Off-flavors in RAS: status on current knowledge on organisms producing off-flavors and a recent example on mitigation of off-flavor problems in a recirculated, experimental system

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Taste-and-odor (TOC) problems in trout RAS in Denmark:

Resume from study of about 200 rainbow trouts in 2011:

- **Sensory panels:**
  63% of the fish from production basins had detectable content of TOCs

- **Chemical analysis:**
  About 90% of fish from production basins had a TOC level >0.1 µg/kg (human detection limit)

- **Supermarkets:**
  Consumer complaints on TOC-tainted fish
Off-flavors make consumers opt out fish from freshwater:

In Denmark Pangasius fish from Vietnam have a low consumer acceptance.
Known off-flavors compounds in fish:

- **Earthy**: Geosmin
- **Musty**: 2-MIB (methylisoborneol)
- **Rancid**: aldehydes, e.g. 2,4-heptadienal (from oxidation of lipids)
- **Woody**: Terpenes
- **Petroleum**: Environmental pollution
Which organisms produce off-flavors?

- If light, N and P are present:
  - Cyanobacteria (bluegreen algae) and some algae

- If organic matter and oxygen are present:
  - Streptomycetes (bacteria)
  - Myxobacteria (slime or gliding bacteria)
Cyanobacteria: free cells or filaments
Streptomyces: Gram-positive, filamentous bacteria
Myxobacteria (*Sorangium* and *Nannocystis*): Gram-negative, slime- and spore-forming bacteria

Molecular method indicate capacity to produce geosmin (presence of the gene encoding the geosmin synthase enzyme)*

*Auffret et al. (2013). Impact of water quality on the bacterial populations and off-flavours in recirculating aquaculture systems. FEMS Microbiology Ecology 84, 235-247*
**Pangasius and tilapia from ponds in Bangladesh:**
Unpleasant taste and flavor in fish but not caused by geosmin nor MIB

- 20 terpenes found in the fish
- 11 of the 20 compounds have woody odor

**Bangladeshi fish:**
- **β-caryophyllene** [clove and hops],
- **α-pinene** [rosemary and pine],
- **β-ionone** [rose and violet], and
- **α-humulene** [hops]

were well above the threshold for human detection. Source(s) of the off-flavors unknown.
Terpenes, geosmin and MIB have same precursor:

Monoterpenes are synthesized from geranyl diphosphate and sesquiterpenes from farnesyl diphosphate by enzymes

Example:
Geranyl diphosphate $\rightarrow$ 2-MIB [and other monoterpenes]
Farnesyl diphosphate $\rightarrow$ Geosmin [and other sesquiterpenes]
Molecular detection of off-flavor production: geoA gene
Do algae produce off-flavors?

Water reservoir in China:

Unpleasant **fishy** odor was caused by dense growth of certain algae (chrysophyte [golden algae] *Dinobryon*: diatoms *Melosira* and *Cyclotella*)

Odor compounds: **aldehydes** (*n*-hexanal, *n*-heptanal, 2,4-decadienal, 2,4-heptadienal)*

*Zhao et al. (2013). Journal of Environmental Sciences 25:2361–2366*
CONTROL OF GEOSMIN AND MIB (1)

PHYSICAL AND CHEMICAL METHODS
Particulate activated carbon (PAC), e.g. for drinking water
Advanced oxidation procedure (AOP): UV light + ozone

BIOLOGICAL METHODS
Australia (drinking water): Bioreactor (sand column) with bacteria isolated from sewage treatment plant: 70% degradation of geosmin at 100 ng/l. Slow process, long contact time (5 ml/min in reactor).

China (RAS): Enrichment of bioflocs with *Bacillus* bacteria: 99% reduction of geosmin at 100 ng/l in 10 l biofloc reactor after 2 days.

Challenge: Geosmin removal from water in tanks
CONTROL OF GEOSMIN AND MIB (2)

BIOLOGICAL METHOD:
SNAILS GRAZING ON BIOFILM

Can snails reduce TOC in RAS?

Davidson and coworkers at Freshwater Institute, Shepherdstown: 500 l experimental tanks with 30 rainbow trouts (111 g)

**Streptomycete** bacteria found in biofilm on walls in *aeration sump*

Freshwater snail *Physa gyrina* living in aeration sump removed biofilm.

Snails reduced density of streptomycete bacteria by 3-fold in the biofilm*. Few streptomycetes in the water.

*from 150,000 to 50,000 streptomycetes per 100 ml biosolids
Biofilm in RAS in Denmark: probably excellent food for snails

Algae
Fungi
Bacteria
Ciliates
INITIATIVE TO REDUCE OFF-FLAVOR IN FISH FROM RAS IN DENMARK 2012:

Recommended treatments:
• Purging of fish for up to 6 days in water with <10 ng geosmin/l
• 6 annual analyses of geosmin in the water

Testing for TOC in fish
Selected fish from each party (loading) are cooked and tasted

Chemical quantification of TOC in fish
No commercial facilities for the analysis are yet available
Fish production in Denmark in 2003:

Comments, questions?
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