Keeping Catfish on Consumers' Menus

Freshwater aquaculture is one of the fastest growing sectors of the U.S. agricultural economy, and channel catfish production accounts for 70 percent of all freshwater aquaculture earnings. The National Agricultural Statistics Service estimates that the 2001 farmgate revenue for channel catfish was about $470 million.

Unfortunately, as much as 60 percent of farm-raised catfish is considered off-flavor at certain times, according to a recent American Fisheries Society study. These off-flavors can lead to delays in harvesting and result in economic losses of up to 20 percent of total farmgate value. Scientists with the Agricultural Research Service are looking for ways to detect and prevent such problems.

Detecting Off-Flavors

Channel catfish are raised in densely populated ponds, where algae and bacteria thrive on the large amounts of nutrients that are available. While most of these algal species are either beneficial or nonharmful, a few produce off-flavor compounds.

PEGGY GREB (K10333-1)

Microbiologist Paul Zimba examines filamentous algae from a catfish production pond. Pond conditions often support blooms of these undesirable algae, resulting in increased production costs.

"Fish can be rejected for flavors that are described as woody, sewage, rotten, and diesel," says Casey Grimm, an analytical chemist in ARS' Food Processing and Sensory Quality Unit (FPSQU) at the Southern Regional Research Center in New Orleans, Louisiana. "But the basis for about 80 percent of all rejections is the muddy/musty aroma produced by geosmin and 2-methylisoborneol (2-MIB)."

Human taste buds are incredibly sensitive to these two compounds. The average consumer can detect 0.7 parts per billion (ppb), and a skilled, professional catfish taster can detect 0.1 ppb in catfish. But these pros are susceptible to colds, allergies, and other problems that impair their smelling and tasting abilities and desensitize them to off-flavors.

To make detection of catfish flavors more efficient, Grimm began developing an instrument method in 1997 for analyzing off-flavor compounds. He and his collaborators, including support scientist Steve Lloyd, created a technique that uses steam distillation/solid-phase microextraction to collect flavor compounds and gas chromatography/mass spectrometry to separate and analyze them.

The instrument is more objective than human flavor checkers and could help standardize the catfish industry. It can run an analysis every 15 minutes, and it detects geosmin and 2-MIB at levels less than 0.05 ppb.

"At a cost of $100,000 per instrument, it's probably too expensive for small producers," says Grimm. "But the state of Mississippi is looking into buying one or more machines and setting up laboratories that could be used by producers from around the region."

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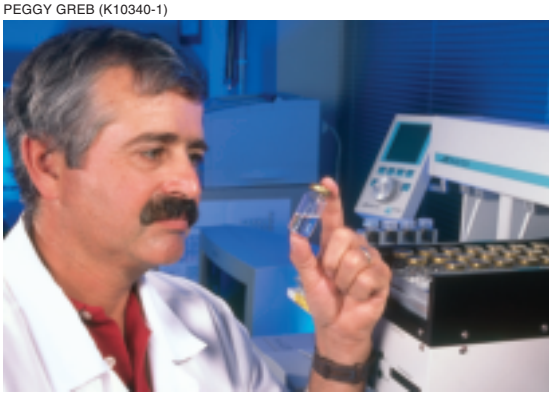

Chemist Casey Grimm examines distilled steam concentrates from catfish fillets before analyzing the off-flavor compounds 2-methylisoborneol and geosmin by an automated gas chromatography mass spectrometer.

Getting to the Source

Detecting off-flavors before they cross the human taste threshold solves only part of the problem. Ultimately, ARS researchers would like to control off-flavor algae or prevent them from forming these compounds. They have begun looking more closely at the biology of the cyanobacteria—commonly called blue-green algae—and other species that are the sources of geosmin, 2-MIB, and other off-flavor compounds.

Paul Zimba, a microbiologist at ARS' Catfish Genetics Research Unit in Stoneville, Mississippi, estimates that between 100 and 200 species of cyanobacteria live in catfish production ponds. But, he says, only four or five of these species are known to produce off-flavor compounds. The rest are beneficial because they oxygenate the water.

Zimba says that the most common management system used in the catfish industry—the multiple-batch system—may contribute significantly to the growth of off-flavors. In this arrangement, hatched fish eggs, or sac fry, are reared in nursery ponds. Once they reach the adolescent, or fingerling, stage, they are moved to production ponds, where they grow to market size.

Farmers harvest the full-grown fish and restock the ponds with more fingerlings, meaning that several different ages of catfish are present in a pond at any one time. The restocking process can continue for several years without the ponds being drained. There is no industry standard designating how often ponds should be drained.

Recently, Zimba and colleagues studied how the age of a catfish production pond related to its water quality, phytoplankton and zooplankton populations, and incidence of off-flavor. They examined 71 catfish production ponds in Mississippi during the hottest part of the summer, when algal and cyanobacterial levels are at their highest. The ponds included in the study were 1, 2, 3, 4, 9, 10, and 15 years of age.

Not surprisingly, the researchers found that fish from younger ponds had lower incidences and intensities of off-flavors than those from older ponds. Zimba says that draining production ponds every 4 to 5 years could decrease occurrence of off-flavors.

Zimba and his collaborators also outlined a basic succession pattern of zooplankton and phytoplankton that grow in catfish production ponds. Among other things, they determined that by year 4, blue-green algae are dominant and continue to increase through year 15. Older ponds also contain higher densities of zooplankton.

Because higher levels of blue-green algae correlate with higher levels of off-flavors, Zimba and the other researchers say that older ponds may be used for holding sac fry and fingerlings. The zooplankton in these ponds could serve as food sources for the fry. Younger ponds are better suited to growing out the fish and purging them of off-flavors.

Normally, farmers must keep off-flavor fish in the production pond or in another holding facility for weeks or months until the flavors dissipate. This holding period can come at a great cost to producers.

Zimba is also working on a way to speed up the time it takes fish to eliminate off-flavor compounds. He used freshwater raceway systems to measure how much time was required for fish to eliminate off-flavor.

"Fresh water is pumped through the raceways to flush out the off-flavors acquired by the fish from the pond system," Zimba explains. "Off-flavor concentrations in the fish gradually lessen as the water flows over them. In our studies, fish purged 50 percent of off-flavors within 24 hours."

PEGGY GREB (K10335-1)

Technician Marilyn Grayer (foreground) samples water to be processed by student assistant Bridget Ester-Fields (center) and Paul Zimba. This study assesses how clay concentrations affect reflectance characteristics of algal populations when monitored remotely from airplanes.

PEGGY GREB (K10334-1)

Charting Microbes' Succession

Though Zimba and his collaborators have made great strides in charting the year-to-year biological succession of various microorganisms in a channel catfish pond, the details are still a little unclear. As a result, the incidence of off-flavor compounds such as 2-MIB and geosmin remains unpredictable.

According to FPSQU chemist Barry Hurlburt, this unpredictability may not be a problem much longer. During the past 2 years, he and his collaborators have developed a molecular assay that can scan a catfish pond and, in less than a day, determine the relative populations of all the microorganisms it contains. Over the next year, they will use this assay to test 30 production ponds once a week and note which species each contains. They will use this data to map the biological succession of the algae and bacteria.

Hurlburt says, "If a certain species always blooms at a certain time before an off-flavor-causing species appears, the assay could be used as a predictive tool by farmers. If their ponds tested positive for a '3-week predictor species,' for instance, they would know exactly how much time they have to salvage their fish before off-flavor compounds begin ruining their crop."

In a similar preventive effort, Zimba and Steven J. Thomson, an agricultural engineer at ARS' Application and Production Technology Research Unit in Stoneville, are studying a remote-sensing technique that may detect unwanted

Student assistant Susan Towery (right) measures oxygen levels in experimental enclosures treated with herbicides to control off-flavor-forming cyanobacteria while Paul Zimba records the data. Changes in oxygen provide an early indication of the herbicides' effect on the algae.

algal species in production ponds before the problem gets out of hand.

The researchers can now identify specific types of algae by their unique color profiles, which they obtain from digital video shot during low-altitude flights. Zimba says that unwanted algae are distinguishable by their unique chlorophyll and carotenoid compounds. With enough data, the scientists can predict when certain types of algae will grow in the cycle.

The Stoneville researchers and colleagues at Mississippi State University's Remote Sensing Technologies Center and the National Oceanic and Atmospheric Administration are currently refining their equipment and technique.

A Solution Could Be in the Genes

Besides looking at biological succession in production ponds, ARS scientists are also studying the genes that cause geosmin and 2-MIB to form. Hurlburt explains, "A researcher in England has isolated the gene responsible for the first step in the biosynthesis of geosmin from the soil-dwelling bacterium *Streptomyces coelicor*. I plan on using this cloned gene in an attempt to isolate the equivalent gene in cyanobacteria."

Hurlburt and his collaborators may eventually be able to use this information to block the biosynthetic pathway that allows geosmin to form in ponds.

Hurlburt is also planning on using a genetic approach to "knock out" genes in cyanobacterial species involved in off-flavor compound production. If any of them stop the synthesis of geosmin or 2-MIB, he will isolate the modified species and introduce them into research production ponds. He will then determine whether the improved species can compete with and eventually displace the off-flavor-causing species.

All these efforts may ultimately lead to more productive and profitable commercial catfish ponds.—By **Jim Core** and **Amy Spillman,** ARS.

This research is part of Aquaculture, an ARS National Program (#106) described on the World Wide Web at www.nps.ars.gov.

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PEGGY GREB (K10341-1)

Chemist Barry Hurlburt prepares to use a centrifuge to harvest cyanobacteria and algae in water samples collected from a commercial catfish farm.