-producing algae. The rate of off-flavor removal is much slower than uptake, and fish are not expected to purge geosmin and methylisoborneol flavors in less than about five days.

Processing plants routinely test fish flavor to ensure that off-flavor fish are not harvested nor processed. Their main concern is timely detection of off-flavors, and fish sampling is scheduled accordingly. When a producer wants to sell fish, a sample usually is submitted for flavor evaluation a week or so before a planned harvest to obtain a tentative approval for purchase. Fish flavor must then be checked one day before or at the day of the harvest to make certain that no off-flavors have developed since fish were scheduled for harvesting. A final sample is taken from the transport truck before fish are unloaded at the plant. Fish must meet flavor standards at all times, or harvesting will be cancelled and fish returned to the pond from the transport truck.

Biweekly on-farm fish sampling for flavor evaluation allows producers to monitor the incidence and length of off-flavor episodes. During the cooler months sampling frequency may be reduced to once per month. To determine the effect of pond treatments to get rid of off-flavor, fish should be sampled immediately before a treatment and approximately five and ten days after the treatment.

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A four-color flavor wheel poster is available for display purposes. The flavor wheel was developed by the Delta Research and Extension Center, Mississippi Agricultural and Forestry Experiment Station, Mississippi State University.

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