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Windrow Composting as an Effective Method to Dispose of Large Numbers of Fish

During July 1998, at the USGS Leetown Science Center, Kearneysville, West Virginia, an epizootic occurred in 16-month-old Atlantic salmon (*Salmo salar*). The cause of mortality was diagnosed as furunculosis, a serious disease in salmonid fishes caused by the bacterium *Aeromonas salmonicida*. The fish were being maintained as part of ongoing research and were held in uncovered 30-m-long concrete raceways, each supplied with about 757 L per minute of 12 °C pathogen-free spring water. The means by which the fish became infected could not be determined, and there was no recent history of furunculosis in the hatchery system.

Controlling the Epizootic

Fish affected with furunculosis are typically treated with one of two FDA-approved and available antimicrobials (Romet® and Terramycin®). Although it was determined by sensitivity testing that the strain of *A. salmonicida* was, in fact, sensitive, surviving fish would become a carrier population after antimicrobial therapy. We were also concerned with containing the pathogen as quickly and effectively as possible, therefore reducing the chance for release into natural waters (e.g., streams) via bird predation or other forms of transfer.

The strategy for control of this epizootic was to depopulate all fish deemed not essential for the research project, disinfect the area, and initiate antimicrobial therapy and external chemical treatments on the remaining essential fish. Those lots of fish remaining were kept either inside buildings or in covered raceways. The total number of fish discarded exceeded 25,000, with an approximate combined weight of 4,273 kg.

Fish Carcass Disposal

Methods to dispose of large quantities of fish carcasses are limited. Further reducing the choice of methods is the fact that the fish were infected with a highly pathogenic bacterium, and containment was our highest priority concern. Direct burial was not considered because our geographic area is primarily limestone with significant below-surface water movement that might ultimately result in surface water contamination. Incineration was considered, but on-site equipment could accommodate only about 227 kg within a 24-h period. Energy costs in fuel and electricity to power the incinerator and for freezing the remaining carcasses were determined prohibitive.

The option selected for disposing of the fish carcasses was windrow composting. This method offered several advantages: all fish could be discarded at once; the proximity of the compost pile site, its design, and operation ensured containment of carcasses; and no leachate would be produced.

The compost site is located on the Vinemont Farm, about 2 km from the USGS Leetown Science Center; the farm property borders the east-southeast boundary of the science center property.

Fish Carcasses Mixed with Horse Stable Bedding

Dead fish that had succumbed to the disease comprised only a small portion of the total. Live fish were sacrificed with a lethal dose of the anesthetic tricaine methanesulfonate (MS222), then were netted to buckets that were placed onto a truck. After each load was emptied, the truck bed was disinfected with chlorine before the truck returned to the science center.

Fish were added to and mixed into a composting material consisting of straw-horse manure with some sawmill shavings-horse manure that came from stable bedding. About nine parts of this material was added to each one part of fish on a weight/weight basis. As more fish were added, more bedding was added, and the finished pile formed what was termed a "windrow" that covered a surface area 6.1 15.2 m and was about 2.44 m high in the center. To form the windrow, fish were offloaded onto a 0.61-m bed of the composting material, and then more material was added and mixed using a rubber tire loader with a 3-cubic-yard bucket. Following thorough mixing, more composting material was overlaid to the top and allowed to fall to the sides to form a "cap" about 0.61 m thick, thus preventing scavenging of carcasses by animals and birds.

A finished windrow has a peak at the top extending along the longitudinal axis, creating a chimney effect for heat to escape while drawing air (oxygen) up from the bottom. During construction, it is important to avoid compaction of the pile, which could reduce this chimney effect. The finished pile was essentially a sandwich of the fish-compost material between the 0.61-m composting mixture base and the 0.61-m composting mixture cap.

Two Compost Piles Established

Two separate compost piles were established at the Vinemont Farm. The first was the largest, containing about 3,727 kg of fish. Fish carcasses were added in three installments (Friday, Monday, and Tuesday) within a period of 5 d. As the fish carcasses were added to form the original sections (Friday and Monday) of the first pile, they were directly added to the bedding material. On that Monday evening, pulverized lime (at a rate of about 22.7 kg per 909 kg of fish-compost mixture) was mixed into the pile. For the Tuesday contribution to the pile, lime was shoveled directly onto the fish carcasses as they were being offloaded to the 0.61 m of base material.

The second compost pile contained the remaining fish and was made 13 d later in one installment. The procedure for construction of this pile was the same as for the first pile, except that the lime was added to the core and was mixed in as the pile was being made.

Pile Core Temperature Exceeds 70 °C By 48 Hours

The piles were allowed to rest and the temperature was monitored using a thermometer with a 0.91-m probe to record the internal pile (core) temperature. At the first pile, core temperatures had reached 68.9-72.2 °C on the second day after formation and had decreased to 64.4 °C at 9 d. Based on previous experience at this particular composting operation, the quick and high temperature response was expected. However, a similar quick, high temperature response was not experienced in Tuesday's installment. We surmised that the lime added directly to the fish had absorbed moisture necessary for breakdown of the carcass tissues. In an effort to promote enzymatic activity, we then added water to dampen the top of this section of the pile. It took 4 d to reach 60 °C; the maximum temperature was

64.4 °C at 8 d.

After the temperature had peaked and began to decrease in the first pile (13 d after establishment), the material was turned and mixed. The material was then separated into two windrows. Turning and mixing are standard procedures for proper windrow composting. Following separation of the material into two windrows, each was capped with fresh compost material. The temperature responses in both of these piles were typical, reaching 71.1 °C just 2 d post-turning.

The core temperature response of the second pile was typically high, reaching 65.5-72.2 °C within 2 d after being formed. Fourteen days later, when core temperatures had dropped, the second pile was turned.

Daily high ambient air temperatures were above 32.2 °C for the duration of the study.

Bacteriological Assessment

As the original piles were disassembled, samples were aseptically collected for bacteriological analysis and pH determination. Samples were taken at various locations to represent a cross-section of the piles: from the cap, at 0.3 m and 0.61 m below the surface; and from throughout the core.

Samples consisted of either dry, partially completed compost or a composite of lime and what was originally fish carcass (greenish-colored) or small pieces of fish filet that appeared as though they had been baked. No intact carcasses were found from either pile. Each sample was weighed and a sterile diluent, 0.1% peptone-0.05% yeast extract (pH 7.0; pep-ye) was added; this mixture was then homogenized and a series of dilutions was prepared from the homogenate in pep-ye. Volumes from each dilution were used to drop inoculate CBB (tryptic soy agar with 0.1% coomassie brilliant blue) plates; incubation was at normal atmosphere at 22 °C for 48-72 h. Colonies representing each morphological type were transferred for identification.

Aeromonas salmonicida *Not Present in Any Samples*

Aeromonas salmonicida was not isolated from any of the samples from either pile. No bacteria were isolated from the four samples taken from the Monday contribution to the first pile, indicative of sterile locations. Two samples from other locations of the first pile gave relatively high total bacterial counts at $1.6\ 10^{10}$ and $1.88\ 10^{7}$ colony-forming units per gram (cfu/g) of sample. Total bacterial counts from the other samples ranged between $3.2\ 10^{3}$ and $1.92\ 10^{4}$ cfu/g of sample. The predominant bacterial genus identified was *Bacillus*, which are Gram-positive, spore-forming rods (4-6 m long). These bacteria are very common soil microbes presumably introduced to the pile via the straw-horse manure, as *Bacillus* spp. are not recognized as salmonid normal flora.

The mean bacterial count from 0.3 m into the cap of the second pile was $3.09\ 10^{6}$ cfu/g. This location in the pile yielded the highest bacterial counts; this was anticipated because cap temperatures do not get as high as those in the pile core. At 0.61 m below the surface (still in the cap), one sample yielded no bacterial growth and another was $9.86\ 10^{3}$ cfu/g. Three of five samples from the core were bacteriologically clean, and counts from the other two were $3.77\ 10^{3}$ and $6.05\ 10^{2}$ cfu/g. As with the first pile, the predominant bacteria isolated were *Bacillus* spp. Values of pH ranged between pH 5.5 and 8.2, with seven of the samples between pH 6.9 and 7.4, which is near neutral pH. All of these pH values are within the range expected for properly managed large-scale windrow composting.

Conclusions

In addition to offering a very efficient and environmentally safe means for disposal of a large volume of diseased fish, windrow composting afforded excellent pathogen containment. When a compost pile is constructed properly, there is no odor of rotting fish--a good indication of this is that scavenging animals did not disturb the piles. The temperatures reached in the piles and the amount of time the pathogen spent within the piles actually goes beyond those parameters for pasteurization; therefore, it should not be surprising that *A. salmonicida* was not isolated. In fact, neither was any coliform bacteria isolated, including *Escherichia coli*, a bacterium present in the horse intestinal tract and expected to be present in piles containing such large quantities of horse manure.

Apparently, the temperature in the pile core kills or at least reduces the numbers of most non-spore-forming bacteria below cultivable with the methods we employed. After the temperature peaks and begins to descend, the spore-forming bacteria begin to grow, and these are the bacteria we noted with the highest prevalence.

Lime was added to the pile for two reasons: (1) we thought it would assist in killing the pathogen; and (2) we were incorporating it for its traditional use in the direct burial method of disposal, where lime quenches odor and prevents animals from digging up carcasses. In retrospect, because of the temperatures reached with windrow composting, we feel that lime is not necessary and, in fact, is detrimental because of its moisture-reduction action.

Additional Benefits of Environmentally Friendly Composting

A large-scale composting operation that is properly designed and managed provides an excellent waste management alternative to traditional waste disposal. The finished compost is an excellent source of nitrogen that is immediately available to crops, providing obvious additional benefits. The farm in this study evaluates soil through sampling and analysis at various locations in a field; using this information, deficient areas are targeted with finished compost, thereby maximizing the benefits. Another of the many advantages of composting is that the total volume of finished compost is about 40% less than the mass present at the beginning of the process but contains greater measurable units of nitrogen per unit weight. This means that significantly less tractor time (and soil compaction) is required in the fields to distribute the same amount of crop nutrient.

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