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ENVIRONMENT-RELATED OFF-FLAVOURS IN INTENSIVELY CULTURED FISH

by

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Abstract

The paper describes the study made at Auburn University of the causes of off-flavour in catfish. Methods of controlling the organisms responsible for imparting off-flavour were investigated. The paper concludes with a number of practical suggestions for controlling off-flavour in pond-raised catfish.

APPARITION D'ODEURS DESAGREABLES EN RAPPORT AVEC L'ENVIRONNEMENT DANS LE POISSON FAISANT L'OBJET D'UNE CULTURE INTENSIVE

Résumé

L'Auburn University a fait une étude sur les causes d'apparition d'odeurs désagréables dans le poisson-chat. Des méthodes permettant de combattre les organismes responsables de ces odeurs ont été examinées. Le document contient un certain nombre de suggestions pratiques en vue de lutter contre l'apparition de mauvaises odeurs dans la chair de poissons-chats élevés en étang.

PERDIDAS DE SABOR DE LOS PECES CULTIVADOS EN REGIMEN INTENSIVO DETERMINADAS POR EL MEDIO AMBIENTE

Extracto

En este trabajo se describen los estudios realizados en la Universidad de Auburn sobre las causas de la pérdida de sabor del bagre. Se estudiaron los métodos que han de utilizarse para determinar cuáles son los organismos responsables de esta pérdida de sabor. El trabajo concluye con algunas sugerencias prácticas para limitar la pérdida de sabor del bagre criado en estanques.

INTRODUCTION

Fish have been aptly described as biological sponges. They can absorb many inorganic and organic materials through their gills as well as from the intestinal tract. Some absorption probably occurs through the skin. Sources of off-flavour compounds may perhaps be industrial or agricultural chemicals and wastes; however, by far the most common types are those synthesized by organisms in the aquatic environment. Considering that there are numerous microorganisms in the pond that synthesize compounds which fish can absorb and store in their bodies, it is understandable that occasionally a few of these may have an adverse effect on the flavour of the fish flesh.

Odours and flavours of a characteristic "earthy-musty" quality are often detectable in drinking waters taken from reservoirs. Several reports in the U.S.A. (Silvey and Roach, 1956; Maloney, 1966; Silvey, 1966; Rosen, 1968; Rosen et al., 1970; and Silvey et al., 1950, unpublished) and in Israel (Leventer and Eren, 1969) have discussed the etiology of this phenomenon in reservoirs and streams and indicated that the causative organisms were species of actinomycetes and blue-green algae.

Thayson (1936) first described this musty flavour in fish in studies of trout taken from rivers in Scotland. He associated the cause of the off-flavour to Actinomyces which grew in mud that was high in organic matter along the river bank. He demonstrated that trout could absorb compounds from water which were elicited by an oderiferous Actinomyces. Aschner et al. (1969) reported that a blue-green alga, Oscillatoria tenuis, was responsible for a disagreeable, earthy flavour in carp which made the fish unacceptable in Israel. They recommended holding the off-flavoured fish in clean, flowing water for several days prior to marketing to improve the flavour.

Lovell (1971) reported that a characteristic, objectionable earthy-musty flavour is frequently found in intensively-cultured catfish in the south-central and southeastern U.S.A. A survey of the catfish processing industry (Lovell, 1972) showed that in the autumn of 1971 several large-scale processors reported that over 50 percent of the ponds tested before being drained contained fish with such intense off-flavour that harvesting was postponed until the flavour improved. Heavy concentrations of odour-producing actinomycetes and blue-green algae have been identified from ponds with earthy-musty flavoured catfish and are suspected of being the organisms responsible for the off-flavour (Lovell, 1972). Conversely, on many occasions off-flavoured fish have been found in ponds which contained actinomycetes and algae not unlike the aquatic flora in ponds where fish had normal flavour. Off-flavour-producing algae and actinomycetes have been found to produce noxious odours or flavours under one set of conditions but not under other conditions (Leventer and Eren, 1969; Lovell, 1971). This contributes to the complexity of defining the etiology of the off-flavour problem in fish.

Several earthy-musty-smelling compounds, with related chemical properties, have been isolated from cultures of aquatic microorganisms and natural waters. Gerber and Lechevalier (1965), Medsker et al. (1968) and Rosen et al. (1970) isolated the earthy-musty-smelling metabolite, geosmin, from several actinomycetes. Safferman et al. (1967) discovered the blue-green alga Symploca muscorum produced geosmin and Medsker et al. (1968) showed that another alga, Oscillatoria tenuis, also produced this compound. Other compounds isolated from actinomycete cultures or natural waters, which differ slightly from geosmin, are mucidone (Dougherty et al., 1966) and 2-methylisoborneol (Rosen et al., 1970).

STUDY OF OFF-FLAVOUR CAUSES

A study was conducted at Auburn University (Lovell, 1972) to determine the capability of geosmin-producing blue-green algae to impart the earthy-musty flavour in the flesh of channel catfish. Cultures of geosmin-producing blue-green algae S. muscorum and O. tenuis were obtained from the Federal Water Quality Control Laboratory in Cincinnati, Ohio. Fifty-gramme channel catfish were held in 150-litre stainless-steel tanks containing dense masses of luxuriantly growing S. muscorum or O. tenuis to determine the capability of these

algae to impart the geosmin flavour in the fish. To measure the rate of off-flavour development in the tanks, four fish were collected from each of two tanks of S. muscorum and four from each of the two tanks of O. tenuis at 1, 2, 4, 6, 10 and 14 days after stocking. After each collection the fish were quick-frozen and stored in hermetically-sealed pouches at -23°C for subsequent sensory analysis. To determine time required to purge the fish of any flavour acquired from the algae, catfish were held in two tanks of S. muscorum for 14 days, then removed and placed in charcoal-filtered, flowing water. The fish were removed from the flowing water after 0, 3, 6, 10 and 15 days and quick-frozen for subsequent analysis.

To determine the ability of fish to absorb the flavour compounds from the water without having an opportunity to ingest the algae, two "algae-free" tanks were stocked with fish. Water passed from two S. muscorum culture tanks into the two cell-free tanks by gravity through a glass wool filter, and was exchanged between the tanks twice daily. The algae tanks and the algae-free tanks both were enriched with nutrient solution; consequently, exchange of water between the two tanks did not dilute the nutrient concentration in the algae tanks. Fish were removed from the algae-free tanks according to the same schedule as was followed with the fish taken from the algae tanks.

After all samples had been collected, the frozen fish were thawed, dressed, and cooked for sensory evaluation for earthy-musty or algae-related flavour by a taste panel composed of four trained, experienced evaluators. They assigned each sample a score of 1 to 10 on the following basis: 10 = no off-flavour; 8 = slight off-flavour; 6 = distinct off-flavour; 4 = intense off-flavour; 2 = extreme off-flavour. Sensory scores were analyzed for differences among means by the Duncan Multiple range test (1955). Within one day the fish from the S. muscorum tanks had developed a distinct earthy-musty flavour, similar to the odour of the alga, which became stronger at two days and reached maximum intensity at ten days (Table 1). Algae-related flavour was only slight, but significant ($P<0.05$), in fish from the O. tenuis tanks at 2 days and reached a maximum at 14 days, but never equalled the intensity of that in the fish from the S. muscorum tanks. Stomach contents of the fish revealed that moderate amounts of both algae were eaten during the first day they were in the culture tanks.

The fish which were exposed to the algae-free filtrate from algae culture tanks developed a flavour qualitatively similar to that of the fish held in direct contact with the algae. This indicated that the fish were able to absorb the dissolved geosmin-like compounds from the water, primarily across the gill membrane, into the blood. Absorption of the off-flavour compounds was appreciably slower by fish held in the algae-free filtrate than by those held in the algae culture tanks (Table 1). Evidently acquisition of algae-related off-flavour by channel catfish is greatly facilitated when the fish ingest the algae.

Flavour of the fish held in the S. muscorum tanks for 14 days was subsequently improved when the fish were transferred to flowing, charcoal-filtered water (Table 2). After three days in clean water at 25°C, the flavour had improved significantly ($P>0.05$). At ten days the flavour of fish transferred from the algae tanks was not significantly ($P>0.05$) different from that of control fish.

The quantitative significance of blue-green algae in the flavour problem in fish has yet to be evaluated. No intensive study has been conduoted to identify algal species from culture ponds containing off-flavoured fish. An alga identified as Anabaena sirceneria was found to be growing intensively and predominantly in ponds with earthy-musty flavoured catfish at the Auburn University Fisheries Research Unit in the spring of 1971 and again in 1972 (Lovell, 1972). Because of the variety of algae which produce noxious odours and tastes in natural waters (Palmer, 1962) and the widespread seasonal and geographic distribution of earthy-musty flavour in cultured fish, it is likely that a number of the blue-green algae may be the cause of it. Because of the ubiquity of odoriferous actinomycetes, the same may possibly be said of these organisms, also.

Table 1

Average sensory scores for channel catfish held for various periods of time in either tanks containing cultures of S. muscorum or O. tenuis algae, or tanks containing algae-free water which was transferred through filters from the S. muscorum culture tanks

Tank Environment	Holding time (days)						
	0	1	2	4	6	10	14
Algae: S. muscorum	9.8	6.8	5.5	5.7	5.7	2.8	3.0
O. tenuis	9.0	8.5	8.0	6.8	6.7	6.6	4.7
Algae-free	9.0	9.1	-	8.8	8.5	6.0	5.3

Table 2

Average sensory scores for channel catfish held in tanks containing S. muscorum for 14 days and subsequently held in flowing, charcoal-filtered water for various periods of time, and for control fish which were held in flowing water only

	Holding time in flowing water (days)					
	0	3	6	10	15	Control fish
Sensory score	3.2	5.7	6.7	8.7	9.0	9.1

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Some of the more important factors known to affect the growth of flavour-producing organisms are availability of nutrients, temperature, sunlight, and oxidation-reduction potential in culture ponds:

Nutrients

The diagram in Fig. 1 illustrates the relationship between nutrients in the pond supplied by unabsorbed feed and off-flavour in fish (Lovell, 1971). The blue-green algae are autotrophic in their nutrient requirements and do not need organic matter, hence, their growth is stimulated by CO_2, P, N and inorganic materials released when fish feed and excrement decompose and NH_3^- is excreted in the water. Actinomycetes, on the other hand, are hetertrophic and must grow on organic matter; consequently, unconsumed feed, faecal material and dead algae may serve as growth substrate for these organisms.

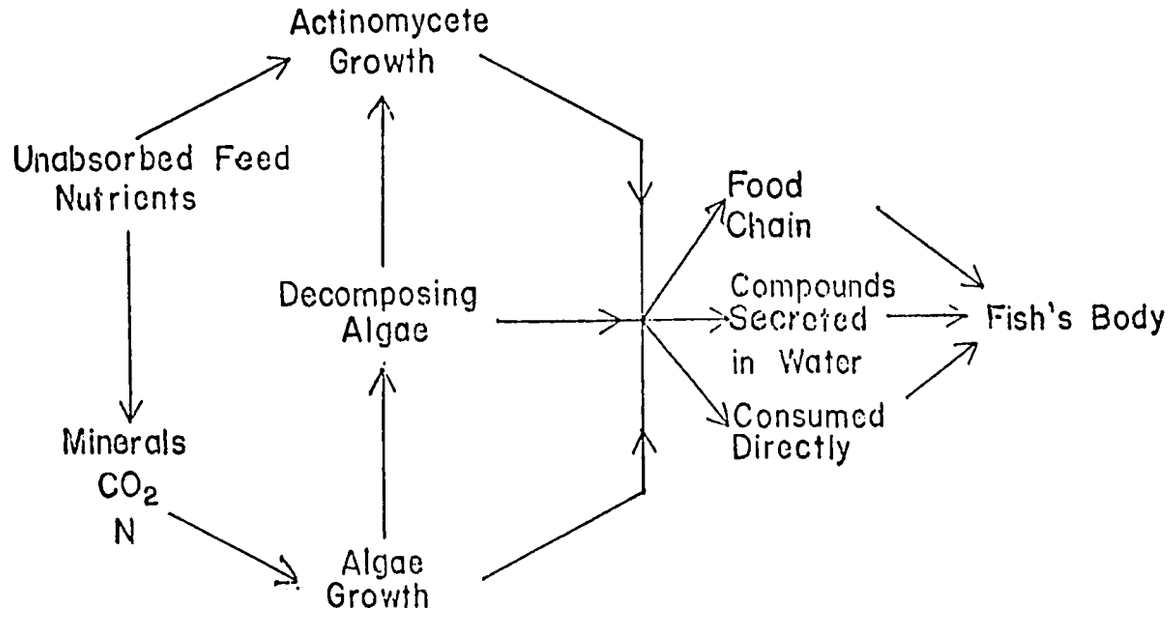

Fig. 1. The diagram shows how uneaten or undigested feed may contribute to the development of earthy-musty flavour in pond-cultured catfish

Temperature

All algae that have been found to produce odorous compounds are generally warm-weather plants. Some may be highly temperature specific. An anabaena species in ponds at Auburn University bloomed intensively when the water temperature had just reached 21°C, and caused earthy-musty flavour in catfish; however, as the ambient temperature increased the alga was found only sparingly and caused no flavour problems. Actinomycetes are considered to be the causative organisms in off-flavoured catfish ponds in cool weather.

Sunlight

Algae need sunlight for growth, consequently by preventing penetration of sunlight below the surface of water their growth may be restricted. Catfish were grown in ponds at Auburn which were kept muddy by releasing compressed air into the ponds near the bottoms. Fish growth was satisfactory in the turbid ponds, very little algae grew, and the flavour of the fish was good.

Oxidation-reduction potential of the water

The amount of dissolved oxygen in the water affects the metabolism of algae and actinomycetes. Oscillatoria chalybea, a notorious odour-producing alga, grew well in an aquarium that was aerated but produced no odorous compound (Leventer and Eren, 1969). In the same medium under low oxygen conditions the organism produced an earthy-musty odour. Actinomycetes are facultatively aerobic and, reportedly, the oxygen condition of the environment influences the ability of some species to produce odorous compounds (Dickson, 1968).

SUGGESTIONS FOR CONTROLLING OFF-FLAVOUR

Removal of the earthy-musty flavour by holding the fish in flowing water was investigated at Auburn University (Lovell, 1971). Three collections of catfish were brought into the Fishery Research Laboratory and held in flowing, filtered water at a temperature of 15°, 22° or 26°C for 15 days. The fish were weighed and evaluated for flavour at 0, 3, 6, 10, and 15 days. Table 3 shows their changes in flavour and weight. The off-flavour may be purged from fish relatively quickly by clean water and an increase in temperature enhances the process. However, the weight loss, especially at higher temperatures, makes this method economically impractical for the catfish industry. Suggestions for controlling off-flavour are as follows:

(1) Pond wastes should be minimized. The farmer can help this situation by using good feeds and feeding practices. Unconsumed and unabsorbed nutrients stimulate the growth of pond microorganisms. Much attention from experimental stations is being directed toward removing wastes from fish culture systems.

(2) Frequent exchange of pond water can minimize opportunity for the development of off-flavour in fish. This removes nutrients from the pond and also reduces the concentration of a specific population of microorganisms.

(3) Chemical control of growth of algae in ponds is possible, but it is questionable whether such a practice would be desirable or feasible. Algae are important in the food chain of pond organisms and in producing oxygen through photosynthesis. Also, poisoning algal blooms will increase the biological oxygen demand in the pond and is hazardous unless there is a water reserve or aeration. Another advantage of a plankton bloom is shading the pond bottom to prevent growth of rooted plants in the pond. It should be remembered that algae are not the only causes of off-flavour, and only a few of the blue-green algae are responsible for the production of these compounds. Chemical treatment only kills the algae and does nothing to eliminate the cause of growth. With profuse quantities of nutrients going into the pond daily, it will require continuous infusion of poison to control algae growth. If too much algae dies at one time the oxygen demand upon the water may increase too rapidly and cause a fish kill. More research is needed on the feasibility of chemical controls.

Table 3

Average sensory scores and weight losses for off-flavoured channel catfish held in flowing, charcoal filtered water at various temperatures

Water temperature (°C)	0 day		3 days		6 days		10 days		15 days	
	Score a/	Weight (%)	Score	Weight (%)	Score	Weight (%)	Score	Weight (%)	Score	Weight (%)
15	4.7	100	6.1	95.6	7.1	93.2	7.4	92.3	9.1	91.2
22	4.9	100	7.0	90.6	8.7	90.5	9.3	87.8	9.6	85.9
26	5.0	100	7.7	87.6	8.7	85.0	9.6	83.1	9.6	82.5

a/ Score descriptions: 10 = no off-flavour; 8 = slight; 6 = distinct; 4 = intense; 2 = extreme.

(4) Other possible methods for controlling microorganism growth in ponds involve biological means. Use of viruses or bacteria to control algae have been suggested. The uptake of pond nutrients by higher plants to prevent algae growth has been investigated at Auburn. Water hyacinths effectively suppressed algae growth.

(5) Mechanical agitation of ponds to increase turbidity, or muddiness, of the water may be an effective suppressor of plankton growth. Also, there is a possibility that suspended particules of clay may act as adsorbents for off-flavour compounds in the water.

The earthy-musty flavour always disappears from catfish over variable periods of time even with no pond treatment. A week to several months may be required, depending upon the persistence of the flavour-producing organisms. Catfish farmers who find off-flavour in their fish are urged to continue to feed the fish, because if fish are hungry they may begin feeding on materials on the pond bottom which may accentuate the problem; exchange the pond water if possible; if a dense plankton bloom accompanies the off-flavour, do not poison the algae unless there is an abundant supply of water for replacement; do not remove the fish from the pond, unless they can continue to feed while the off-flavour is being cleared up because weight will be excessive.

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