SRAC Publication No. 192

Southern Regional Aquaculture Center

August 1999

Managing Off-Flavor Problems in Pond-Raised Catfish

Craig S. Tucker and Martine van der Ploeg*

Problems with inconsistent flavor quality occur in all food industries, but are especially important in aquaculture because these foods are often more expensive than other sources of animal protein. To capture and maintain market share, aquaculture products must be of consistent, superior quality. Flavor quality is all the more important in farm-raised catfish because catfish are not a customary part of the diet for consumers outside the southeastern United States. If catfish with off-flavors are marketed, first-time buyers may be reluctant to make future purchases in favor of more familiar foods, such as poultry, pork, beef or seafood from capture fisheries.

Types of off-flavor

Most of the seafood off-flavors noticed by consumers are the result of improper post-harvest handling of the product. **Post-harvest flavor problems** occur in aquaculture products, as well as in seafood from capture fisheries, and are caused by bacterial spoilage or by oxidation of fats (rancidity) during prolonged or improper storage. Post-harvest off-flavors can be prevented by using sound processing, packaging and storage methods.

Off-flavors may also develop in fish before harvest, although most consumers are not aware of **pre-harvest off-flavors** in catfish because processors screen fish for flavor quality before harvest. If a sample of fish from a particular pond is found to be off-flavor, the fish in that pond are not harvested until flavor quality improves. Although pre-harvest flavor screening reduces the impact of inconsistent flavor quality at the market level, the inability to harvest and sell off-flavored fish is a serious economic burden for farmers.

Some pre-harvest off-flavors are caused by substances in the diet that are absorbed across the gastrointestinal tract and deposited in the flesh. **Diet-related off-flavors** are rare in fish fed high quality commercial feeds. However, pond-raised catfish occasionally eat other foods, and some of those may cause flavor problems. For example, "decay" or "rotten" off-flavors are occasionally noted in pond-raised catfish during winter when many catfish farmers do not routinely feed their fish. These flavors probably develop when fish eat decaying organic matter as they forage for natural foods.

Most pre-harvest off-flavors develop when odorous compounds in the water are absorbed by fish and accumulate in the edible tissue. Some **environment-related off-flavors** are caused by accidental pollution of the water, although such problems are uncommon in aquaculture because it is easy to locate facilities so that routine exposure to odorous water pollutants is avoided. However, petroleum off-flavors occasionally develop in pond-raised fish when waters are contaminated by accidental spills of diesel fuel or gasoline from boats, well-pump engines, or farm equipment.

Most pre-harvest flavor problems are caused by odorous compounds produced by naturally occurring aquatic microorganisms. The compounds are synthesized by algae or bacteria, released into the water, and then absorbed through the gills, skin or gastrointestinal tract of fish. The most common off-flavors are described as "earthy," "muddy," "moldy," or "musty." These off-flavors have been described in writing at least since 1550 and, as evidence of long-standing negative consumer sentiment, a 1909 German newspaper article reported that a customer sued a restaurant owner for serving muddy flavored fish.

*Mississippi State University; Delft University of Technology, The Netherlands.

Common off-flavors in catfish

The common off-flavors in pond-raised catfish are grouped below on the basis of suspected origin. Grouping flavor problems by origin, rather than by similarity of flavor, is useful when considering options for managing the problem.

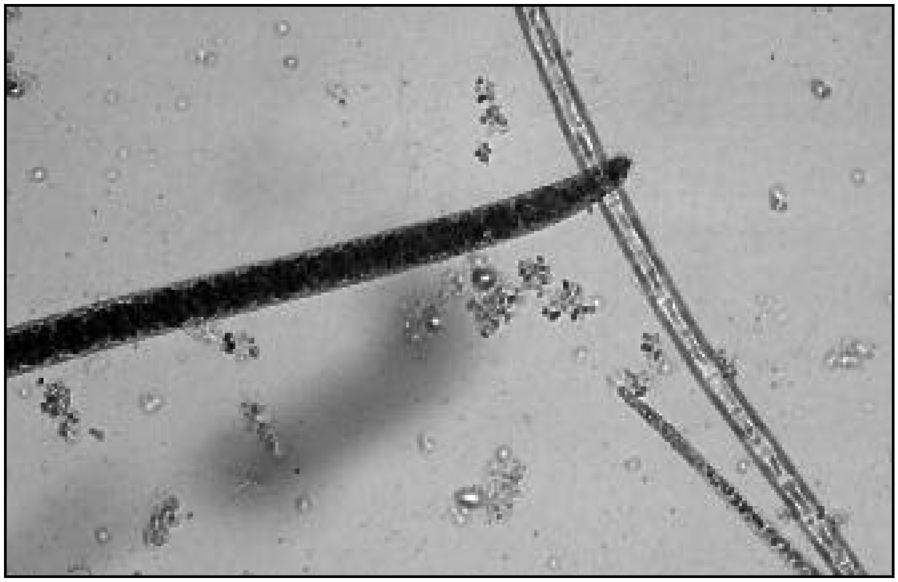

Figure 1. Filament of Oscillatoria peronata*, a species of blue-green algae that produces 2-methylisoborneol (MIB). The filament is about 10 µm in diameter. The lighter-colored filament running vertically is* Aulacoseira*, a filamentous diatom.*

Blue-green off-flavors

Three common off-flavors are placed in this group based on their known or suspected origin as metabolites produced by blue-green algae, which are plant-like bacteria common in the blooms of many fish ponds. Two off-flavors in this category—2-methylisoborneol and geosmin—are known to be caused by blue-green algae. The third off-flavor, called "woody," is commonly included in this category although there is only weak evidence that it is caused by blue-green algae.

The most common cause of flavor problems in catfish raised in northwest Mississippi, southeast Arkansas, and northeast Louisiana is caused by **2-methylisoborneol** (MIB). The chemical causes a unique musty-medicinal off-flavor that can be quite intense and disagreeable. In catfish ponds, MIB is nearly always produced by the microscopic blue-green alga *Oscillatoria perornata*, although in other environments MIB can be produced by several other species of blue-green algae, as well as by actinomycete bacteria.[1]

Blooms of *O. perornata* consist of free-floating, straight filaments that are slightly bent and gradually tapering at one end (Fig. 1). The filaments are 7 to 12 µm wide and 500 µm long or longer.[2] Cells of *O. perornata* contain many gas-filled vesicles that make the filament look dark and grainy when viewed under a microscope. The organism grows slowly when water temperatures are below about 70 degrees F (20 degrees C), so *O. perornat*a is usually present only during the warmer months. Populations may develop in any nutrient-enriched freshwater pond but the organism appears to be most common in waters of high total alkalinity and hardness. *O. perornata* is most likely to develop in ponds where populations have grown in previous summers. The organism probably overwinters in the pond bottom muds and then begins to grow when water temperatures rise above 60 to 70 degrees F (15 to 20 degrees C) in the spring.

Off-flavors caused by MIB can develop rapidly, but they dissipate slowly. Fish exposed to MIB become noticeably off-flavor within minutes or hours. Fish purge the chemical naturally when exposure ceases, but days or weeks may be needed for the off-flavor to completely dissipate. The rate at which the off-flavor disappears is related primarily to water temperature and the size and fat content of the fish. Small, lean fish held in warm, odor-free water purge MIB off-flavors within 2 to 4 days. Large, fatty fish held in cold water may not purge the flavor for weeks or months following exposure.

Another common "blue-green" off-flavor is caused by **geosmin**. Geosmin gives fish a distinctive earthy or muddy flavor that is somewhat reminiscent of the odor of a damp basement. In catfish-producing areas outside the Mississippi River floodplain, geosmin off-flavors are often more common than those caused by MIB. Many species of blue-green algae and actinomycete bacteria can produce geosmin, but in catfish ponds the main geosmin-producers are species of the blue-green algae *Anabaena* or, less commonly, *Aphanizomenon* or *Lyngbya*.

Members of the genus *Anabaena* are easy to recognize, although it is difficult to differentiate geosmin-producing species from those that do not produce geosmin. The microscopic filaments of *Anabaena* (Fig. 2) are free-floating, straight or coiled, and consist of a series of spherical

---

[1]Actinomycetes are a group of branching, filamentous bacteria that are somewhat similar in appearance to filamentous fungi. Actinomycetes are routinely found in freshwater environments, but they are primarily soil microorganisms. In fact, the characteristic earthy smell of soil is caused by the production of MIB, geosmin and other odorous metabolites by actinomycetes.

[2]The blue-green algae that cause off-flavors cannot be seen with the unaided eye. Metric dimensions are provided as an identification aid for readers with access to a microscope equipped with an ocular micrometer.

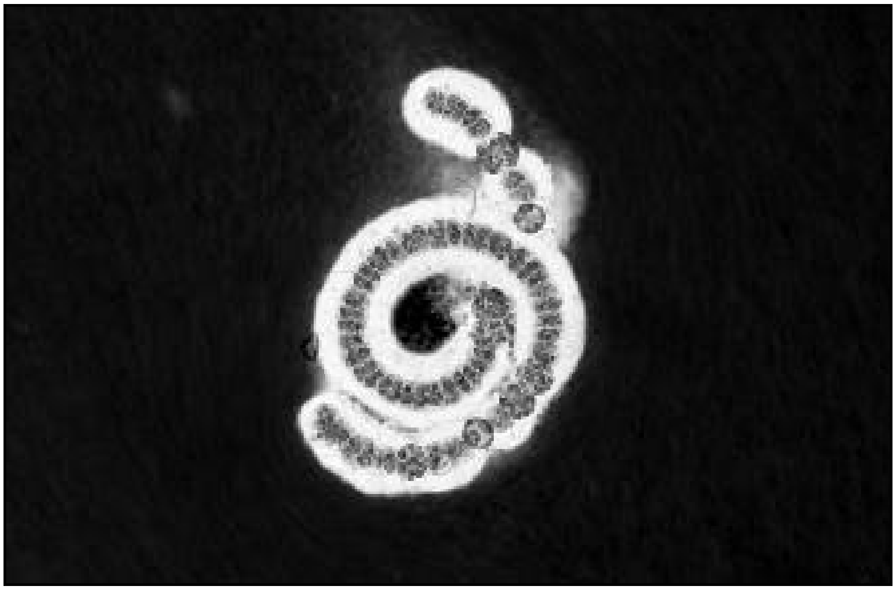

Figure 2. A filament of Anabaena*, a geosmin-producing species of blue-green algae. The sample was photographed in a solution of India ink to show the mucilaginous envelope (the clear halo) surrounding the filament. The cells are about 8 µm in diameter.*

or barrel-shaped cells that look like a string of beads.

Individual filaments of *Aphanizomenon* (Fig. 3) somewhat resemble straight filaments of *Anabaena*, but unlike the individual or tangled filaments of *Anabaena*, filaments of *Aphanizomenon* usually lie parallel in free-floating bundles or flakes. Although geosmin-producing blooms of *Anabaena* and *Aphanizomenon* may occur at any time when water temperature is warm, they are most common in late spring when water temperatures are rapidly increasing.

Unlike *Anabaena* and *Aphanizomenon*, which float free in the water, the geosmin-producing species of *Lyngbya* found in southeastern fish ponds usually grow in tangled clumps or mats on the pond bottom or among shoreline vegetation. The individual filaments of *Lyngbya* have a firm sheath that usually extends beyond the end of the filament (Fig. 4). Like the other odor-producing blue-green algae, *Lyngbya* is found most frequently during the warmer months of the year.

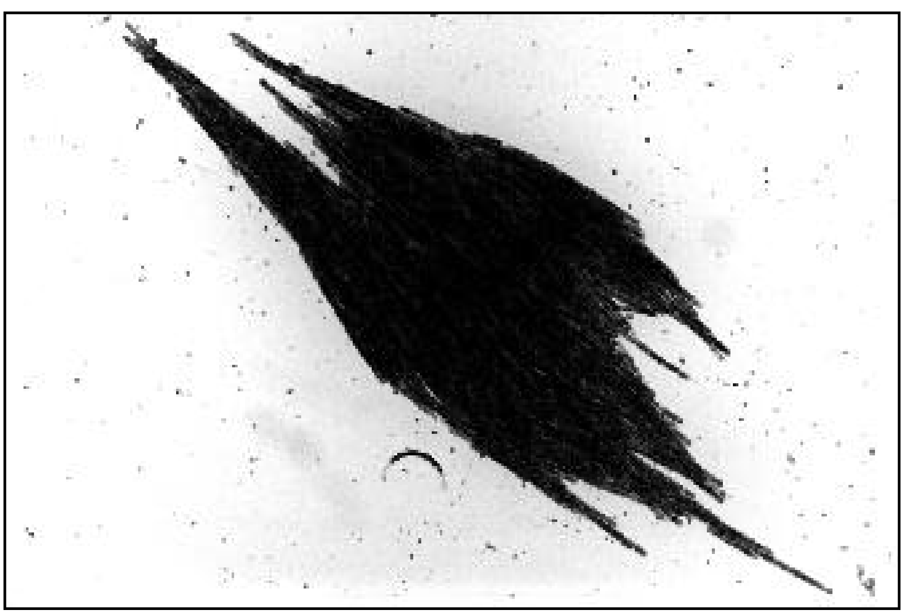

Figure 3. A flake-like bundle of filaments of Aphanizomenon flos-aquae*, a species of blue-green algae that produces geosmin. The individual filaments are about 5 µm in diameter and the flake is about 300 µm broad.*

The rates at which fish acquire and purge geosmin off-flavors are similar to those for MIB.

The third off-flavor in the blue-green category is called "**woody**." The flavor is usually not very intense, and some people find it difficult to detect. The flavor is most frequently described as reminiscent of wood chips, although some people find the flavor to be somewhat like that caused by low levels of MIB. Woody off-flavor is often accompanied by an astringent or bitter aftertaste that is not experienced with other off-flavors. The chemical cause of the woody off-flavor is not known.

Woody off-flavors in pond-raised catfish are most common in late autumn and winter. There is weak evidence (that may well prove to be wrong) that the woody off-flavor is related to prior exposure of fish to MIB. This is the only basis for including woody flavors in the blue-green category.

Woody off-flavor purges from fish much more slowly than off-flavors caused by MIB or geosmin. In one study, channel catfish with woody off-flavor were held in clean, flowing well water at 75 degrees F (24 degrees C) for 21 days with only modest improvement in flavor quality. Intense MIB off-flavor was completely purged from fish in 4 days under the same conditions.

Decay/rotten off-flavors

A wide variety of offensive off-flavors are grouped into this category. Descriptions of flavors in this group include "egg-sulfury," "sewage," "decaying vegetation," and "rotten." All have an apparent common origin in the decay of plant or animal matter in a pond. In one study of off-flavors in pond-raised catfish, "rotten" off-flavors were most common in the winter months and in ponds that contained large numbers of dead

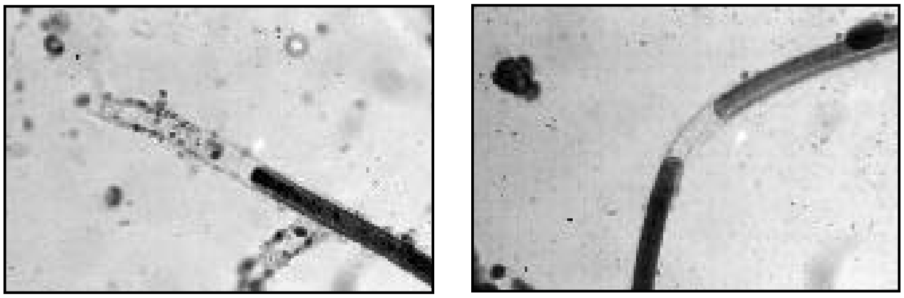

Figure 4. Two views of the filamentous blue-green alga Lyngbya *sp. Surrounding the filament of vegetative cells is a firm, transparent sheath which can be seen extending past the end of the filament (left) or at an internal break in the filament (right). The filament of this species is about 25 µm in diameter. Some species of* Lyngbya *produce geosmin.*

fish. The intensity of the "rotten" flavor varied widely from fish to fish, and may have developed as fish fed on dead flesh as they foraged for food. Other flavors in the category are more reminiscent of decaying plant material, but it is not known whether the flavors were derived from fish feeding on decomposing plant material or whether odorous compounds were released into the water by decaying plants and then absorbed from the water by fish. Rates of flavor impairment and rates of purging are not known for any of the off-flavors in this category.

Petroleum off-flavors

Petroleum off-flavors can develop when fish are exposed to gasoline, kerosene, motor oils or most other petroleum products. Nearly all petroleum off-flavors in pond-raised fish are caused by accidental spills of diesel fuel from farm equipment or from fuel tanks on diesel-powered well pumps. Exposure to diesel fuel gives fish a flavor so charactistic that it can usually be detected and identified without much difficulty. The concentration of diesel fuel in water needed to cause off-flavors has not been determined, but laboratory studies indicate that it may be as little as 1 or 2 gallons of diesel fuel spilled in a 10-acre pond.

Petroleum hydrocarbons are absorbed quickly from the water and stored in the fatty tissues of fish for long periods after exposure. Fish exposed to petroleum products develop off-flavors very rapidly and lose the flavors slowly. Petroleum off-flavors may persist for weeks or months. Purging of the flavor is especially slow in cold water.

Management of off-flavors

Off-flavors are difficult to manage in pond aquaculture, in large part because "off-flavor" describes a variety of problems, each with a unique (and often unknown) origin. It is, therefore, impossible to eliminate off-flavors with a single management strategy. Control of pre-harvest flavor quality is also difficult because catfish ponds are ideal habitats for blue-green algae, which cause most off-flavors. The incidence of off-flavor could be dramatically reduced if blue-green algae were eliminated from ponds, but this has proven to be difficult without using chemical algicides.

Fish cropping systems

Opportunities to harvest and sell fish are greatest when the farm is managed with a cropping system that maximizes the number of ponds that contain fish of marketable size throughout the year. This was a major factor leading to the widespread use of the "understocking" cropping system in channel catfish aquaculture.

In the understocking system, ponds are initially stocked with a single year-class of fingerlings. The faster growing individuals are then selectively harvested using a large-mesh seine, and fingerlings are added ("understocked") to replace the harvested fish and other losses incurred over the production period. The process of selective harvest and understocking continues for years without draining the pond. After a few cycles of harvesting and understocking, all ponds on the farm contain a wide range of fish sizes, from recently stocked fingerlings to fish that may be several years old. Understocking is an alternative to the "clean-harvest" cropping strategy, where single year-classes of fish are maintained by harvesting all fish in a pond before restocking fingerlings.

Economic analyses indicate that clean-harvested ponds can generate more profit than understocked ponds if fish can be harvested and sold without constraint. In the real world, however, where off-flavors often prevent timely fish harvest, the understocking system is favored because more ponds on the farm will contain fish of marketable size at any one time. In other words, if fish from a particular pond can't be harvested because the fish are off-flavor, it is probable that there will be acceptable fish to sell from another pond.

Managing around off-flavor episodes in this manner is obviously not an ideal strategy, particularly when the incidence of off-flavor is high. Even when the understocking strategy is used, harvests will be delayed and cash-flow hindered, especially on small farms with few ponds. Also, the understocking system may not be appropriate for the production of fish other than catfish.

The role of routine taste testing

Off-flavors in pond-raised fish are sporadic events, so a routine program of monitoring fish flavor is important to find "windows of opportunity" in which flavor quality is acceptable and fish may be sold. Another reason to monitor flavor quality is to know when problems might be treated with the greatest probability of success.

In flavor testing you must determine both the type and intensity of the off-flavor. The type of off-flavor helps determine whether the problem will respond to certain treatments. If a good record of the flavor quality is kept, changes in flavor intensity will indicate whether the problem is getting better or worse, and that information may influence the choice of treatment. For instance, a dramatic improvement of flavor quality in two consecutive samples taken a week apart indicates rapid purging of the off-flavor and the likelihood that no treatment is required.

Many fish farmers rely on personnel at processing plants to determine fish flavor quality. However, it is better to set up an intensive flavor monitoring program on the farm rather than relying on commercial processors. On-farm testing is simple, saves time, and will alleviate some of the routine sample burden from taste-testers at the processing plant. However, on-farm testing is for farm management purposes only and should not replace flavor quality control procedures at the processing plant. Results of on-farm testing should never be used as a point of contention when they disagree with the taste-testing results at the processing plant.

On-farm flavor testing is described in SRAC Publication 431, "Testing Flavor Quality of Preharvest Channel Catfish." The procedure simply involves cooking a sample, without seasoning, in a microwave oven. Then an experienced person tastes the fish. The taster must be able to identify the blue-green off-flavors from the other off-flavors found in pond-raised fish. It is also important to be consistent in identifying the flavors and in ranking the intensity of the flavor. The results of the test should be recorded on a simple form that includes a numerical ranking of the flavor intensity and a flavor descriptor. For example, you may rank fish from 0 to 5, with 0 = no off-flavor, 1 = very mild off-flavor, up to 5 = extreme off-flavor. You should also use descriptors such as "geosmin," "woody," "rotten" and so on.

Preventing blue-green off-flavors

The most common off-flavors in pond aquaculture are caused by blue-green algae, so most off-flavor management practices are aimed at manipulating phytoplankton communities to eliminate that group of organisms. A variety of schemes have been proposed for managing phytoplankton blooms, but most approaches have either been unreliable or impractical. At present, using chemical algicides is the only relatively successful means of preventing off-flavors caused by blue-green algae.

Copper sulfate and certain chelated or complexed copper products are currently the only algicides labeled for use in aquaculture ponds.[3] Copper algicides are not ideal for off-flavor management because they are not selectively toxic to odor-producing blue-green algae. Copper also interacts strongly with other water quality variables, and one important consequence of those interactions is that copper products become more toxic to fish and algae as water hardness and alkalinity decrease. This makes it difficult to obtain safe, effective treatments because copper products are most effective as algicides under the same conditions (soft waters of low alkalinity) that make them very toxic to fish. On the other hand, copper products are safe to use in hard, alkaline waters but they are much less effective as algicides. Despite this dilemma, copper products can be relatively effective tools for managing off-flavors caused by blue-green algae when used cautiously under the proper conditions.

In waters with total alkalinity and hardness concentrations between 100 and 300 mg/L as $CaCO_3$, copper sulfate can be applied weekly through the spring and summer to reduce the incidence of off-flavors caused by MIB or geosmin. Treatments should begin in the spring only after average daily water temperature is consistently above 70 degrees F (20 degrees C). Treatments are discontinued after fish have been harvested or when average water temperature falls below 70 degrees F (20 degrees C) in the fall. Copper sulfate is applied weekly in the mid-morning of sunny days at a rate of 1.25 pounds of copper sulfate pentahydrate per acre-foot (for example, 5 pounds per acre in a pond with an average depth of 4 feet). The easiest way to apply the chemical is to place the required amount of copper sulfate crystals in a burlap bag and then put that burlap bag inside another burlap bag. The double bags slow the rate at which the copper sulfate dissolves in water. Suspend the bags of copper sulfate about 20 feet in front of a paddlewheel aerator. Run the aerator until all the copper sulfate is dissolved; this usually requires an hour or two.

Copper sulfate treatments cause poor water quality and more aeration will be required in copper-treated ponds than in untreated ponds. Therefore, use copper sulfate only if you plan to harvest fish before fall and only if there is good reason to believe that fish will be tainted with blue-green off-flavors if no treatment is undertaken. Do not make routine copper sulfate treatments for algae control in fingerling ponds or in broodfish ponds (off-flavors are not a problem in those fish). And finally, do not use this treatment regimen in waters of low

[3] At the time this publication was written, an organic herbicide—diuron—was approved for use in some states by the U.S. Environmental Protection Agency under an emergency exemption. Diuron is approved in those states only for control of MIB off-flavors in farm-raised channel catfish. Regulations and instructions for diuron use are presented in "Managing Catfish Off-Flavors with Diuron" by C. S. Tucker and A. T. Leard, available from the National Warmwater Aquaculture Center, P.O. Box 197, Stoneville, Mississippi 38776. Check with your Extension aquaculture specialist regarding current state and federal regulations for diuron use.

hardness and alkalinity (generally considered to be less than 50 ppm as $CaCO_3$) because copper sulfate may stress or kill fish.

Eliminating blue-green off-flavors

Off-flavors can be eliminated from fish only after exposure to the odorous chemical is discontinued. This can be accomplished in three ways: 1) leave the fish in the pond until the odor-producing algae disappear from the bloom community; 2) move the fish to another pond; or 3) kill the organism responsible for the odorous compound. After exposure ceases, fish flavor quality will improve over time as the the odorous chemical is purged from the flesh.

Wait and see

The composition of pond phytoplankton blooms constantly changes. Individual species increase in abundance and then eventually disappear, only to be replaced by other species that likewise grow and then disappear. The constant reordering of the bloom community causes the sporadic recurrence of off-flavors in pond-raised fish. When an odor-producing species grows in a pond, fish become off-flavored. But when the bloom changes and the odor-producing blue-green algae disappear, MIB or geosmin will be purged from the flesh and flavor will improve. So, one way to "manage" off-flavors caused by geosmin or MIB is simply to wait until the odor-producing species disappears naturally.

The main drawback to this approach is that it is impossible to predict how long the odor-producing blue-green algae will remain in the pond—they may disappear in a week or they may persist for months. This wait-and-see procedure is the most common approach to addressing flavor problems, but some farmers dislike the uncertainties involved in this passive approach and try to speed up the process.

Moving fish to another pond

The most dependable method of purging off-flavors is to move the fish to clean, odor-free water. The "purging pond" may be a pond freshly filled with well water or a pond with an existing population of fish. A freshly filled pond is best because it is less likely to develop a bloom of odorous blue-green algae soon after the fish are moved.

If an existing production pond is used to purge fish, it should have a low standing crop of fish so that the total weight of fish in the pond does not become excessive after adding the off-flavor fish. Any fish already in the pond should be taste-tested to verify the absence of off-flavor because nothing is accomplished by moving off-flavored fish from one pond to another that also has a problem. Fish from both ponds should also be checked for fish diseases because you do not want to transfer diseases from one group of fish to another.

A major risk in using an existing production pond as a purging pond is the possibility that odor-producing algae or other microorganisms may begin to grow in the pond during the purging process. There is no way to predict whether this will happen and no sure way to prevent it. Although the chances of new off-flavors developing in purging ponds is lowest in the winter, purging times are much longer in cold water, so there is more time for new off-flavors to develop. Conversely, off-flavors are purged more quickly in warm water, but the risk of new off-flavor development is greater because blooms of odorous algae can grow rapidly in warm water.

The "woody" off-flavor is lost much more slowly from fish than flavors caused by MIB or geosmin, so purging times will be long, which will increase the chances that fish will develop some other flavor problem during the purging process. However, the source of woody off-flavors is unknown, so the only management option (other than doing nothing and waiting for the flavor to improve) is to move the fish to another pond in the hope that the flavor will improve faster than it would if the fish were not moved.

Bear in mind that moving fish from one pond to another for off-flavor purging is different than transporting fish to the processing plant. Harvest and transport to the processor is a dead-end trip, but fish are expected to thrive after they are transferred to a pond for purging. Ideally, fish should not be moved during the hot summer months but, unfortunately, the incidence of off-flavor is highest at that time. You must, therefore, handle them in a manner that minimizes stress and ensures long-term survival. Seine, load and transport the fish as quickly as possible and put fewer fish in hauling tanks than when taking them to the processing plant.

Using algicides

Using algicides to treat off-flavors caused by blue-green algae is just another approach to purging. After the algicide kills the odor-producing algae, any geosmin or MIB in the water naturally dissipates and the off-flavor purges from the fish without having to move them to another pond. Under the right circumstances this can be a reasonably successful practice, but using copper algicides in fish ponds is always risky.

The key to successful use of algicides as an off-flavor treatment is to confirm that blue-green algae are the cause of the problem. First, be sure that MIB or geosmin is present in the fish by taste-testing a few samples. Second, look at a water sample microscopically (using a total magnification of 100 to 300x) to make sure that blue-green algae known to produce MIB or geosmin are actually present in the water. If either piece of evidence is missing, the role of blue-green algae in the flavor problem cannot be proven and the effectiveness of copper sulfate cannot be guaranteed. If both pieces of evidence are in place, however, there is a reasonable chance that proper use of copper sulfate can improve fish flavor quality.

Note that the "woody" off-flavor is not known to be directly caused by blue-green algae. There is, therefore, no reason to believe that using algicides will hasten the disappearance of that off-flavor.

If copper sulfate is used as an algicide to treat blue-green off-flavors, sufficient chemical must be applied to kill the entire population of odor-producing blue-green algae in the pond without harming the fish. Consistently safe and effective treatment rates are difficult to determine because copper toxicity depends on pH, temperature, alkalinity, water hardness, and the amount of dissolved organic matter in the water. Copper sulfate treatment rates listed on labels of the commercial product range from about 0.25 to 2 ppm (0.7 to 5.4 pounds / acre-foot) of copper sulfate depending on the type of algae to be controlled and the chemistry of the water, although label instructions are usually vague regarding the effects of water quality. The label may simply warn that toxicity to fish increases in "soft" water and that more chemical may be needed to kill algae in "hard" water. In an attempt to compensate for the effects of water chemistry on copper toxicity, some workers base copper sulfate treatment rates on total alkalinity:

Copper sulfate (ppm) = total alkalinity (ppm as $CaCO_3$) ÷ 100

For example, if the total alkalinity is 150 ppm as $CaCO_3$, you would apply 1.5 ppm of copper sulfate. This formula ignores the effects of other water quality variables on copper toxicity, and is, therefore, of limited value as a predictor of successful application rates. Perhaps the best advice is to seek guidance from someone experienced in making copper sulfate applications in aquaculture ponds.

Copper sulfate is not a selective algicide, so if enough chemical is used to eliminate the odor-producing blue-green algae, it will probably kill all, or most, of the other algae in the pond. Acute depletion of dissolved oxygen is sure to follow, so there must be plenty of mechanical aeration to cope with the problem. The serious water quality problems that follow copper treatments are good reasons to be sure that blue-green algae are the cause of the flavor problem before treating. Copper sulfate is a powerful algicide, but the difference between concentrations that are algicidal and those that kill fish is small. So the chemical should never be used unless there is good reason to believe the treatment will be beneficial.

Copper-based algicides are not always effective in controlling off-flavors, perhaps because treatment rates are too low to kill all the odor-producing blue-green algae. Copper sulfate is quickly lost from water (within a day or two after treatment) and has no residual activity, so any algae not killed immediately may rapidly repopulate the pond and continue to cause flavor problems.

Copper sulfate applications are often ineffective when water temperatures are below 60 degrees F (15 degrees C) because the effectiveness of all aquatic herbicides is diminished in cool water. Furthermore, even if treatment kills the algae, off-flavor purging rates are slow in cold water and fish flavor quality may not improve for many weeks. Another possible reason for treatment failure is that it is unlikely that blue-green algae are growing and producing odorous compounds in cold water. So, if blue-green off-flavors are present, they are probably the result of MIB or geosmin produced and absorbed by fish during an earlier period of warm water. In other words, killing the algae present in the pond does nothing to remedy the situation because the flavor problem is related to previous exposure, not current conditions.

The simultaneous presence of multiple flavor problems in the same fish is another common reason for the failure of copper treatments to improve fish flavor. Flavors caused by MIB and geosmin are very intense and can mask other off-flavors. Copper treatment may kill the odor-producing algae and the MIB or geosmin off-flavor may disappear, but other off-flavors may remain. The woody flavor is a common secondary off-flavor in fish tainted by MIB, and removal of the intense, musty MIB flavor often leaves a mild, but unacceptable, woody flavor that is difficult to eliminate. Problems with one off-flavor masking another are difficult to manage because simple taste testing and microscopic examination of the water usually do not reveal the presence of the secondary flavor problem.

Managing decay/rotten off-flavors

Other than moving fish to clean water to accelerate purging, there are no consistently effective treatments for flavors in this category because their origins are unknown. Some of these flavors may develop when fish scavenge on dead fish or other decaying organic matter during periods when they are not being fed. If that is the cause of the off-flavor, it may help to offer adequate manufactured feed at all times of the year. It may also be possible to reduce decay / rotten off-flavors by removing dead fish from the pond when they first appear, although this is a difficult task on large commercial catfish farms.

Managing petroleum off-flavors

Petroleum off-flavors in pond-raised fish develop only after contamination of the water, as might occur when diesel fuel leaks from the fuel tank of a tractor. Prevention is the only logical management approach, since petroleum off-flavors are extremely difficult to purge from fish once they develop. Fuel and oil storage facilities should be located away from ponds. Care should be exercised when refueling vehicles or equipment or when handling petroleum products near ponds. Everyone working on the farm should be made aware that even small spills of diesel fuel and other petroleum products can cause noticeable off-flavors in fish.

If fish develop petroleum off-flavors, the only recourse is to let the flavor purge by moving the fish to another pond. Fish with petroleum taints should not be mixed with other fish in the purging pond because it may take months for the off-flavor to completely leave the fish. Once the off-flavored fish are removed, the petroleum-contaminated pond should be drained and allowed to air-dry for as long as possible before refilling. This may be a good time to renovate the pond bottom and levees. Air-drying and reworking the bottom and levees will promote volatilization and weathering of hydrocarbon residues, which reduces the possibility that the subsequent fish crop will develop off-flavors from residual contamination.

Furthur reading

Engle, C. R. and G. L. Pounds. 1993. Trade-offs between single- and multiple-batch production of channel catfish, *Ictalurus punctatus*: an economics perspective. *Journal of Applied Aquaculture* 3(3/4):311-332.

Engle, C. R., G. L. Pounds and M. van der Ploeg. 1995. The cost of off-flavor. *Journal of the World Aquaculture Society* 26:297-306.

Johnsen, P. B., S. W. Lloyd, B. T. Vinyard and C. P. Dionigi. 1996. Effects of temperature on the uptake and depuration of 2-methylisoborneol (MIB) in channel catfish *Ictalurus punctatus*. *Journal of the World Aquaculture Society* 27:15-20.

Tucker, C. S. and J. F. Martin. 1991. Environment-related off-flavors in fish. Pages 133-179 in J. R. Tomasso and D. Brune, editors. *Water Quality in Aquaculture*. The World Aquaculture Society, Baton Rouge, Louisiana.

van der Ploeg, M. 1991. Testing Flavor Quality of Preharvest Channel Catfish. Publication 431, Southern Regional Aquaculture Center, Stoneville, Mississippi.

van der Ploeg, M. and C. S. Tucker. 1993. Seasonal trends in flavor quality of channel catfish, *Ictalurus punctatus*, from commercial ponds in Mississippi. *Journal of Applied Aquaculture* 3:121-140.

van der Ploeg, M., C. S. Tucker, J. A. Steeby and C. R. Weirich. 1995. Management Plan for Blue-Green Off-Flavors in Msississippi Pond-Raised Catfish. Publication 2001, Mississippi State University Extension Service.

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 94-38500-0045 from the United States Department of Agriculture, Cooperative States Research, Education, and Extension Service.