Proceedings of the 1991 Fisheries By-Products Composting Conference

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Introduction

"There is no waste until it is wasted," observed one of the participants at the national Fisheries By-products Composting Conference hosted by the University of Wisconsin Sea Grant Institute in October 1991. H. Clark Gregory spoke for a group that was determining how to not waste the results of human enterprising that turns fisheries resources into fisheries products — and fisheries by-products.

Like other enterprises, commercial fisheries and sport fisheries produce primary products, such as food and trophies, as well as secondary products, which are neither palatable nor hung on walls. Nonetheless, these secondary products, the fisheries by-products, are not without value. Indeed, these proceedings focus on using fisheries by-products — not waste.

Composting is a low-cost, environmentally beneficial and potentially profitable use of fisheries by-products. Variable daily amounts of fisheries by-products are difficult to accommodate in meal plants and extrusion or liquefaction processes, but can be readily combined with other recyclable materials and converted to useful composts.

These *Proceedings of the 1991 Fisheries By-Products Composting Conference* enable composters to better analyze the techniques-of-the-trade and to choose the processes most suited to specific needs. Also summarized are (1) diverse uses for the composts, ranging from traditional garden and crop applications to several more innovative functions, (2) the physical and chemical properties of the composts produced by the various methods and (3) the economics of fisheries by-products composting.

Several papers reviewing other uses for fisheries by-products provide a broader perspective on the issue. The stimulating discussion sessions identify common international problems requiring research initiatives and also alert fisheries by-products composters to potential problems. Several experts who were unable to participate in the conference are cited throughout the proceedings and listed in reference sections.

Composting: A By-Products Alternative for Marina-Based Fish-Cleaning Facilities

by David G. White
New York Sea Grant Extension Program

Abstract

As a result of the enactment in 1985 of the Fish Carcass Disposal Law by New York state, marine facilities on New York's Great Lakes are having to deal with up to 2 million lb. of salmonid fishery by-products annually. Though these by-products can currently be disposed of via land spreading, land filling or waste treatment, many impediments exist to these alternatives. In the case of waste treatment, most lakefront communities either do not have a treatment facility or, if one is in operation, it is most likely inadequate to handle an increase of this magnitude. Land filling is limited in its ability to meet this increased use due to the concern over extending the life of landfills, and land spreading is currently not being conducted due to its low cost-effectiveness.

In an effort to identify alternatives that would allow for disposal in a cost-effective manner and provide for a useful outlet, an applied research demonstration project on composting salmonid fishery by-products was embarked upon. A marina cooperator was identified, and the project commenced, utilizing a tested process of composting fisheries by-products and peat moss. Results have shown that this static pile process decomposes solid fisheries by-products in less than six months.

This process has proven to be an alternative to costly disposal, resulting in a useful, marketable organic mulch. In the case of a small to mid-sized marina, three to four compost piles (300 sq. ft. each) could potentially handle fisheries by-products for an entire year.

Introduction

The New York state Fish Carcass Disposal Law was enacted in response to the increasing problems associated with fish entrails being deposited along and into major bodies of water in New York. The law states that:

It is illegal to discard any fish carcass, or parts thereof, into the freshwaters of the state within 100 feet of shore or upon any public or private lands contiguous to and within 100 feet of such water, except:

- by owners of such lands.
- live fish or fish required to be returned pursuant to other laws and regulations.
- proper disposal into suitable garbage or refuse collection systems or by burial.
- incidental cleaning of fish for consumption, but not within 100 feet of any public launching or docking site unless into suitable refuse collection systems.

With this law has come the establishment of fish-cleaning stations along New York's Great Lakes that are handling over 2 million lb. of by-products generated by the salmonid fishery. The presence of contaminants (PCB and mirex) limits disposal options for the fishery by-products to land filling, land spreading and waste treatment. In an attempt to identify a usable alternative, Cornell University and the New York Sea Grant Extension Program carried out a compost demonstration project using the by-products from Lake Ontario salmon combined with peat moss. The process of composting fisheries by-products with peat moss, originally developed in Canada and refined in Maine, Wisconsin and New York, was used as the basis for this project (Goldhor and Regenstein 1989).

Project Description

At the start of the project, the owners of a marina and a sport store were identified as cooperators. The agreement reached with the cooperators was that all materials (excluding fishery by-products) and technical expertise would be provided by the research team. The marina and sport store staff would be responsible for subsequent pile construction and monitoring.

To reflect local conditions and user demands, two piles were constructed at each site, using different confinement structures and compost mixtures. The size of the piles was arrived at after reviewing the projected needs of the facility, quantity of fishery by-products generated and traditional composting processes. Confinement structures were all 4 ft. high, 5 ft. wide and 16 ft. long. Two structures were built utilizing six wooden fence posts and 24 1-in. by 5-in. by 8-ft. boards, while the other two were built utilizing six metal fence posts and 32 ft. of 1/2-in. wire fence.

Each confinement structure had a 6-in. layer of gravel, on top of which eight 4-in. drainage pipes with holes pointing up were laid widthwise, to provide bottom aeration during the composting process. A 6-in. layer of peat moss or wood chips was then put down as a base for the pile.

A layered approach was initially used, alternating 4- to 6-in. layers of peat moss and fishery by-products with a final layer of peat moss covering the pile at the end of each day. To initiate the composting process, a commercial compost starter was added to each layer of fishery by-products. Water was also added to maintain a 40% to 60% moisture level.

In constructing the piles, no labor was required beyond the daily pile construction as this was a static process where aeration through the pipes replaced turning. Maintaining a good cover of peat moss controlled odors and rodent infestation problems, and contained leachate. By the end of pile construction, the cooperators had placed between 3,000 and 5,000 lb. of fishery by-products into each pile.

The amount of peat moss utilized to construct one of the piles was significantly higher than expected due to the pile being constructed over several days with each day's fishery by-products covered with a layer of peat moss. This resulted in an elevated cost of construction. Another pile was constructed utilizing a base of gravel, covered with wood chips, with the fishery by-products mixed and layered with peat moss, in an effort to reduce the cost. This method resulted in the amount of peat moss on a percentage basis being cut in half, while still providing the conditions necessary for the composting process to occur.

Project Results

The composting process utilized in this project, though tested, had to be modified as composting commenced, to accommodate some of the piles being built on a daily basis over an extended period. The piles constructed in the wood structure worked very well, retaining their integrity, while the wire structure bulged at its sides. The decomposing fishery by-products reached a maximum temperature of 138°F for approximately three days. As long as a complete cover of peat moss was maintained, odors, as well as problems with rodents and maggots, were minimal. All piles decomposed fully, odors were controlled and labor was kept to a minimum. Our results indicate that composting is an effective on-site method of handling fisheries by-products. Problems encountered included dealing with the rather messy fisheries by-products and the time consumed in pile construction as part of a small business.

Regulation

Contaminant analysis conducted as part of this project indicated that the composted product met the criteria to be classified by state law as Class II compost. In New York, composting is regulated by the New York State Department of Environmental Conservation under part 360 Solid Waste Management Facilities Regulations.

Application

The following recommendations are based upon the results of this demonstration project.

- A confinement structure a minimum of 4 ft. by 5 ft. by 16 ft. should be utilized. The structure should be constructed to maintain its integrity. There should be a base of gravel (4 to 6 in.) and perforated pipe (holes up) placed widthwise every 2 ft. for aeration.
- A base layer of peat moss or wood chips (6 in.) should be spread over the gravel.
- Construct the piles with alternating layers of fisheries by-products and peat moss, with peat moss mixed directly in with the fisheries by-products to speed decomposition.
- Each layer of fisheries by-products could need a commercial compost starter added to begin the process.
- Water should be added as needed to maintain a 40% to 60% moisture level. (This could require that the peat moss be wet before being added.) Water should also be added if the pile temperature exceeds 160°F.
- The pile should be allowed to compost for up to 10 months (depending upon local conditions and the composition of fisheries by-products in the pile).
- The pile should be mixed once prior to application to complete the composting process.

Recreational or other facilities interested in utilizing this process are encouraged to contact the SUNY College at Oswego Sea Grant office and the cooperators who actually participated in this project.

Acknowledgments

Special thanks are extended to Brad and Chris Frost, Frost Haven Resort, Fair Haven, N.Y., and to Rick Sorenson, Pineville Sport Store, Pulaski, N.Y., for their assistance in developing this process.

Reference

Goldhor, Susan H., and Joe E. Regenstein. 1989. *Improving Fish Waste Handling*. n.p: New York State Sea Grant Institute.

Alternatives to Land Filling By-Products from Blue Crab and Calico Scallop Processing Plants

by James C. Cato
University of Florida Sea Grant College Program

Introduction

By-products from blue crab and calico scallop processing plants in Florida have always been land filled. Since these by-products are highly organic and putrescible, they have created an environmental landfill problem. Various options have been examined to deal with these and other seafood-processing by-products. These examinations range from specific analyses — including dehydration for use as meal along with other handling methods (Cato et al. 1977; Andree 1988) and as a feed stuff for swine (Myer et al. 1987) — to a complete overview of all seafood-processing by-products management problems nationwide (Otwell 1981).

Chapter 88-130 of Florida Statutes, enacted into law during the 1988 legislative session, mandated major changes in solid waste management in Florida. A portion of that legislation focused on handling by-products from certain seafood-processing activities. Section 60 of Chapter 88-130 specified that:

"The Department of Environmental Regulation, in cooperation with Brevard, Dixie, Franklin, Taylor and Wakulla Counties, shall undertake demonstration projects in fiscal year 1988-1989 to find acceptable solutions to problems created from the disposal of seafood processing byproducts, including shellfish parts, at public landfills. Such projects shall (1) Identify alternatives of disposing of such seafood processing byproducts; and (2) Determine the feasibility of disposing of such seafood processing byproducts in an environmentally acceptable manner."

Blue Crab

Blue crab processing in Florida generates 1,300-2,200 tons of by-products annually. When cooked, blue crab yield 20% water, 12%-14% meat, 35% shell (carapace) and 31%-33% remaining body parts. Most of the by-products management problem occurs in Dixie, Franklin, Taylor and Wakulla counties of northwest peninsular Florida. In Wakulla County, by-products from blue crab processing plants have represented about 20% of landfill volume and consumed about 25% of the solid waste budget.

Prior work and discussions leading to the demonstration projects reported in this document indicated that alternatives for handling the by-products from blue crab processing plants could be listed in three categories: (1) dehydration, (2) wet form uses and (3) ocean disposal. The advantages and disadvantages of dehydration had received attention due to the existence of a plant in Wakulla County and a recent analysis (Andree 1988). Wet form uses considered were direct land application, composting and use in animal feed. Ocean disposal had the fewest positive aspects, primarily due to difficulties in permitting, on-shore handling and high costs of equipment and maintenance.

Land filling was recognized as the current method for disposal of blue crab processing by-products — which has not been satisfactory due to handling costs and environmental concerns. Specific problems have resulted from (1) large by-products volumes arriving at day's end, (2) large by-products volumes relative to all other wastes received, (3) large proportion of landfill costs due to the by-products, (4) odors and (5) physical handling problems.

Calico Scallop

Calico scallop production is normally highly concentrated in Brevard County on the Atlantic coast. However, production on a daily, weekly, monthly and annual basis is inconsistent and unpredictable. Typical annual production ranges from 2 million to 15 million lb. (edible meat weight) — in one recent year reaching 30 million lb. Processing requires large amounts of water, with the by-products including processing effluent, shell and raw viscera. By-products can represent over 80% by weight of the original vessel production.

Disposal management concerns have been listed in two general categories. Water quality concerns have included effluent volume, basic constituents in the effluent (biochemical oxygen demand, suspended solids, etc.) and specific constituents in the effluent (heavy metals, ammonia, etc.). Solids disposal problems have resulted from limited access to public and private landfills, resultant odors and ground water quality concerns.

Significant legal and public debates and agreements have transpired between the regulators and industry. Some firms have attempted secondary water treatment and ocean disposal. In-plant controls have been limited to flow restrictions, flow segregation screening, cyclones and "trickle" filtration/pre-treatment. Solid utilization options have been well examined. Shells can be directed for use as oyster clutch, drainage control, fill, etc. Viscera has been ensiled as a swine feed (Myer et al. 1987) and considered as a fertilizer for citrus and a feed for aquaculture species. The options have not been attractive in that viscera supply has been inconsistent and shells are desired for current local filling of low-lying areas.

Alternatives examined for demonstration included in-plant controls such as by-products restrictions and segregation, alternative screening and recycling; secondary and innovative secondary treatment facilities; composting of the viscera and by-catch; land filling or ocean disposal; use as oyster cultch or animal feed; refining current ocean dumping operations and controlling odor; and sludge disposal from treatment facilities.

Demonstration Projects

A number of demonstration projects were conducted under an agreement with Department of Environmental Regulation staff, county officials, seafood industry leaders, private consultants and university faculty. Demonstration projects chosen were:

- In-plant methods for blue crab by-products control
  - Wet extrusion
  - Compacting
  - Anaerobic bioconversion
- Composting
  - Blue crab
  - Calico scallop
- Blue crab compost marketing
- Blue crab compost as a soil amendment
- Nematode control using blue crab compost

Results

The results of each demonstration project are reported in a number of articles written and published by demonstration project team members. Many of these projects are described in this publication in connection with presentations made at the Fisheries By-Products Composting Conference. Summaries of the demonstration projects and their results are available (Cato 1991; Cato n.d.) and detailed project descriptions and specific recommendations are forthcoming (Cato et al. n.d.). This paper provides only an overview of the demonstration projects and resulting recommendations.

Recommendations

Blue crab and calico scallop processing by-products have been land filled, creating waste management problems. Alternative methods of in-plant compacting, anaerobic bioconversion potential, composting, compost marketing, compost crop applications and nematode control using compost were examined. It appears feasible to compost blue crab and calico scallop processing by-products, and there appear to be uses for the final compost products. Composting is a viable alternative to land filling these seafood-processing by-products. However, composting should only be attempted after consideration of the complete production process, final product use and other problems created by the composting operation.

General recommendations resulting from each project are listed below. The final reports referenced should be consulted for specific information.

Wet Extrusion

- Grinding and pelleting blue crab by-products for use as aquaculture feed for spiny lobster, shrimp and freshwater crayfish is not recommended without additional research.

Compacting

- Compacting and grinding to reduce the volume of blue crab by-products in-plant is feasible. These methods do not eliminate the by-products but do change their form and make them easier to store for later disposal. However, the liquids resulting from the process become more difficult to handle.

Anaerobic Bioconversion

- Production of gas using blue crab by-products has potential, and the fluids were found to have more potential than the solids. Volume reductions of 30%-50% were achieved, and the gas could be used for energy generation at the plant site if economically feasible. More research would be necessary on-site with prototype systems before exact recommendations could be made.

- Most blue crab processing plants are isolated and in rural areas, which would require biogas generation facilities on-site. The capital costs could be too large for these small businesses, particularly without subsidies, and as long as more convenient alternatives such as composting are available, anaerobic bioconversion does not appear to have potential.

Open Windrow, Blue Crab By-Products Composting

- Large-scale centralized composting using mechanical aeration is recommended as a by-products management option where adequate blue crab by-products exist and can be transported to an acceptable central site.

- A number of materials, including fresh cypress sawdust, aged cypress sawdust, pine bark and yard trimmings can be used as C sources to compost blue crab by-products with variable qualities of final products.

- A large-scale blue crab by-products composting operation similar to the one demonstrated in Taylor County, Fla., producing approximately 5,000 tons of final product could be operated at a break-even level, using the assumptions noted.

Low Technology, Static Pile, Blue Crab By-Products Composting

- For smaller blue crab processors, this technology will work and is recommended. Sawdust, bark, yard trimmings and brush will work as C source materials. Existing "landfill type" equipment is all that is necessary for turning the compost. Additional grinding after composting will be necessary to produce a desirable final product.

- The cost for this type of composting operation is substantially less than that for using the more sophisticated mechanical aeration equipment.

Calico Scallop Viscera Composting

- The composting of calico scallop viscera will work and is recommended. However, more cooperation at plant sites with calico scallop processors is necessary (due to the high portion of cracked shells and other materials that must be removed) than is necessary with blue crab processors. Several types of C sources also appear satisfactory for calico scallop viscera composting.

Compost Use and Marketing

- Composting should not be attempted without prior analyses of the potential market and/or use of the final product. Lack of such analyses is often a major and fatal flaw in "new-use" concepts.

- It appears that blue crab by-products compost can be successfully marketed in the areas of the demonstration projects. Public acceptance appears genuine. However, promotional and educational programs will be necessary, the product and supply must be consistent, and the price must be competitive.

- There could be both bulk and bagged market potential.

- The compost should be marketed without a nutrient analysis on the label to avoid being considered a fertilizer and subject to regulations. However, it is critical that regular lab analyses be conducted periodically to indicate the value of the compost regarding its use as a plant supplement and soil amendment. If possible, where consistency can be achieved, a nutrient analysis on the label should be considered, and the compost should be made subject to regulations. This will enhance its marketability.

- It is critical that the compost be free of contaminants such as weed seeds and other biological and chemical risks that could result from either the blue crab by-products or the organic matter used in the composting. Consumers will want this security.

- A complete marketing study needs to be conducted in association with any large-scale compost study. This will help define potential customers, competing products, product form, prices, and general grades and standards that the compost is expected to achieve.

- It is critical that studies also be conducted on various uses of the compost. Customers will want to know the benefits from various applications for the compost. Specific information on plant and soil response to the compost will be critical to the success of the marketing program.

Blue Crab Compost Use as a Soil Amendment

- Raw blue crab by-products seem to offer considerable potential as a soil amendment for crop production at sites where the initial odor and fly problems from unincorporated portions are tolerable.

- Blue crab compost, though considerably more desirable from an aesthetics standpoint, is of quite limited value as a nutrient-supplying amendment.

- Long-term effects on soil organic matter levels and adequacy of nutrient supply for slow-growing crops, including pine plantations, are other considerations where blue crab compost could be of considerable value. These uses need to be evaluated through additional studies.

Nematode Control

- Blue crab compost provided a lower level of nematode suppression than that reported for raw blue crab by-products in other studies. The depletion of nitrogenous compounds and the reduction of energy sources probably reduced chitin concentrations and the nematode suppressive characteristics of the blue crab by-products.

- Effective nematode control using blue crab by-products compost would require an application rate of 200 T./ha., which would not be economically feasible for nematode control in large-scale agriculture. The greatest potential for use of blue crab by-products compost for nematode suppression would be in container grown plants and organic home gardens. High loading rates are normal practices in these production systems.

- The ability of blue crab by-products to increase organic matter and soil water retention and to provide/retain soil nutrients could be of more value than suppressing nematodes.

Environmental Concerns

- Some areas exist with sandy, well-drained soils, low levels of organic matter and low moisture retention capacity. In these areas, ground water could be susceptible to contamination from applied insecticides, herbicides and fertilizer nutrients. Laboratory condition tests indicate that As, Se and Mn leached from the blue crab compost could be at higher than desired levels. Whether this is a problem under actual field conditions at recommended compost use levels and under varied rainfall conditions is yet to be determined.

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Preparation and Use of Compost from Fisheries By-Products

by Lynn Frederick and Allen H. Miller, University of Wisconsin Sea Grant Institute; Robin Harris, Maribeth Milner and Stacy Kehrmeyer, University of Wisconsin-Madison Department of Soil Science; Lloyd Peterson, University of Wisconsin-Madison Department of Horticulture

Abstract

Sport and commercial fisheries by-products were composted in static piles using a base layer of wood chips, a composting mixture of one part fisheries by-products to three parts wood chips and a cover layer of wood chips and started compost. The piles were constructed during the July-September fishing season. Temperatures were monitored to follow compost development. The piles were turned in the fall, composted through the winter and chopped in the spring prior to use on field crops.

Initial nutrient values were calculated from the raw materials. Nutrient and trace metal values were measured at intervals from three to 12 months. Physical properties such as porosity and color were also measured.

The compost was applied to cabbage, beets, tomatoes and beans at the rates of 5 tons/a. and 10 tons/a. in a Latin square design consisting of three replicate plots of each treatment and a control. There were no significant differences in yields among the treatments. N, P and K values as well as trace metal and PCB levels were tested in the edible portions of the plants. N, P and K values and trace mineral levels were all within normal ranges. PCBs were not detected in any of the samples.

The compost was also finely ground and tested for use as a seed starter. Various mixtures of compost, sand and perlite were compared for germination and damping of seedlings. Germination was highest in a mixture of four parts compost to one part sand to one part perlite. There was significantly less damping of seedlings in sterilized compost.

Introduction

Composting is a simple, inexpensive method of converting organic wastes into valuable soil conditioner. Fisheries by-products, because of their putrifiable nature, present a particular challenge for composters. Several methods of composting have been simultaneously developed to meet requirements of varying volumes of fisheries by-products, different types of bulking materials and varying levels of technology and capital (Brinton and Seekins 1988; Mathur et al. 1988). Initial fisheries by-products composting operations were based on aerated pile sewage sludge composting techniques and rapidly adapted to specific conditions (Hay and Kuchenrither 1990).

The purposes of this study were (1) to develop a simple, odor-free method of composting fisheries by-products with other readily available organic materials and (2) to characterize the resulting compost for potential horticultural use.

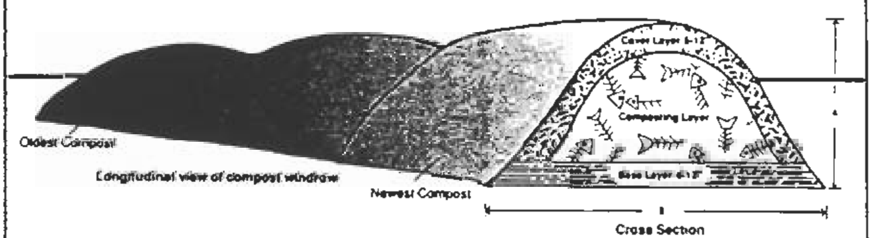
Preparation

The basic compost pile was constructed as a trapezoidal windrow (Frederick et al. 1989). Commercial whitefish and chub fisheries by-products or recreational trout and salmon fisheries by-products were composted with (1) milled hardwood chips, (2) chipped brush and tree trimmings and (3) chipped hardwood bark. During initial studies, the hardwood chip compost piles were built on a concrete slab to better facilitate analyses. The chipped brush and bark piles, as well as all compost piles during subsequent pilot projects, were based on the ground.

The study piles were constructed by first forming a base layer with two parts wood chips. A reactor layer consisting of one part fisheries by-products mixed with one to three parts wood chips was piled on top of the base, and a cover layer of one part wood chips mixed with one part started compost was placed over the reactor layer (Figure 1). Initial pile dimensions were approximately 2 m. (8 ft.) wide by 1.5 m. (4 ft.) high by as long as necessary.

FIGURE 1

Fisheries by-products composting process



Composting Temperatures

Temperatures within the reactive layer of the pile averaged 41°C within 12 hours of pile formation and reached 55°C within 24 hours. Temperatures within the reactive layer reached a high of 68°C after 48 hours and remained in the range of 55°-63°C for the next seven days. For the next two weeks (10-23 days), temperatures in the reactor layer were 45°-51°C; by 30 days, temperatures in the reactor layer had dropped to 29°-35°C. Temperatures on the side of the pile exposed to the wind were 2°-4°C lower than those on the sheltered side. During this time (30 days), the air temperature ranged from a low of 13°C to a high of 24°C. After 30 days, the pile was opened for evaluation and then turned. There was no odor of fish, although an ammonia odor was present. The fisheries by-products were decomposed except for a few large bones, which were mummified. There was a layer of mold where the fisheries by-products had been. The compost pile was thoroughly mixed, and part of this compost was incorporated into the cover layer (one part started compost) for the next system. The remainder was re-piled to continue composting.

Nutrient Content

Initial N, P and K values of the compost mixture were calculated based upon levels in fisheries by-products and wood. N, P and K values were measured after three to 12 months, when the materials had decomposed (Schulte et al. 1987). Total N values declined from anticipated amounts in the chipped brush and bark piles (Figure 2). Total N values in the wood chip pile were higher than the levels calculated from literature-based estimates for fisheries by-products and wood. Soluble and insoluble N values as well as available phosphate and potash levels are shown in Table 1.

FIGURE 2

Percentage total N of fisheries by-products composts over time

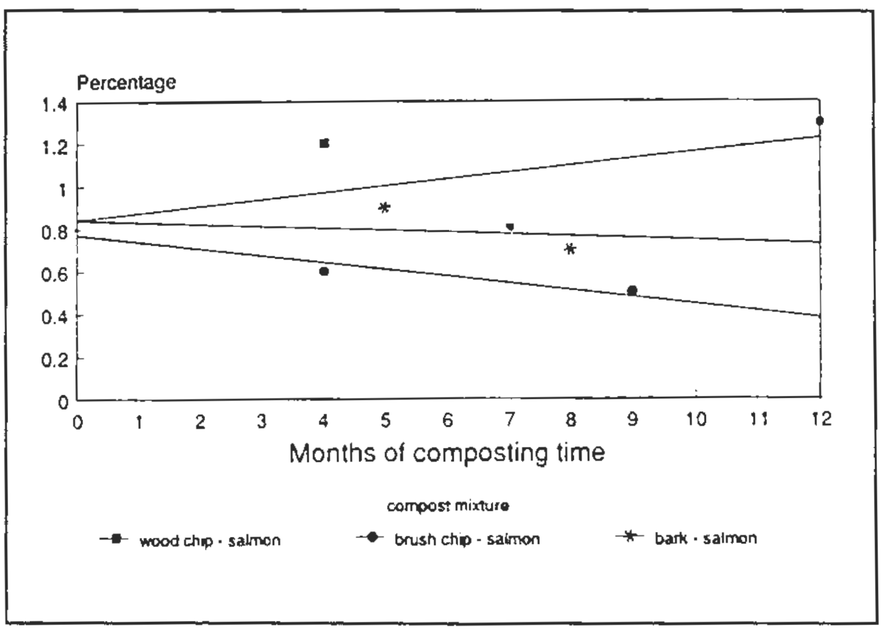


TABLE 1

Comparative fertility value of representative fisheries by-products composts, commercial composts and commercial organic fertilizers

Organic Soil Conditioner Components	Composting Time	Code or Trade Name	N Total	N Water Insoluble	N Water Soluble	Available P_2O_5	Available K_2O
	(months)		%				
Fisheries By-products Composts New Lisbon wood chips/Door Co. salmon	4	A10-1	1.2	1.1	0.10	0.50	0.5
	7	A10-3	0.8	0.7	0.10	0.20	0.2
	12	A10-4	1.3	1.3	0.04	0.30	0.2
Madison shredded brush/ Door Co. mixed fisheries by-products	7	A13-1	1.2	1.2	0.03	0.50	0.3
Door Co. shredded brush/Door Co. salmon	4	S2-1	0.6	0.5	0.10	0.10	0.2
	9	S2-2	0.5	0.5	0.04	0.10	0.2
Door Co. shredded bark/Door Co. salmon	5	S3-1	0.9	0.8	0.10	0.10	0.2
	8	S3-2	0.7	0.6	0.10	0.10	0.1
Commercial Composts Wood chip/raw sewage sludge (Beltsville)	22	BR	1.0	1.0	0.01	--	0.2
Wood chip/digested sewage sludge (Beltsville)	22	BD	0.6	0.6	0.01	--	0.1
Municipal waste/digested sewage sludge (Lodi)	--	LD	0.8	0.8	0.00	0.03	0.4
Shredded bark/sewage sludge	--	Paygro	0.9	0.8	0.10	--	--
Bedding material/cow manure, ----	--	Fertilife	1.0	0.8	0.20	1.00	1.0
	--	Farmer Green	1.0	0.6	0.40	1.00	1.0
Commercial Organic Fertilizers Bone meal/dried blood, ---	--	Garden Food	5.0	4.0	1.00	5.00	5.0
Dried sewage sludge	--	Milorganite	6.0	5.5	0.50	2.00	0.0

[a]Percentage by weight of bagged material, fisheries by-products and municipal waste; composts were assumed to contain 50% water

[b]Paygro is sold as an organic soil conditioner rather than a fertilizer and does not list nutrient content on the label

Physical Properties of Compost

The bulk density, field moisture capacity and air-filled porosity of compost prepared with commercial hardwood chips, shredded bark and shredded brush were measured (Buscher and Van Doren 1973) and compared to those of other compost (Table 2).

The water-holding capacity is similar to that of peat-based, fisheries by-products and crab-processing by-products compost (Mathur et al. 1986) and is probably dependent on characteristics of the C source rather than the by-products.

According to Mathur et al. (1986), characteristics of peat-based, fisheries by-products compost are similar to those of other compost used in potting mixes.

TABLE 2

Physical properties of fisheries by-products composts used for greenhouse and field crop growth trials

Parameter	Units	Organic Bulking Agent						
		Wood Chips		Shredded Bark		Shredded Brush		
		A10-1	A10-3	S3-1b	S3-1c	A13-1	S2-1a	S2-2
Curing time	months	3	7	4	5	7	6	9
Bulk density	g./ml.	0.11	0.10	0.20	0.23	0.16	0.21	--
Field Moist Compost: Mass-based water content	%(W/W)[a]	379.3	331.9	210.6	217.4	242.6	224.2	--
Volumetric water content	%(V/V)[b]	42.8	33.1	19.1	49.7	39.7	23.0	--
Air-filled porosity	%(V/V)[c]	41.1	52.7	47.7	12.3	33.1	42.4	--

[a]Expressed as g. of water/100 g. of oven-dry compost
[b]Expressed as ml. water/100 ml. of field-moist compost
[c]Expressed as ml. air/100 ml. of field-moist compost

Chemical Properties of Compost

Heavy metal, soluble salt and PCB analyses were performed on the compost as well as on plants grown in the compost to ascertain that none of the contaminants were at levels hazardous to human health or at levels that could inhibit plant growth (Table 3). There were no detectable levels of PCBs in the compost or the vegetables grown in the compost, and levels of all trace metals and soluble salts were within acceptable concentrations (U.S. Environmental Protection Agency 1985).

TABLE 3

Heavy metal, PCB and soluble salt properties of composts

		Compost					
		Wood Chips		Shredded Bark		Shredded Brush	
	Units	A10-1	A10-3	S3-1b	S3-1c	S2-1a	S2-2
Curing Time	months	3	7	4	5	6	9
As	ppm[a]	4.8	4.3	<25.4	<29.4	<29.1	<29.1
Cd	ppm	0.5	<0.6	<0.9	<1.0	<1.0	<1.2
Cr	ppm	3.8	5.2	7.3	8.2	11.0	15.6
Cu	ppm	16.4	16.3	9.9	10.6	14.1	15.5
Ni	ppm	1.8	<2.5	4.8	<5.3	6.3	10.7
Pb	ppm	20.9	22.5	17.0	<16.7	<11.6	23.3
Zn	ppm	862.0	122.0	306.0	464.0	100.0	75.1
PCB	ppm	<0.1	<0.1	<0.1	--	--	<0.1
Soluble Salts	mmhos/cm.	2.0	1.7	5.3	5.7	2.7	6.1

[a]µg./g. oven-dried weight of compost

Uses of Fisheries By-Products Compost

Fisheries by-products compost was tested for effects on yields of a root crop (beets), a leaf crop (cabbage) and fruit crops (tomatoes and beans). Three replicates each of a control as well as plots for application rates of 5 tons/a. and 10 tons/a. were planted in a Latin square design (SAS Institute 1982). On the relatively fertile soils of the state experimental farm, there were no significant differences in yield at these levels. Possibly, higher application rates are necessary to show growth differences in fertile soil.

Fisheries by-products compost mixtures were also tested for their value as a potting medium. Mixtures of compost, perlite and silt loam soil were prepared as a potting mix at ratios of one part compost to one part soil, two parts compost to one part perlite and a control of pure soil. Three replicates of each were watered daily with distilled water and three with a solution of 200 ppm (15-10-30) fertilizer. Rooted chrysanthemum cuttings were potted and shoot dry weight, plant height, time to flowering and number of flowers were measured.

Among the unfertilized replicates, mixtures of one part compost to one part soil showed greater shoot weight than the control, although there were no significant differences in plant height. Plants grown in both compost-soil and compost-perlite mixtures showed a significantly shorter time to flowering than the control, although there were no significant differences in numbers of flowers.

Among the fertilized samples, chrysanthemums grown in compost-soil and compost-perlite mixtures showed significantly lighter shoot weights than the control. Differences in plant height, days to flowering and numbers of flowers were not significant.

The compost was also tested for use as a seed starter. Preparations included:

Seed Starter Recipes

- four parts compost to one part sand to one part perlite (4-1-1)
- three parts compost to one part sand to one part perlite (3-1-1)
- two parts compost to one part sand to one part perlite (2-1-1)
- one part compost to one part sand to one part perlite (1-1-1)
- zero parts compost to one part sand to one part perlite (control)

Radishes were used as the test organism. The 4-1-1 mixture showed 85% emergence. Mixtures of 3-1-1 and 2-1-1 also showed approximately 85% emergence but lacked the consistency of the 4-1-1 mixture. These three preparations showed significantly greater emergence than the 1-1-1 and control mixtures. There tended to be damping off of seedlings in all mixes, with greatest damping occurring at the 4-1-1 and 1-1-1 levels.

All compost mixtures showed significantly greater germination and growth when the samples were steam sterilized. Emergence at the 4-1-1, 3-1-1 and 2-1-1 levels approached 97%. Radish shoots grown in the 3-1-1 and 2-1-1 mixes generally were taller than those grown in the 4-1-1, 1-1-1 or control mixes. The best potting mixes appear to contain 50%-60% compost and 20%-25% each of sand and perlite.

Conclusions

These studies indicate that fisheries by-products can be composted successfully, using wood as a C source. Compost macronutrient concentrations were: for N 1.3%-2.5%, for P 0.2%-1.0% and for K 0.4%-0.8%. Heavy metal and PCB concentrations in the compost were well below recommended limits for agricultural application. Heavy metal concentrations in crop tissue were below toxic levels, and PCBs were not detected in any of the crop tissues.

There were no significant differences in yield or tissue analyses of crops grown in compost treatments of 5 tons/a. and 10 tons/a. There were differences in shoot weight and time to maturity of plants grown in unfertilized potting mixes.

These results indicate that there are no harmful effects from utilizing compost made from Lake Michigan sport and commercial fisheries by-products and wood. Appropriate levels to be used in garden/field applications require further study. The compost appears to be useful in potting mixes with mineral soil and perlite, and the high germination rates indicate potential for use in sterile seed starter mixes.

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Low-Input Blue Crab By-Products Composting: A Case History

by Herbert L. Brodie and L.E. Carr, University of Maryland Department of Agricultural Engineering, and A.T. Tolley, Toddville Seafoods, Inc., Toddville, Md.

Blue crab processors in Dorchester County, Md., produce approximately 3,000 tons of blue crab by-products annually. Most processing plants produce 3-10 tons/day of blue crab by-products during the season peak. However, a significant portion of the total is generated in small amounts by a variety of home-based processors. Previously, most of the blue crab by-products were deposited in a landfill, where their intense odor was a common complaint. In 1990, the processors were facing landfill closure and the possibility of tipping fees and increased transport costs for disposal at another site. This paper describes the activities of planning, demonstration and successful adoption of a composting process as an alternative blue crab by-products treatment in Dorchester County.

Initial Steps

At the request of blue crab processors, a committee of extension, research, government and processing representatives was formed in early 1990 to investigate alternatives to landfill disposal. Aerobic composting was chosen as the treatment method most likely to succeed. The establishment of a regional composting facility, which could treat blue crab as well as other organic by-products from a multi-county area, was proposed. The start-up cost was estimated at more than $100,000. Although the possibility of a partial grant from the state existed, individual blue crab processors and the Dorchester County government were unwilling to help finance such a facility. As long as big systems and big dollars were discussed, there was no local interest in self-help.

Changing Attitudes

As an attempt to foster self-help, the alternative of small "back-of-plant" composting systems was explored with one processor during the summer of 1990. Objectives of the effort were (1) to demonstrate that the composting process was adaptable to blue crab by-products treatment and (2) to develop an acceptable composting procedure that could be adopted by small processors. An acceptable procedure required low investment, minimal operator time and skill, and minimal environmental impact. The total cost could not exceed the expected tipping fees for landfill.

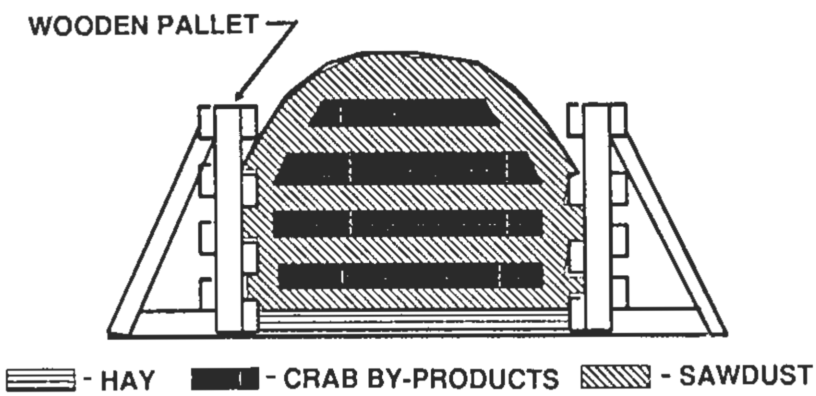
A batch system of composting was proposed. Blue crab by-products produced each day were mixed with a bulking agent and formed into a separate compost pile. Each pile was turned for aeration on a weekly schedule. After two weeks, new blue crab by-products were mixed with the old compost to control space and bulking agent investment. A schedule of one pile made and one pile turned each day was developed. A demonstration of the treatment of blue crab by-products through this short-duration, low-tech composting process resulted in a sufficiently stable product with minimal air quality problems.

A blue crab by-products and pine sawdust mixture representing the processing load from one day was batch composted in a wooden bin located outside the blue crab processing plant. Materials were handled and mixed using a small tractor front-end loader. Compost temperatures were monitored with a long stem dial thermometer. Air quality was judged by odor as perceived by the plant operator.

The site chosen for the compost bin was approximately 36 m. (120 ft.) from the processing plant. A rectangular three-walled bin was erected utilizing wooden pallets supported on edge between wooden posts (Figure 1). The inside pallet walls of the bin were lined with building paper. The unlined ground area was approximately 9 sq. m. (100 sq. ft.). A front wall was made from horizontal wood planks that could be removed for access by the front-end loader.

FIGURE 1

Compost bin



Compost Recipe

Pine sawdust was chosen as the C source for the compost recipe. Agricultural products such as hay or soybean straw cost less to procure than sawdust, but the ease of handling and storage of the sawdust made it a more desirable product. Sawdust has limited ability to provide bulking for air space in the pile. However, the blue crab shells provide initial bulking.

The proportions of blue crab by-products and sawdust required were determined from product analyses (Table 1) through the University of Maryland Department of Agronomy. Wood products have a large range of C to N ratios, which appears primarily due to the variation in N. The sawdust used for this project had a high C to N ratio.

TABLE 1

Analysis of compost ingredients

Product Parameter (wet weight basis)	Crab By-Products	Pine Sawdust	5-Wk-Old Compost
Percentage C	29.8	46.6	47.0
Percentage N	5.70	< 0.06	0.66
C to N ratio	5.2	> 750.0	71.0
Bulk density kg./cu. m. (lb./cu. ft.)	320(20)	401(25)	360(23)

A recipe of equal volumes of blue crab by-products and fresh sawdust was selected to provide simplicity of measurement using the front-end loader and to minimize the sawdust cost. The resulting 18 parts C to one part N ratio was in a range that could allow ammonia release. Odor tolerance was a subjective measurement in the demonstration.

Compost replaced sawdust in later mixes to reduce overall cost. A recipe change was necessary because the N content of the compost was greater than in the original sawdust (Table 2). Blue crab by-products were added at a ratio of two volumes of blue crab to five volumes of old compost to achieve a 20-25 parts C to one part N ratio.

Compost Process

The compost pile (pile-1) was formed in 20-cm. (8-in.) thick layers (Figure 1). The blue crab by-products and sawdust were not mixed before being placed in the pile because the time and the equipment needed for mixing were not available. Hay was used as a ground

TABLE 2

Compost mix recipes

Compost Mix (wet weight basis)	C to N Ratio 30	25	18
Sawdust to crab, by weight	3.0	2.0	1.3
Sawdust to crab, by volume	2.0	1.7	1.0
Old compost to crab, by weight	5.0	3.6	2.0
Old compost to crab, by volume	4.0	3.0	1.7

layer so that in subsequent pile turning the tractor operator could judge the bottom and not scoop soil into the compost.

Water was added to the sawdust as the pile was formed to increase moisture content. The operator had no means of measuring the amount of water necessary or the resulting moisture content but used a squeeze test. Moisture content was considered sufficient when a squeezed handful of sawdust would hold the form a compact ball without the release of water.

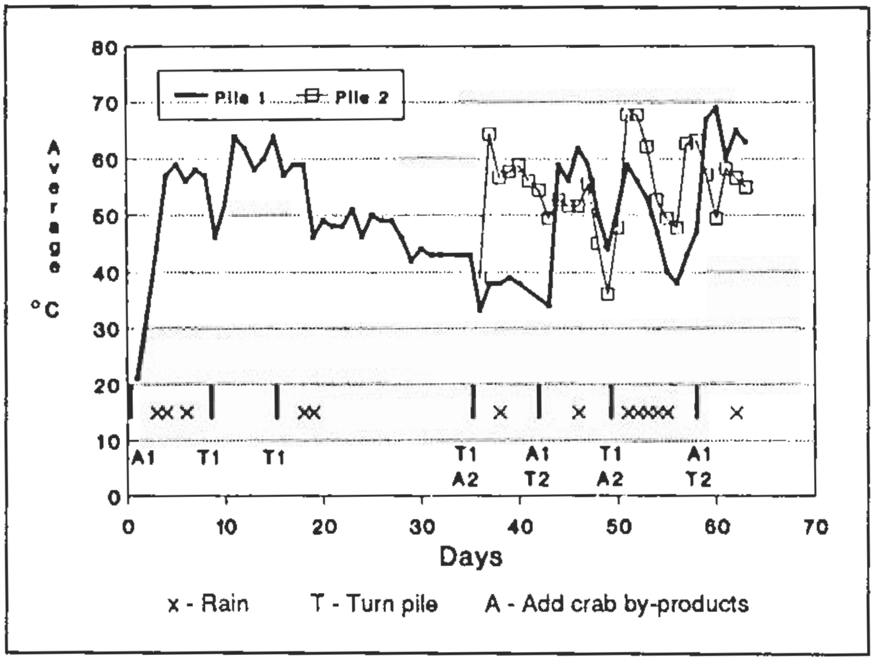
Approximately 8 cu. m. (10.5 cu. yd.) each of sawdust and blue crab by-products were used in pile-1. The initial pile contained approximately 2,560 kg. (2.8 tons) of blue crab by-products. The completed pile was covered with a tarpaulin. Within several weeks, the operator considered the tarpaulin a hinderance, and it was discarded.

Compost aeration by turning with the front-end loader was scheduled once weekly. Although only one pile was made for the first demonstration, in practice one pile would be constructed and one pile would be turned each processing day. The operations schedule followed is indicated in Figure 2.

Pile-1 was turned twice in 15 days. A shortage of labor prevented scheduled composting activities for the following 20 days. At 35 days, the pile was equally divided into two bins to allow trials using compost rather than new sawdust in the recipe and to allow the operator to develop a procedure for making a pile and turning another on the same day. Each of the two piles (pile-1 and pile-2) were turned or mixed with new blue crab by-products once each week. The procedure was continued for three weeks. The piles were then left to mature without turning for two months.

FIGURE 2

Crab by-products sawdust compost temperature and operations schedule



Demonstration Results and Discussion

Blue crab tissue in the shell was rapidly changed in the compost. The combination of heat and bacterial breakdown transformed most of the tissue within a week. Shell had begun to deteriorate to a paper-thin structure by the end of two weeks. After five weeks, most of the shell had deteriorated with only small claw ends and back shell points remaining.

Compost Temperature

The compost pile average temperature is shown in Figure 2. The maximum temperature variation within the piles was 10°C (18°F). Four days after start-up, the average pile temperature was 58°C (136°F). Temperature decline coincided with rainfall and with when the piles were opened for mixing with new blue crab by-products or for aeration. Temperature increase or recovery occurred within two days after these events. The piles were small enough that heat loss prevented the development of excessive temperatures.

Odor

There was no evidence of the putrid odor normally associated with a rotting pile of blue crab by-products. However, ammonia odor was noticeable and could have been a problem in a less remote area. The low C to N ratio of the compost mix was expected to provide some ammonia release.

Ammonia odor was evident near pile-1 five days after the starting date. By six days, the ammonia could be noticed 40 m. from the pile.

By seven days, the odor had abated but release was noticeable during the turning process. After turning, ammonia release was reduced and was not evident more than a few meters from the pile. The operator found the odor tolerable. However, the development of ammonia from multiple piles of different ages could have been more intense.

The pile was divided and the recipe changed to increase the C to N ratio when new blue crab by-products were introduced to the old compost in pile-2. The odor returned within two days but not at the intensity earlier experienced.

Previous experience with ammonia emission from broiler litter indicated that high pH could allow ammonia release. The pH of the compost exceeded 8. Reduction of ammonia release through system pH adjustment was tried. Powdered ferrous sulfate applied to the top of pile-2 to reduce surface pH resulted in a small improvement in odor control. With the next addition of blue crab by-products, odor control was achieved by adding ferrous sulfate to each layer as the pile was constructed. The quantity of ferrous sulfate applied was not measured but was enough to coat the blue crab shells with a dust. Odor was not reported as a problem after adopting this technique. One application of ferrous sulfate in this manner sufficiently buffered the system for two subsequent additions of blue crab by-products. The operator did not measure the resulting pH of the compost.

Recycling Compost

Compost was recycled into the recipe to replace purchased sawdust for three cycles. The demonstration showed no effects of a constant mix ratio of blue crab by-products and recycled compost. The C to N ratio of the recycled compost decreased with each cycle as shown in Table 3. If the C to N ratio of the compost mixture was to remain somewhat constant, then the ratio of blue crab by-products to re-

TABLE 3

Analysis of recycled compost

Product Parameter (wet weight basis)	Recycle Frequency 1	2	3
Percentage C	47	22	20
Percentage N	0.66	0.70	1.20
C to N ratio	71	31	17

cycled compost should have been decreased with each additional cycle. The addition of ferrous sulfate could have affected the response to the lowered C to N ratio of the compost mix. A three-part recipe of recycled compost, new sawdust and blue crab by-products would allow decreased sawdust use while maintaining consistent C to N ratios.

Insects

During the first week after blue crab by-products were added to a pile, fly larvae were plentiful in the surface layer of sawdust and blue crab. When the pile was turned, the larvae were moved to the hotter areas of the compost and apparently were cooked. Adult flies were not evident in numbers greater than normally found in the area. Had the pile not been turned within the seven- to 10-day fly life cycle, a fly problem could have developed.

Compost Operations

Volume-based compost recipes allowed workers to easily grasp mixing quantities with "a scoop of this and two scoops of that" instructions. A calendar-based turning schedule for small batch piles was effective. The composting process did not require knowledge of "complicated" technology or continual monitoring by the operator. Temperature measurement showed the development of biological activity in response to operations. Observing temperature changes helped maintain operator interest in the project. With time, the novelty and measurement activity could wane, but the experience was sufficient to develop an understanding of the operations scheduling required to make the composting process work.

Compost Quality

Sixty days after the last blue crab by-products had been introduced, compost, made with new blue crab by-products and old compost for three cycles, appeared as sawdust with a few shell parts and had the odor of peat. Analysis of nutrients revealed a low plant fertilizer value with a high Ca content (Table 4). Metal concentrations were well below allowable limits for application of the compost to cropland.

Economics

The value of composting blue crab by-products is dependent on many variables. These include the present and predicted cost of landfill disposal, the capital and operating costs of the composting process and the amount of returns from sale of the compost.

At the demonstration site, land and equipment were available and not considered a capital cost. Sawdust at $20/ton was a major portion of the cost but was minimized by recycling compost into the recipe. Operating costs were estimated by the operator at $6/ton of blue crab

TABLE 4

Crab by-products and sawdust composts chemical analyses

Nutrient Parameter (dry weight basis)		Compost-1	Compost-2	Compost-3
N	(%)	0.89	1.55	1.91
NH_4-N	(%)	0.03	0.41	0.26
P_2O_5	(%)	1.49	1.90	2.51
K_2O	(%)	0.30	0.44	0.26
Ca	(%)	8.64	10.7	7.79
Mg	(%)	0.42	0.64	0.91
S	(%)	0.18	0.18	0.08
Mn	(ppm)	128		128
Zn	(ppm)	75	73	
Cu	(ppm)	23	24	

Compost-1: 35 days old, sawdust mixed with crab by-products once at a total volume ratio of one part crab to one part sawdust.

Compost-2: 60 days old, compost-1 mixed with crab by-products two times at a mix volume ratio of two parts crab to five parts compost-1, resulting in a total volume ratio of 1.8 crab by-products to sawdust.

Compost-3: Composite sample of landfill compost made with pine wood chips and recycled compost. Mix ratios and recycle frequency unknown.

by-products composted. These costs included fuel, labor and sawdust procurement.

The compost bin was made from discarded wooden pallets at no cost. The processor initially considered the bin necessary and developed a plan for a roofed structure of multiple bins. However, the predicted cost was prohibitive. As more experience was gained with composting, the processor decided that simple piles on well drained soil were adequate for the process.

The market value of the compost could decrease with increased recycling through the process because of the expected accumulation of various salts. Recycling compost with new blue crab by-products reduces the total end volume of compost produced. Although recycling compost through the process reduces operating cost, potential receipts are also lost because of the lesser volume available for sale.

Compost markets were not investigated. However, the low fertilizer value eliminated any thoughts of selling the compost to farmers. Additional work is necessary to determine the value of the compost to the nursery industry.

Agronomic Response

Blue crab by-products compost was applied to field corn plots in the spring of 1991. The compost was applied to provide plant-available N at 135 kg./ha. (120 lb./a.) assuming a 50% first year mineralization rate. Preliminary yield response data from four replications indicates that the blue crab by-products compost provided an effect similar to broiler litter manure when used as a fertilizer for corn (Table 5).

TABLE 5

Preliminary corn yields, 1991

Treatment	Corn Yield, cu. m./ha. (bu./a.) no-till	conventional
Ammonium nitrate	1,749 (152)	1,897 (165)
Broiler litter manure	1,615 (141)	1,742 (151)
Crab by-products compost	1,589 (138)	1,742 (151)

Landfill Operations

In the fall of 1990, composting trials were conducted at the landfill after county officials reviewed the progress of the batch-composting work. Blue crab by-products were mixed with sawdust, one to one by volume, and placed in piles of approximately 15 cu. m. each. No water was added to the sawdust. These piles were turned for aeration with a bucket loader whenever the measured temperature exceeded 70°C (158°F). The landfill compost piles were larger and retained more heat than the processing plant piles. The average time between turnings was four days. New blue crab by-products were added every 14 days.

Odor was considered insignificant relative to that experienced with burial practices. No pH control was practiced. Most likely, the open remote area and the normal odors of the landfill prevented the ability to identify the compost piles as a single odor source.

The county landfill operator became convinced that composting blue crab by-products was a desirable practice for the landfill. He stated that composting provided better odor control and was easier on equipment than burial.

All blue crab by-products received at the two Dorchester County landfills during the 1991 season have been composted. However, sawdust has not been available in the quantities required. Wood chips, shredded wood shavings and sewage sludge compost have been used as C sources in the compost recipe. Also, maximum recycling of compost through the process has occurred. Other bulking agents and C sources such as soybean straw, corn stover, tree trimmings, residential yard waste and municipal solid waste could be used, but the county has been unable to afford the capital cost of the machinery necessary to grind these products to the particle size most advantageous for composting.

At one site, two equipment operators mixed ingredients with differing exactness. Usually, there was insufficient wood bulking stored on-site. Thus, a majority of the bulking has been recycled compost. No equipment has been made available for wetting the compost windrows. The resulting compost mix has been variable from day to day with occasional ammonia odor release.

At a second site, sewage sludge compost scheduled to become mixed with soil for intermediate landfill cover has been mixed with blue crab by-products and stockpiled. The mix ratio of blue crab and sludge compost is unknown and appears to be whatever the machine operator determined useful. Fortunately, the sewage sludge compost component has been greater than the blue crab by-products component. No analysis of the compost ingredients has occurred, and pile temperatures were occasionally monitored but not recorded. The piles have not been aerated and remain in place for a month or more before application as landfill cover material. The piles heat enough to transform tissue material in the blue crab shells. Within the mixture of odors of the landfill, there was no identifiable odor from the compost piles. Operation in this manner has allowed the county to minimize input and to count the quantity of both sewage sludge and blue crab by-products as part of the state-mandated recycling of material.

Using the compost for landfill cover eliminates the need for exacting composting procedures. There is no need for a uniform product. Metal salts, fertilizer nutrients and physical appearance are unimportant. There is no need to grind or blend to finish the compost or search for a market. The composting process only has to produce a reasonably stable product while controlling odor.

Landfill Economics

Although data were not available for analysis, county officials believe that composting at the present level of input is cost effective. Site preparation costs were minimal because composting occurred on a landfill cap. Compost required slightly less labor and equipment time than burial. Operators claimed that they preferred the compost environment and believed that composting was easier on machines, relative to burial. Labor was not needed for response to blue crab by-products odor complaints. The cost of obtaining landfill cover was reduced through replacement with compost.

Wood product for bulking was a major cost. The county has adopted a tipping fee of $10/ton of blue crab by-products as an attempt to recover this cost. The fee will help ensure that the necessary bulking is on-site when needed. Many processors will compost at home before paying the fee.

Conclusions

1) For individual processors, small pile composting of blue crab by-products is a reasonable method of stabilizing the by-products for storage until a land application site is available. Pine sawdust is a good C source for blue crab by-products compost.
2) In remote areas where ammonia odor can be tolerated, a blue crab by-products to sawdust volume mix ratio of one to one can be used. A one to two blue crab to sawdust volume ratio, the addition of ferrous sulfate and daily aeration can be used for odor control.
3) A tractor with front-end loader is required for moving material and turning the compost. A dump truck is optional. Composting can occur in open piles or in covered bins.
4) Twice-turned, two-week-old, blue crab by-products compost is sufficiently stable to store without releasing odor.
5) Blue crab by-products compost can be recycled as a C source in the composting process. C to N ratios must be maintained by blending the recycled compost with fresh C material.
6) Blue crab by-products compost is a low-grade fertilizer.
7) Low-input composting at landfills can be economical when all aspects of burial are considered.
8) Ammonia odor from compost at landfills is difficult to separately identify among the other odors of the landfill.
9) Where composting procedures are not exacting, the resulting low quality compost can be used as a landfill cover.

Composting Recreational Fisheries By-Products at Minnesota Resorts

by Dale R. Baker, University of Minnesota Sea Grant College Program; Tom Halbach, University of Minnesota Department of Soil Science, and Robert L. Stauffer, University of Minnesota Extension Service

Summary

A yearlong demonstration of composting recreational fisheries by-products at Minnesota resorts was initiated in March 1990. Five projects were carried out in four northern Minnesota counties. All of the projects included building an enclosure and using a static process to compost the by-products from fish that were recreationally caught at the resort or brought into the marina. Each of the five enclosures was built according to a different design and composts were processed with different combinations of sphagnum peat moss, wood chips and bark as the bulking agent.

Daily records of (1) temperatures of the compost piles and (2) volumes of fisheries by-products added to the compost piles were kept for each project. The piles were checked periodically for O_2 and CO_2 levels. At the end of the year, "finished" compost was tested for percentages of total N, P and K. The compost piles were also tested for PCBs and seven heavy metals. The concentrations are presented in this paper. This paper also gives recommendations to compost up to 10,000 lb./year of fisheries by-products at a northern Minnesota resort. These recommendations represent the best information available after the one-year demonstration.

During 1991, the Cass County extension director used this composting technique with 12 additional resorts in the county. There are 210 resorts in Cass County, many of them dependent on recreational fishing as an attraction to visit the resort. The county extension director has acted as a consultant to these 12 resort operators and has not been able to keep up with the demand for information on these projects. Resort owners who have used the process are now becoming volunteers to help others initiate this composting effort. The cost for resorts to build enclosures and initiate the composting effort are averaging about $300 (including the initial purchase of bulking agents). The county extension director estimates that by 1994, 100

resorts in Cass County will be using this technique to dispose of recreational fisheries by-products.

Introduction

Recreational fisheries are important to Minnesota. They provide a direct economic impact in excess of $778 million to the state annually (U.S. Fish & Wildlife Service 1989). Minnesota anglers harvest an estimated 30 million lb. of fish each year (Payer pers. com. 1991), generating at least 15 million lb. of fisheries by-products annually (Gunderson pers. com. 1991). State rules and regulations make it unlawful to dispose of fish offal in public waters, on the ice or on public lands (Minnesota Department of Natural Resources, 1991 Fishing Regulations). Waste management and reuse are major issues facing Minnesota in the 1990s. Practices commonly utilized to dispose of recreational fisheries by-products today, in many cases, will not be tolerated later in this decade.

Many resorts and marinas do not have proper facilities to dispose of fisheries by-products. Placing fisheries by-products in plastic bags and having them end up in a landfill is a common practice. Fisheries by-products are high in N and other nutrients. It is ecologically sound to have this resource recycled directly back to the land. How to do that in an aesthetic way, with minimum odors and leachate, and maintain or improve economic viability is the challenge.

Waste management has become a major issue in Minnesota in the decade of the '90s. Many smaller landfills have been closed, and costs of land filling have dramatically increased. Recycling and composting are strongly encouraged by the state. Some landfills and waste haulers will no longer accept fisheries by-products. The time is here to look at alternatives for disposing of fisheries by-products.

During the 1990 recreational fishing season in Minnesota, five demonstration projects in four northern Minnesota counties (Lake, St. Louis, Itasca and Cass) were carried out by the Sea Grant Extension Program and the Minnesota Extension Service. The resorts in these counties were considered representative of resorts that catered to recreational fishing in Minnesota. Staff members of the Minnesota Extension Service coordinated the projects for their respective counties. The type of enclosure built and types of bulking materials used differed from project to project. The information presented here is what the authors judged as the best combination of designs and ratios of materials that came out of the demonstration. In the fall of 1990, resort tours were held to show the results of these demonstration projects to the public.

Background

Composting of fisheries by-products is one way to reduce odor problems and, at the same time, effectively return organic material back into the soil. Research conducted in New York, Wisconsin and Maine (United States) and in Ottawa (Canada) has demonstrated that composting fisheries by-products can be done in those areas (Mathur et al. 1986; Frederick et al. 1989; White et al. 1989). In 1990, a demonstration project was implemented to see if this technology could be successfully adapted to Minnesota conditions.

Most organic materials can be composted successfully if some basic principles are followed. Every compost operation is unique, and site conditions are specific. Some of the benefits of composting include:

1) development of a finished product with a weight and volume reduction of 30%-40%,
2) synthesis of a stable product that can be stored and spread with greatly reduced insect (especially fly) and odor problems,
3) destruction of most pathogens because of the temperatures and other conditions that occur during processing and
4) improvement of physical properties, including more uniform particle size, lower moisture content, more friable texture (more easily broken apart in your hands) and higher bulk density over that of the starting materials.

The project was funded by Minnesota Sea Grant Extension, Minnesota Extension Service, St. Louis County, Minnesota Tourism Center and Itasca County. Technical assistance and advice also came from the Minnesota Pollution Control Agency and the Natural Resources Research Institute. The resort and marina participants were the Knife River Marina, Little Sweden Resort, Mal Bay Resort, Northland Lodge and Stoney Point Resort-Leech Lake. The authors express their appreciation to the cooperators, the county extension staff involved, the funders and the advisors.

Recommendations from Demonstration Projects

At the end of the first year of the demonstration projects, the logs from all five projects as well as the data compiled were all brought together. Fisheries by-products composting projects were also viewed in other locations. It was from the results of these projects as well as information developed in other composting efforts that the following recommendations were made, summarizing what the authors judged as the best information available on composting fisheries by-products in northern Minnesota.

Building the Compost Enclosure

The compost structure should be sited where water drains away from it. The site should be convenient to your fish-cleaning station (about

50 ft. away), 150 ft. from any shoreline and 100 ft. from any well. Surface drainage away from the compost site should not be towards a well. The site should be 100 ft. away from buildings where people are housed or work for more than four hours/day. The location should be such that all sides of the site can be mowed to keep grass short and a 20- to 30-ft. zone, free from brush and trees, can be maintained around the compost structure.

When a good site is selected, one additional option is to put down a gravel base, 1-3 in. deep, on which to build your confinement structure. However, when your site can only be located on rock without top soil, you will need at least double this gravel base in order to provide adequate surface drainage. When you install the gravel base depends upon the type of structure you build. A structure that uses posts set into the ground should have the gravel base installed after the posts have been set. For a structure without posts set into the ground, the gravel base should be installed first.

The confinement structure for fisheries by-products composting should be 5 ft. wide by 5 ft. high by 16 ft. long (can be longer or shorter, depending on fisheries by-products load). A structure of this size can handle 5,000-10,000 lb. of fisheries by-products over one summer season. It is not advised to make the structure any wider than 5 ft. Piles wider than 5 ft. can have deficient internal O_2 levels and also have shown temperatures higher than desired. Some people have found that two or more structures, of the recommended size, allow greater management flexibility.

A Permanent Structure

It is most likely advantageous to build a permanently placed structure if a location exists where the structure can be placed permanently and poles can be positioned 3-4 ft. into the ground. The permanently placed structure is somewhat easier to design and build, and it requires less building material (Table 1).

TABLE 1

Materials recommended to build and develop a permanent structure

Material	Amount Required
Gravel (optional) enough to cover area inside structure	1-3 in.
8-in. diameter fence poles (8-10 ft. long)	8 poles
2-in. by 6-in. by 8-ft. boards	24 - 32 boards
2-in. by 6-in. by 6-ft. boards	6 - 12 boards
1/2- to 1-in. mesh wire or plastic netting (5 ft. wide)	60 ft.
1/2- to 3/4-in. lightweight plastic netting (7 ft. wide)	20 ft.
8-ft. PVC drain pipe (4-in. diameter)	7 pipes
Sphagnum peat moss (4 cu. ft. bales)	50 - 60 bales
Wood chips	variable (2-4 pickup trucks)

A wooden structure made of cedar or other naturally rot-resistant lumber, or pressure-treated rot-resistant wood (using 24-32 boards that are 2-in. by 6-in. by 8-ft.; six-12 boards that are 2-in. by 6-in. by 5-ft., 6-in.; and eight-10 posts that are 8-in. diameter by 8-10 ft. long) has proven to have the strength and durability needed for this type of operation. A well built structure using these types of materials should last at least 10 years. We found that structures made of wood were aesthetically acceptable to both the resort owners and their guests.

Others have attempted to build structures of lighter weight materials. With the weight of the compost against the sides, many of these enclosures did not last even a single fishing season. The average annual cost of a structure built from durable materials will usually be lower than a flimsy structure that needs to be rebuilt every year.

There are different designs for building a permanently placed enclosure. There will be a lot of weight pushing out on the walls of the enclosure. The most common design specifies putting posts into the ground 3-4 ft. deep and nailing boards inside of the posts to create a smooth interior wall.

A Moveable Enclosure

In one demonstration a "box" type structure was built that was self-standing, without posts in the ground. These types of structures take more design work and are more expensive initially. They do have greater flexibility in that they can be moved. They also have the advantage of being more useable in areas where you have rock that makes setting posts in the ground impractical.

Expanding on the self-standing structure is the idea of 4-ft. "modular" sections that can be quickly connected and detached as needed. This makes lengthening the structure easier, if there is a need for greater composting capacity. It also makes removal of the finished compost easier, especially when using power equipment. There is a lot of opportunity for innovation in this area of structure design.

With both structural types, the interior should have a wire or plastic netting attached to it. The netting mesh size should be 0.5-1.0 in. A total of 60 ft. by 5 ft. of the netting is required to cover the inside surfaces of the structure and to make the three internal divisions necessary to build the four vertical cells of the pile. This will help keep the compost material in the structure and will also help keep birds and small animals out of the pile. Chicken wire, hardware cloth and extruded square-mesh plastic netting have all been used successfully. The netting should extend from within the gravel base to the top space between the boards.

How to Develop the Compost Pile

Once the enclosure is built, the pile can be initiated. A base layer of 4-6 in. of wood chips should be placed down within the confinement structure. Next PVC pipes, with pre-drilled holes (drainage pipes) should be installed across the pile every 2 ft. as each vertical cell is completed. The PVC pipes can be set into the wood chips. These PVC pipes are extremely important to bring air into the center of the pile. In addition to the pre-drilled holes, a 5-ft. row of 0.5-in. holes, placed every 2.5-3.5 in. on center, along the center of the pipes, can be added halfway between the pre-drilled holes to draw more air into the pile. The row of extra holes must face up.

The first 4-ft. vertical cell will require two air pipes centered and put across the pile in 2-ft. spacings. Eventually, a total of seven 4-in. diameter by 8-ft. long PVC pipes are required. These PVC pipes should be placed 2 ft. apart, lengthwise across and on top or into the wood chips, as each vertical cell is built. The ends of these PVC pipes should extend out of the structure by a little more than 1 ft. on each side. The ends of the PVC pipe can be covered with netting (held by duct tape) to prevent flies from getting into the pile, in case the compost does not heat up fast enough and flies become a problem. Wood chips should be added until the pipes are covered. Next, a 5- to 6-ft piece of wire mesh should be stretched across the pile. The wire mesh should be placed 4 ft. from the end and about 2 ft. up the sides of the structure. This netting provides the outline for the first cell. Enough netting material should be saved so that as height is built up in the first vertical cell of the compost structure, the netting can be attached to the sides of the structure before capping the first cell and building the second cell. The fisheries by-products can now be added.

The center of the pile should be filled with a mixture of one volume of fisheries by-products to two volumes of peat moss and one volume of wood chips. (Bark can be used in place of wood chips). We found that piles with some wood chips work better than those with peat moss as the sole bulking material.

There are two choices for putting the bulking material and fisheries by-products on the pile. One option is to layer the fisheries by-products and follow each layer with a layer of bulking material. The other method is to mix one volume of fisheries by-products with one volume of bulking material and then put this mixture into the center of the pile. All of the fisheries by-products must be covered by 4-6 in. of bulking material by the end of each day no matter which system you use.

The first five-10 layers of the pile should have a shovel of mature compost (mature fisheries by-products compost is ideal) or top soil added to make certain that there are sufficient microorganisms present to begin the composting process. (It was not necessary to purchase a compost "starter.") The first five-10 layers can benefit from adding a cup of 10-10-10 fertilizer uniformly spread to speed up the initial compost heating process. When the fisheries by-products/ bulking materials are a full 5 ft. high and the cell is full, it is time to "blanket" the pile. With experience, the operator could experiment with reducing the amount of bulking material.

The pile should be covered with a blanket of 4-6 in. of peat moss, followed by 4-6 in. of wood chips. This blanket is designed to absorb odors from the composting process. The piles should continue to be built by filling each vertical cell until the structure is full. Some reduction (up to 40% is possible) in volume is normal as the composting process goes on. Do not go back over the top of the pile and add fisheries by-products after a cell is completed. Once a vertical cell is completed, leave it alone for one year to let it compost.

In dry years, it could be necessary to add water to keep the pile moist enough for good composting to take place. However, in most years, this will not be necessary because the compressed bagged peat moss, wood chips and fisheries by-products combination will usually be in the correct moisture range naturally (50%-55% initial moisture by weight).

The pile should begin to heat one-three weeks after the addition of fisheries by-products to the pile (depending on outside temperatures). The temperature within the compost pile should reach a maximum of 140°-150°F and then slowly decline to where the internal pile temperature is approximately the same as the outside air temperature. The pile will stay warm well into the fall and early winter.

The piles can be left unturned and allowed to age for 12 months from the time the fisheries by-products were put into the piles until the compost is utilized. The final compost appearance can be improved by mixing the material after 12 months, to break up bones and make the mixture more homogeneous. Then, let the mixed material sit for an additional two to four weeks and use as a soil amendment or mulch.

A key to a successful fisheries by-products composting operation is to incorporate the fisheries by-products into compost piles as soon as possible, and no later than 24 hours after cleaning the fish. If the fisheries by-products are incorporated immediately into the peat moss, the odors will be noticeably reduced. If the fisheries by-products cannot be put into the compost pile within a day, they should be kept as cool (not frozen) as possible and covered with a layer of peat moss. The fisheries by-products should be put into the compost pile in such a way that fisheries by-products are not left exposed. The fisheries by-products must be covered with bulking material if the system is to work and remain "odor free" (most people will be able to smell peat moss and wood chips) so it is not an attraction to animals. The composting process should be a regular part of the fish-cleaning operation. If the composting site is conveniently located near your fish area, composting is more easily made a part of the daily operation. It is also advisable to have someone responsible for building and maintaining the pile. It is also recommended that a lightweight plastic netting be laid over the top of the enclosure. We found this discouraged birds from entering the pile.

Results of the Demonstration Project

The Finished Compost

The finished compost is the fisheries by-products, peat moss and wood chip mixture that has been composted. The exact finished compost will depend upon the materials put into the process, the environment maintained during the process and the amount of time the process is given to work. During the composting process, C and O_2 will be converted to CO_2 and some of the moisture will be lost from the pile. The finished compost will be lower in moisture content than the starting materials.

The Minnesota Pollution Control Agency (MPCA) has set standards for compost produced at a "solid waste compost facility" (Table 2). Even though backyard composting is exempt from these rules, we thought it was important to compare our fisheries by-products compost chemical analysis to the Class I compost standards. MPCA Class I compost may be distributed for unrestricted use. That means it should be safe for most uses.

Sample average percentages were 2.2% for N, 1.3% for P and 0.6% for K. Limitations of this information include that it is based on a very

TABLE 2

MPCA Class I Compost

Contaminants	Maximum Allowable Amounts (ppm)	Actual Compost Averages from the Demonstration Projects (ppm)
PCBs	1	< 0.50
Cd	10	< 0.30
Cr	1,000	3.60
Cu	500	9.70
Pb	500	11.20
Hg	5	0.03
Ni	100	2.70
Z	1,000	57.00

small sample size of eight and the concentrations could change over time as the composting process continues. It is important to note all eight of the samples taken were of higher quality than the MPCA standards for Class I compost. The samples contained less heavy metals and PCBs than what is allowable for Class I compost.

Daily records of the temperature of the compost piles as well as the volume of fisheries by-products added were kept for all of the piles. Figure 1 shows daily temperature measurements from the composting demonstration project at Stoney Point Resort in Cass County. Figure 2 shows the gallons of fisheries by-products added daily at Stoney Point Resort.

Issues Encountered in Composting Fisheries By-Products

In Minnesota, we completed a season of composting at the five demonstration sites. Because of rich abundance of peat moss and wood in the northern portion of the state, we used a combination of wood chips or bark with the peat moss. Odor control was important in all of the demonstration areas, and we found that if we used adequate volumes of peat moss that we had little or, in most cases, no problem with odors.

We found that if we used two volumes of peat moss and one volume of wood chips to one volume of fisheries by-products, odors were adequately absorbed by the peat moss. We also found that by using a bulking mixture that included one volume of wood chips with two volumes of peat moss, pore space and O_2 levels in the piles were in-

FIGURE 1

1990 fisheries by-products compost temperature curve, Stoney Point Resort, Cass County, Minn.

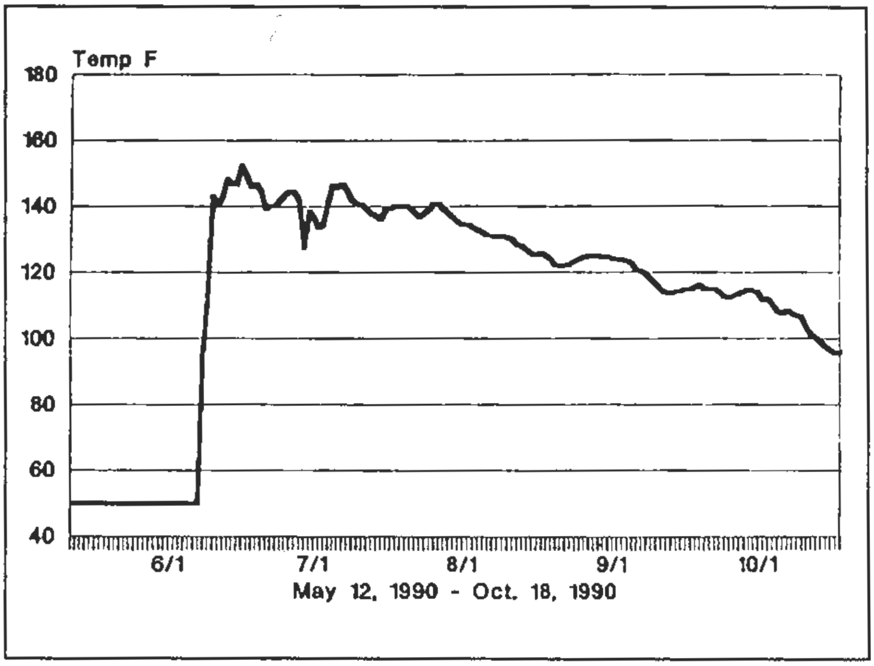
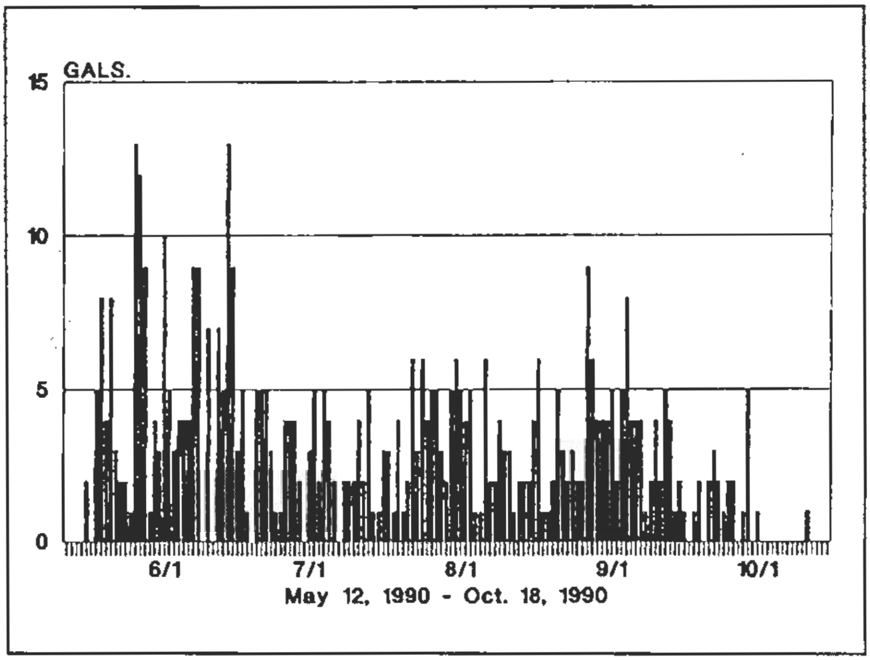


FIGURE 2

1990 fisheries by-products compost added per day, Stoney Point Resort, Cass County, Minn.



creased over corresponding measures when peat moss was the sole bulking material. In one case where we used peat moss as the sole bulking material, pore space in portions of the pile were completely water-filled after a major rainfall and O_2 levels were near zero.

We also found that when O_2 levels were below 5% within the pile, we had fly problems on the pile surface. Piles that had O_2 levels above 5.5% throughout the pile had minimal fly problems. If flies became a problem, we found that spraying with a pyrethrin-based spray was most effective.

Odors were at no time a major problem, regardless of the O_2 levels encountered. Odors were always the lowest when O_2 was in the 6%-11% range. Peak temperatures in the demonstration piles were 140°-176°F with a mean peak temperature of 151°F. When the enclosures were covered with lightweight plastic netting, no problems were encountered with birds. In uncovered piles, there were periodic problems with birds, especially where fisheries by-products were not completely covered with peat moss. In all cases, a light plastic netting stretched over the top of the enclosure took care of bird issues.

Small animal issues were encountered in some of the piles (digging on the surface and sides of the pile). To correct these problems, different modifications were made such as better coverage of the fisheries by-products with peat moss and care not to spill liquids when adding to the pile (when fisheries by-products liquids are spilled on the ground all of the wet soil should be dug out and put into the pile). A major reason for the recommendation to attach wire mesh to the inside of the enclosure is to keep small animals from digging into the pile.

In one situation, a pile was built in the area where a bear lived and had eaten fisheries by-products dumped in the area for a number of years. Once the bear found the pile, nothing could be done to discourage the animal from coming back every night, so the pile was buried. Other demonstration sites where bears crossed next to the pile were documented, and there were no problems with the bears in the compost pile. A well managed pile has odor levels so low that it will not attract bears. At two of the sites that were remote from intensive human activity, black garter snakes found the final wood chip blanket an excellent place to sun, and some nested in this layer. The snakes usually avoid the hot composting center of the pile, but they are attracted to its warmth on cool nights and in the fall. A compost pile that has regular human activity could be less likely to have snakes as guests. The snakes could startle some people but do not hurt the composting process.

All the problems we encountered with composting of fisheries by-products were resolved with better pile maintenance procedures and the addition of more peat moss with the fisheries by-products.

The Costs of Composting Fisheries By-Products

A question commonly asked is: How much will it cost me to compost fisheries by-products by this technique? There is no simple answer to this question at this time. The costs you will incur are associated with costs to build the enclosure (materials and labor) and costs to purchase the bulking agents (peat moss and wood chips). In the demonstration projects, we found individuals were innovative at getting different types of materials to build the enclosures. Most individuals will use their own labor to build the enclosures, so labor costs have not been included in the enclosure costs. You could include your own labor costs as appropriate for your situation. We found that costs for materials to build the enclosures were $163-$283 for a 5-ft. by 5-ft. by 16-ft. structure.

Once the materials were purchased and transported to the site to build the enclosure, it took two people the better part of a day to build the enclosure. After the holes were dug and the posts were placed in the ground, building the sides of the enclosure proceeded quickly. Proper planning appeared to be the key to make the job proceed quickly.

The costs for peat moss are even more variable depending on whether you buy peat moss in bulk, baled as seconds or baled retail.

The peat moss that we utilized was classified as seconds, and we picked it up from the bogs. A standard 5-ft. by 5-ft. by 16-ft. structure will require 55-65 bales (4 cu. ft. each) to start the first year's pile.

It should be clear that there are costs involved with this technique of composting fisheries by-products. Some of these are not minimal and are dependent on your ability to locate materials, your costs for labor and how expensive it is for you to get wood chips and peat moss. A ballpark estimate is that costs will be $300-$1,000, not including labor. These costs must be compared to the costs for land filling this volume of fisheries by-products. (If you haven't checked your garbage pick up costs recently, they could shock you!) The potential benefits from utilizing the compost must also be realized in making comparisons.

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Composting Fisheries By-Products: A Demonstration Project

by Richard Novak, University of North Carolina Sea Grant College Program, and Frank Hudgins, North Carolina Aquarium

Objective

The objective of this project was to demonstrate alternative containment structures and to experiment with various composting materials that could be used with fisheries by-products. By constructing the demonstration project at a public facility with heavy pedestrian use, we hoped to create public awareness of composting as well as recycling in general. The project was also a useful means to dispose of fisheries by-products generated at the North Carolina Aquarium and a small fish-cutting operation.

Project Description

The project was a cooperative effort between the North Carolina Aquarium and Sea Grant. The Aquarium provided a site for the project, personnel and mini-grant funds to buy materials.

Three 4-ft. by 8-ft. impoundment structures constructed of different materials were located just south of the Aquarium. One was constructed of wood, one of galvanized chicken wire and cedar lattice, and one of welded link fencing. A variety of construction materials were used to determine how well each would work and to make the site more aesthetically pleasing.

Each impoundment had a different compost mixture. The first was a combination of cornstalks and fisheries by-products. The second was peat moss and fisheries by-products, and the third was wood chips, peat moss and fisheries by-products.

Results

Over the three years of working with the project, we have learned a variety of "lessons" related to odor and pest control, and there are now several small fisheries by-products composting sites in the area.

Calico Scallop By-Products Composting: Brevard County Style

by William T. Mahan, Jr., Florida Sea Grant Extension Program

In 1988, the Florida Legislature passed the Solid Waste Act, which mandated major statewide changes in solid waste management practices. As part of the act, Brevard County was identified as one of five counties eligible to receive state funding to design and develop demonstration projects to find acceptable alternatives to burying seafood-processing by-products at public landfills.

As a result of this legislation, the Florida Sea Grant College Program received a contract from the Florida Department of Environmental Regulation in 1989 to investigate the feasibility of composting calico scallop and blue crab by-products as an alternative to land filling. Working with consultants from the Woods End Research Laboratory in Mount Vernon, Maine, Florida Sea Grant conducted a calico scallop viscera composting demonstration project at the Brevard County landfill in Cocoa, Fla.

Brevard County was chosen as a demonstration site because of the calico scallop viscera disposal problems that were encountered by landfill operators. These problems primarily involved odor control and the additional costs incurred by the county from the use of chemicals, extra soil and the additional labor to handle and bury the material quickly. These problems came to a peak during the years of 1987 and 1988 when, according to 1988 landfill records (the first full year records were kept on calico scallop), the county processed 3,586 loads of viscera totaling 43,032 tons.

However, since that time, the local calico scallop industry has collapsed. What had been a seven-day-a-week, year-round operation has been reduced to a late fall through winter fishery that operates on an almost day-to-day basis. The exact reason for the collapse is not known. However, bottom water temperatures, which have been monitored since 1983, increased in 1988 and have remained elevated since that time. Coinciding with this temperature change has been the appearance of a parasite that interferes with the calico scallop reproduction cycle and has killed a high percentage of adult calico scallop in a number of beds located off the Brevard County coast.

As a result of the current unpredictable nature of the calico scallop harvest and the sporadic operation of the processing plants, several problems were encountered during the compost demonstration project. The major problem proved to be the lack of calico scallop viscera during the two-month compost production phase of the project. Although the demonstration began in January, normally a peak harvest period, only 96 tons of calico scallop viscera and by-catch were available before the processing plant closed. This, coupled with not knowing when or how much calico scallop viscera would be sent to the landfill each day, made planning and formulating a compost recipe challenging.

An additional problem that occurred was the result of the large amount of calico scallop, and conch and whelk shells and fragments, that were mixed into the last loads of viscera from the processing plant. As a result, the compost from the windrows that received these last few loads contained a large amount of shell that required screening to remove. Also, the large whelk shells that avoided detection and removal from the viscera, once mixed into the windrows, proved to be hazardous to several of the SCAT's tires.

Although none of the problems proved to be fatal to the project, they did point out potential problem areas that will need to be considered if a future, full-scale calico scallop viscera composting program is to continue in the county.

Overall, Brevard County landfill officials were impressed with the results of the demonstration project. In fact, the county's Solid Waste Management Department would like to continue to compost the calico scallop viscera and by-catch by incorporating them into a planned yard trimming, mulch and compost operation that is scheduled to begin by the end of 1992. If this is the case, the current limited calico scallop harvesting season could prove to be a blessing in disguise for the landfill operators. With calico scallop being processed during a four- to five-month period each year, the county will only need to plan for a short calico scallop viscera compost production period and can allow the rest of the year for the compost to cure.

Currently, seven potential uses for the compost as a soil amendment have been identified in the county, and demonstrations have begun or are being planned. The uses are: turf/sod farms, pasture lands, vegetable garden/farms, lawn dressing, roadside median strip wildflower displays, ornamentals/potting soil and citrus.

Calico Scallop Viscera
Compost Recipe

- 1,200 cu. yd. of pine chips, bark and shredded tree trimmings
- 100 cu. yd. of cypress sawdust
- 96 tons of calico scallop viscera and by-catch
- 32 tons of red algae
- 24 tons of citrus
- 14 tons of horse manure
- 8 tons of water hyacinth

AND MIX WELL!

Composting Lake Erie Recreational Fisheries By-Products on an Island

by Reggie Langford, Ohio Department of Natural Resources

In the western basin of Lake Erie are a group of islands known as the Bass Islands. The most popular of these is South Bass Island. Measuring 3 mi. long by 1 mi. wide, this island caters to the tourist trade for income, the same as Mackinaw Island in Michigan. The island, which has a permanent resident population of 400, can host more than 10,000 people on a peak summer day. The average yearly visitor attendance can total 500,000.

Various recreational activities abound on South Bass Island for all ages: boating, swimming, camping, sightseeing, nightly entertainment and fishing. Fishing in the western basin of Lake Erie is one of the most popular income-producing activities. Millions of dollars are spent on the Lake Erie islands just in the pursuit of catching fish. Tons and tons of fish are caught and cleaned in and around the islands each season. The most popular species are walleye and perch.

Of all the rental cottages (70), camping areas (two) and numerous private homes on the island, approximately 50% have fish-cleaning facilities. These range from single tables to elaborate cleaning stations, such as the facility at the South Bass State Park campgrounds.

Tons of fish offal have been deposited at the local landfill on the island in large ground pits. Each time a pit was filled, another was dug. This method was not the best way to solve the problem. Nauseous odors, flies and rodents were always present — plus, when you dug another pit, invariably you dug into a previously full pit of half-decayed fish.

PROBLEM: **Lack of adequate dumping space, odor, rodents, flies and rancid liquid entering into the subsoil and then into underground aquifers that supply water to the many residents with wells.**

SOLUTION: **Fisheries by-products composting.**

Having attended a seminar on a new system being developed in the states of Wisconsin and New York on fisheries by-products composting, I decided to develop this system in the state park on South Bass Island.

Not being totally satisfied that composting would work without odors, leaching and the problem with rodents, I decided to contact island officials and try this system at the landfill, where space and odors were no problem.

Ironically, the officials were in the process of buying a wood chipper for composting fisheries by-products, but no one knew how to set up the system. Realizing we all had a problem with fisheries by-products, I agreed to help them institute a compost operation.

Following the guidelines in Frederick et al. (1989) and White et al. (1989), we started our compost operation one week prior to Memorial Day. Wood chips were supplied from the mainland via the state park packer truck. Once a week, we made a trip from the mainland to the park to haul refuse. So, when we went over, the packer was loaded with wood chips to be deposited at the landfill. Then, we returned to the mainland with the truck full of park refuse. Therefore, there was no extra expense for procurement of bulk material delivery.

Having no idea what size windrow would be needed, we started one that was 8 ft. wide by 50 ft. long. If this did not fit our needs, we would build another one right alongside the first. When the base layer of wood chips was down, we were ready for our first batch of fisheries by-products. Participants using the compost operation were to spread their own fisheries by-products on the windrow, and the landfill employees placed the wood chips on top.

There was skepticism at first among the authorities regarding the problems of odors and liquids leaching into the aquifers, but doubts soon changed after the first few layers of fisheries by-products were applied and the compost started to take shape. Now, those comments are nothing but positive. Before the summer was half completed, people wanted to buy the material for their gardens.

Throughout the summer, I monitored the compost for temperature and moisture content. The highest temperature reading was 162°F, with the mean temperature around 140°F. Lack of rain and moisture from the fisheries by-products presented problems with maintaining a moist compost, so the landfill employees would hose down the windrow.

Flies, along with maggots, presented the biggest problem. It seems the maggots were removing the fish flesh faster than the bacteria. What maggots ventured outside the pile were consumed by birds.

As per the guidelines on layering the wood chips 4 in. to 6 in. thick, we layered only 2-5 in. and still maintained our final results. At the present time, we have one windrow that measures 8 ft. wide by 50 ft. long by 4 ft. high. The compost in this windrow will be the starter for next year's compost. A chemical analysis was not taken to see if the compost contains Hg, nitrates or any other harmful agents, but one will be conducted.

In summary, the composting of fisheries by-products solved a long-standing problem, on an island that is concerned with protecting its natural resources while maintaining a recreational base for visitors and year-round residents.

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Composting Sport and Commercial Fisheries By-Products in Michigan

by Walter J. Hoagman, Michigan Sea Grant College Program

Introduction

Composting leaf and vegetable waste is a common practice throughout the United States and the world. An inorganic fertilizer is usually necessary to supply base chemicals for the fungi and microbes to decompose the organic base. Internal aeration is achieved by diffusion and frequent turning. The end product becomes a useful additive to all types of soils, while providing slow release nutrients to plants.

Fish and fish offal have a long history of being effective fertilizers, but mechanisms for wide-scale usage have been limited by availability, packaging problems, application constraints and inappropriate methods of handling. Typically, whole fish parts buried in a garden are dug up by rodents or other animals within days. Often they anaerobically decompose, creating offending stenches.

Blending the natural process of composting with fisheries by-products solves many local problems of waste disposal and creates a useful product, which has market potential. In many situations, the com-poster can eliminate the entire costs of fisheries by-products disposal, utilize that savings to pay labor and related costs of composting, then sell the end product. Our two fisheries by-products composting projects in Michigan have prevented approximately 200,000 lb. of fisheries by-products from entering the waste stream in two years.

The Michigan Experience

Many years ago, laws were passed that prevented cleaning of fish "at sea." This prevented the commercial and sport fishers of the Great Lakes from processing their catch en route to port. For the sport fishery, fish-cleaning stations were established at hundreds of ports. The fisheries by-products was either ground up and added to the local sewage load, or picked up for landfill disposal. Commercial fisheries contracted waste haulers, with the fisheries by-products discarded at landfills. A few operations began land application of their by-products through special permit.

Subsequently, the entire system of landfill regulations and waste stream requirements was stiffened. This resulted in hundreds of landfills closing and tipping costs escalating at the remainder. For the fisheries by-products producer, the squeeze was on.

Techniques to compost fisheries by-products date back to the 1960s and 1970s when Canada and states of the northeast United States began experimenting with sawdust and peat moss as the bulking agent. New York and Minnesota Sea Grants have developed small-scale fisheries by-products composting, using peat moss and aeration pipes, for operations that have a few buckets of fisheries by-products a day. These procedures were successful, but a bulking agent with greater porosity was necessary to eliminate frequent turning and complicated internal aeration devices. Wisconsin Sea Grant (Frederick et al. 1989) developed the technique of using chipped brush as the bulking agent and demonstrated that the end product was a useful growing medium. The process helped eliminate the fisheries by-products disposal problems of several commercial operations there.

We decided to try composting large salmon carcasses in Harrisville, Mich., utilizing chipped brush donated by Consumers Power Company. A second pilot project was begun in Rogers City, Mich., using whitefish by-products and wood chips purchased from a wood-fired generating station. Two cooperating composters were identified, and they agreed to handle the operations.

Results

The Harrisville project mixed salmon carcasses and chipped brush in a 1 to 4 ratio (by volume) on an 8-in. layer of pure chips, covered by 8-10 in. of pure chips. The end ratio of fish to chips thus became 1 to 10, when thoroughly mixed after the initial decomposition. The project was started in mid-fall, with outside temperature falling to 0°F soon after. Internal temperature of the windrow was monitored on a daily basis for the first eight weeks (Table 1).

Internal pile temperatures climbed to around 145°F and stayed there during the composting cycle. This is the desired range; lower temperatures retard decomposition, and higher temperatures kill off the necessary micro-organisms. After eight weeks, the internal temperature remained 80°-90°F, while snow covered the entire pile except for a small area at the apex.

Upon opening the pile for inspection (after eight weeks), we found complete decomposition of the salmon parts. All that remained were scattered vertebrae. The internal temperature was 80°F, while the

TABLE 1

Average weekly temperature of fisheries by-products compost pile (internal) compared to air, in °F

Week Number	Daytime Air Temperature (1)	Daytime Pile Temperature
1	71	95
2	43	131
3	45	142
4	31	133 (2)
5	34	146
6	26	124
7	22	98
8	20	83

(1) Subtract approximately 20°-30°F for overnight temperatures

(2) 6 in. of cover chips were added to topside of pile after this week

Note: Maximum pile temperature recorded was 158°F.

outside temperature had fallen to -10°F the previous night. Direct olfactory examination of various portions revealed only a slight fishy smell. Overall, the odor was very similar to a rotted stump, like humus. Offensive odor or leachate was not a problem.

The Harrisville pilot project was expanded to receive approximately 30,000 lb. of fisheries by-products in 1990 and 1991, which accounted for nearly the entire waste load generated by this small sport-fishing town. Chipped brush became difficult to obtain in quantity, so the composter began recycling the compost with new fisheries by-products. Again the process continued normally.

In Rogers City, the Department of Natural Resources required the composter to construct a concrete slab, 110 ft. long by 12 ft. wide, to serve as a composting platform. The wood chips used were approximately two to four times the size used in Harrisville. Whitefish remains were mixed with chips, 1 to 4 by volume, placed on a base layer of pure chips and covered with an 8-in. layer of pure chips. The windrow was added to over the summer and fall.

After six to eight weeks, the whitefish fisheries by-products had disappeared like the salmon fisheries by-products. Subsequent inspection of the chip windrow showed the larger chips take much longer to break down than chipped brush. This project handled approximately 70,000 lb. of fisheries by-products in 1990 and an equivalent amount in 1991. The wood chips began to break down the second year but were still adequate for a second and third cycle of fisheries by-products composting through 1991.

Additional fertilizer was not added at either site nor were the piles watered. After the first eight weeks, the entire windrow could have been scooped up and formed into a conical pile for final decomposition. When the bulking agent became decomposed so it felt soft in the hand, a hammermill shredder (or equivalent) was necessary to make a suitable soil additive. Small animals, crows and black bears can be attracted to fisheries by-products compost operations, thus various exclusion devices can be necessary. We needed to construct an electric fence to discourage bears from sleeping in the warm windrow. A slated snow fence was used to cover the windrow to keep crows and vultures from digging out fisheries by-products pieces.

In both operations, the weight and volume of the materials required the use of light-duty handling equipment. Front-end loaders and mixers of commercial size would be necessary for any major operation. The piles or windrows were not aerated mechanically during the composting cycle.

Conclusions and Discussion

The composting process of chipped brush mixed with unground fisheries by-products gives an organic soil additive after approximately 18 months. If wood chips are used, two or three years are necessary for complete composting before shredding. The woody materials can be used for two or three cycles of fisheries by-products. Based on the Wisconsin experience, where fisheries by-products compost sold well alongside regular compost at several test outlets, we are confident our initial product can be marketed. Fisheries by-products composting has the potential to solve a problem intractable by other methods and can save the fisheries by-products producer considerable money.

For fisheries by-products amounts above 10,000-15,000 lb., pick-and-shovel mixing, turning, handling, etc., is best replaced by mechanical handling equipment. A smooth base (concrete or asphalt) for the operation facilitates mechanical handling and allows a cleaner operation overall. The final product should be shredded and aerated to a nearly dry state before packaging in plastic bags.

The potential to expand fisheries by-products composting in Michigan is very high. The commercial fishery lands approximately 16 million lb./year. The sport fishery is made up of 1.2 million resident and 0.4 million non-resident anglers, who typically land 18 million to 25 million lb./year (Table 2). Since the edible portion of most fish ranges only

35%-45% of the total weight, approximately 21 million to 24 million lb. of fisheries by-products are discarded annually in Michigan.

These fisheries by-products could be composted in small backyard sites, incorporated with municipal leaf composting operations and composted on-site at the commercial processing facilities. Currently, fisheries by-products are added to the sewage load via garbage disposals, incorporated in the waste stream bound for landfills and, in a few situations, mixed directly into farm soils. If only half of the total waste could be composted, 11 million lb. of fisheries by-products would be diverted from the waste stream and would result in an equivalent value of several million dollars of soil additives returned to the land. A further benefit would be the overall reduction in manufacturing, transportation and usage of processed inorganic fertilizers.

TABLE 2

Estimated catch of the major sport species from all Great Lakes waters of Michigan and seven tributaries(1)

(Data from Lake St. Clair not included)

Number by Species (thousands)

Year	Perch	Walleye	Chinook Salmon	Lake Trout	Rainbow Trout	Coho Salmon	Brown Trout
1988/89(2)	5,509	2,181	332	237	92	71	28
1987/88(2)	7,330	1,133	523	200	95	166	41
Avg. no.	4,100	1,657	428	219	94	119	35
Avg. wt.(3) (lb.)	.25	2.4	11.4	5.4	6.4	4.6	4.9
Total (lb.)	1,605	3,977	4,879	1,183	602	547	172

Grand Total Weight = 12,965,000 lb.
(plus 2 million-4 million lb. for all other species and 5 million-8 million lb. from the inland sport fishery)

(1) Data summarized from Rakoczy and Rogers (1988 and 1990)

(2) Sample year is April 1 to March 31

(3) Lake Michigan and Lake Huron mean weight average

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Fish Liquefaction

by David A. Stuiber, University of Wisconsin
Sea Grant Advisory Services

Abstract

The liquefaction of fish is a relatively straightforward procedure. The intended degree and rate of liquefaction can be regulated by creating an appropriate environment in which natural digestive processes take place. As is the case with handling and processing of any fishery material, liquified fish product quality will depend upon the nature of starting raw material and the intended end use of the liquified material.

This presentation deals with a study designed to develop a process that utilized fisheries by-products culminating in a liquid fish fertilizer product. Results of the study indicated that fisheries by-products can be converted into a liquified material in a time frame of as little as 12 hours. The liquid material obtained from the process was found to be shelf stable as a result of acid addition, and the integrity of the product maintained for periods of two or more years.

Introduction

Procedures for producing liquefied fishery products have been available and used for centuries. A good example of such a process is the commercial process used to produce a Thai fish sauce (Nampla), which has changed little throughout the years. The Thai fish sauce process involves heavily salting fresh, whole fish and allowing the fish to naturally digest over a period of six months to a year (Beddows and Ardeshir 1979; Chayovan et al. 1983). There are any number of process variations one can use to liquify fish, and each process will depend upon the product's end use. For example, one fish liquefaction procedure has been developed to produce animal feed ingredient products such as fish silage (*Fishery Products of Commerce — Fish Ensilage* 1964; Green et al. 1974; Krishnaswamy et al. 1965; McBride et al. 1961) and another for plant food products such as fish emulsions.

Regardless of the process or the intended end use of the liquid fish product, all processes basically result in the reduction of fish proteins into a mixture of polypeptides, free amino acids and other N-containing compounds with the concurrent release of water. The final result is the conversion of the solid starting material to fluid.

In almost every case, the principal agents promoting digestion are the functioning, naturally occurring enzymes already present in the system (Hale 1969). The rate and degree of digestion can be altered or assisted by the addition of non-native enzymes, modifying system pH through additions of either acid or alkali, or raising or lowering temperature (Hale 1974; Mohanty and Ray 1955).

The University of Wisconsin became involved in fish liquefaction in the early 1970s when the U.S. Environmental Protection Agency established new restrictions on disposal of certain types of processing wastes in sanitary landfill sites. Fisheries by-products were among the items that appeared on the restricted list, which caused disposal problems for fish processors in the state. As a result, a project dealing with fisheries by-products utilization was initiated and funded as part of a joint effort by the University of Wisconsin Sea Grant Institute and the Upper Great Lakes Regional Commission (Stuiber et al. 1976).

Fisheries by-products treatment and processing posed some interesting questions to project researchers. Points to ponder included such things as the nature of the starting raw material, quantities of material requiring processing, the time element and its effect upon processing the material, and the potential marketability of an end product produced from fisheries by-products.

Several limiting factors helped sharpen project focus and establish process priorities. The main project objective was to consider development of a method that would effectively deal with varying quantities of fisheries by-products generated during a normal working day (approximately 1,500-4,000 lb./day for plants in Wisconsin). The 24-hour time restriction within which to process fisheries by-products was based upon limited cooler and freezing facilities available for storage in most of our smaller fish-processing units in the region and upon the rapidity with which off-odors and spoilage develop in fisheries by-products held for extended periods. The holding of fisheries by-products for periods longer than 24 hours, particularly during the warm months of summer, can also result in localized bacterial build-up, development of unsanitary conditions and potential health hazard situations within a processing facility.

Acid has been shown to increase the enzyme reaction rate of digestive fish tissue enzymes (*Fishery Products of Commerce — Fish Ensilage* 1964). After weighing options and the potential of various utilization procedures, we settled upon the acid-assisted fish liquefaction procedure as being the better method to pursue in solving the problem. The acid selected for the procedure was technical grade phosphoric acid. Phosphoric acid was chosen because analysis of the base fisheries by-products indicated that P concentrations was relatively low. Thus, phosphoric acid would not only serve to lower mix pH and speed up the enzymatic digestion process but would also help raise the final P level of the product.

Mix acidification provides several other benefits in addition to enhancement of enzymatic activity. Acid action aids in the softening and dissolving of bone particles in the mix. Another benefit is the reduction or elimination of bacterial growth in the mix. Low pH levels (less than 3.5) aid in preservation and stabilization of the mix. Fisheries by-products contain large bacterial loads. If bacteria were allowed to grow, they would produce undesirable off-odors and gas, both of which cause problems with storage and marketing of the product.

Odor is an important factor to be considered when producing a fertilizer product. The odor associated with a liquid fish product will depend upon the condition of the starting material. Odors generated during fish spoilage are offensive, tend to be very persistent and are difficult to mask. If the starting material is reasonably fresh and free of off-odors, a slight fishy aroma is observed during the initial stages of digestion. As the process continues, a malty, slightly oxidized fish-oil aroma combination develops and remains with the product throughout the digestion process. This odor will persist for at least six months.

If the starting material has begun to break down, putrefactive odors and other offensive aroma compounds associated with decomposing fish will be apparent. This odor profile will remain with the product throughout the remainder of its existence. If the off-odors are not too pronounced, it is possible to successfully mask them by adding perfume-like odor compounds. However, such additions add an additional cost to production and might not be effective. It is therefore to one's advantage to ensure that spoilage and decomposition of the material be controlled, not only during processing but also during storage.

The Process

The University of Wisconsin fish liquefaction and fertilizer manufacturing process consists of a combination of specific steps:

1. Particle size reduction (grinding)
2. Acid addition (lowering pH)
3. Digestion (aided via agitation and heat)
4. Screening (removal of undigested bone particles)

5. Product standardization (producing a constant, guaranteed analysis)
6. Storage (large bulk tank storage or warehousing of bottled product)

Grinding

The grinding step is necessary to reduce fisheries by-products such as bony frames, scrap fish, offal and fish trimmings to a uniform semi-solid mass of approximately similar particle size. This allows for ease of mixing and blending of additives such as acid, and uniform heat transfer in the mix during the digestion step. It was observed during the study that the smaller the particle size, the more rapid and efficient the digestion process.

Particle reduction (grinding) was accomplished using a Hobart food chopper, Style 201, equipped with a 3/4-horsepower motor and a Number 12 size head. Because of the nature of the fisheries by-products being ground, there was a tendency for bone chips, scales and fish skin particles to plug holes in the grinder plate. This resulted in frequent stoppages in processing to clean and remove impediments from the small diameter holes in the grinder plate. Downtime was reduced when the grinding head was fitted with a grinder plate having 1/4-in. holes. As a result, it was recommended that a grinder plate having holes 1/4-in. in diameter or the next size larger be used for particle size reduction. The use of these grinder plates resulted in less down time to disassemble, clean and reassemble the grinder, yet produced a small enough particle to complete the digestion within the time allotted for the process.

It was also observed that fish skins from larger fish such as lake trout and salmon were difficult to chop and force through the grinder plate. This problem can be partially overcome by partial freezing before grinding. If frozen fisheries by-products are to be used, they should be tempered prior to grinding. Complete thawing will result in drip (water loss), and water may have to be added to produce a readily stirred, semifluid mass capable of being handled by the equipment. The main recommendation was that fisheries by-products be used as soon as they become available rather than freezing them for use at a later time.

Acid Addition

The semisolid mass obtained from the grinding step was acidified at a rate of 6.96 lb. of 85% phosphoric acid or 7.96 lb. of 75% phosphoric acid per 100 lb. of ground fisheries by-products. The reason for the two acid figures was to allow a processor to take advantage of the prices of acid when one form was less expensive than the other. Adding the amount of acid indicated should provide approximately a

4% P level in the finished product and reduce the pH of the mix to 4.0 or lower.

The added acid is thoroughly mixed into the mass by stirring with a mechanical agitating device or by hand-mixing with a paddle. If the primary method of mixing is to be accomplished by means of a recirculating pump, one could find the particularly solid batch of flesh difficult to move via a pump at this stage of digestion. It will take about 45 minutes to one hour into the digestion process before the material can be effectively pumped. A more fluid beginning mix capable of being moved via a pump can be obtained if a quantity of previously liquified fisheries by-products is added and mixed into the initial ground fisheries by-products mass in the digestion vessel.

Sizing the Digestion Tank

To size a tank for use in the digestion process, the following points should be taken into consideration:

1) Approximately 10 lb. of fisheries by-products will occupy approximately 1 gal. of tank volume.

2) The tank selected should be capable of handling the quantity of fisheries by-products generated during any 24-hour fish-processing period plus a reasonable percentage safety margin for periods of flush processing activity.

Digestion

After mixing the appropriate amount of acid into the ground fisheries by-products, the temperature of the digesting mixture is raised to 140°F and maintained throughout the digestion period. The temperature at which the digestion is allowed to proceed will have a marked effect upon the digestion rate. Digestion rate experiments were conducted at temperatures ranging from 100°-140°F. Using the digestion rate observed at 140°F as the standard digestion, we found processing times to range from 96 hours at 100°F to 12 hours at 140°F. It was also observed that digesting the mix at temperatures above 140°F should be avoided due to the risk of denaturing (inactivating or destroying) the digestive enzymes in the macerated fish mixture.

It is also important to make sure that the mixture in agitated and thoroughly mixed during the digestion process. This is especially true for the first few hours of the procedure. A lack of agitation and mixing leads to settling of the material to the bottom of the tank and results in putrefaction and incomplete digestion of a portion of the material.

Screening

The liquid obtained from the digestion processing step is screened to remove the larger undigested bone particles. Screening is accomplished by passing the digest through a mesh screen. It was found that some of the larger bone fragments produced from fractured vertebrae and bones from fish heads, particularly carp heads, had a tendency to persist in the digest after the initial 12-hour digestion period. Extending the digestion period beyond the recommended 12-hour time frame could result in complete digestion of bone. However, since this particular process was designed to accommodate fisheries by-products generated daily during normal fish handling and filleting operations, extending the process time to digest large bone particles was dropped from consideration.

The bone digestion problem solves itself when the fish digest is pumped into storage and held for two or three weeks. During the holding period, digestion continues and the large bone fragments digest. If the material is to be put into bulk storage for any length of time, it could be possible to eliminate the screening procedure.

Standardization

After the 12-hour digestion period, standardizing materials (urea, potash, more acid) were added directly to the digestion tank and mixed for a half hour to dissolve and distribute them throughout the mix. By law, a fertilizer product must carry a minimum quality guarantee for N, P and K on the product label. To ensure that indicated labeled amounts of intended plant nutrients N, P and K are present in the product, a fertilizer producer can supplement the mixture with N-, P- and K-containing compounds. The use of appropriate chemical compound additions enables a producer to obtain specified N, P and K levels in the product. A partial listing of N, P and K sources is given in Table 1.

TABLE 1

Partial listing of chemicals commonly used as fertiizer supplements

Essential Nutrient	Chemicals
N	ammonium nitrate, anhydrous ammonia, organic materials, ammonium sulfate, sodium nitrate, ammonium nitrate-limestone, urea, calcium nitrate, calcium cyanide
P	ordinary superphosphate, triple superphosphate, ammonium phosphates, phosphoric acid
potash	mine run (muriate) salts, muriate of potash, sulfate of potash, sulfate of potash magnesia, potassium nitrate, potassium hydroxide, potassium carbonate and bicarbonate, potassium metaphosphate

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Discussion Session on Compost Regulation

by David G. White, New York Sea Grant Extension Program

Participants in this discussion session examined the regulation of fisheries by-products composts and composting operations from both the regulator's and the composter's points of view. Although every state has different regulations and classifications, common elements could be incorporated into model legislation.

First considered was the composting process. Many communities regulate yard-waste composting. Because fisheries by-products are an amendment to yard waste, composting sites that use fisheries by-products are regulated under industrial-waste or landfilling criteria. Also, wood chips are considered yard waste, while sawdust is considered industrial waste, and different guidelines apply. Some states consider fisheries by-products to be food-processing wastes.

From a regulator's viewpoint, composting *process requirements comprise three categories:*

1. The composting operation should not be a nuisance.

   The composting operation should be free of noxious odors, visually attractive and/or appropriately bermed.

2. The composting operation should not affect surface or ground waters.

   Some states require impermeable padding; others require leachate assessment, soil analyses, and surface- and ground-water monitoring. Some states require monitoring nitrates and coliform bacteria only; others require monitoring a full spectrum of nutrients, trace elements and heavy metals.

3. The compost should not contain unacceptable levels of contaminants.

   Composting should not contaminate surrounding soils or waters beyond their normal background levels. However, continued full spectrum analyses for heavy metals, PCBs, dioxins, furans, other contaminants, nutrients and trace elements are costly. Also, a monitoring interval must be determined.

The group concurred that model legislation would cover siting, safeguards to soil and water, odor control and appearance. Composting operations could be divided by size (less than 50 cubic yards or more than 500 cubic yards, for example). Permits based on windrow dimensions, cubic yards per acre and soil type would be particularly useful if developed by composters, researchers and regulators cooperatively.

Also considered were compost quality and use. All states have standards distinguishing between fertilizers and soil amendments (composts). Departments of agriculture usually require the listing of ingredients and substantiation of claims on product labels. Beyond these requirements, departments of natural resources or environmental regulation have various restrictions on compost use related to contaminants. In most instances, restrictions developed for sewage sludge composts also apply to fisheries by-products composts. In some instances, PCB levels from fisheries by-products restrict the compost use to non-food applications, and the packaged compost must be labelled accordingly. Likewise, heavy metal contamination from pressure-treated wood chips or sawdust can restrict the compost use. However, compost quality concerns are usually met by proper labelling.

Agricultural Uses of Sea Urchin Shell and Viscera

by Bruce Wyatt, California Cooperative Extension
Sea Grant Marine Advisory Program

The agricultural uses of sea urchin fisheries by-products are being investigated in Sonoma County, Calif. They are as follows:

- Direct land application
- Composting and land application
- Hydrolysis of the liquid sea urchin material

Land applications of shells and viscera on forage crops (clover and rye) showed that a 30% increase in production could be obtained by adding up to 32 tons/a. of sea urchin fisheries by-products. There was a steady increase in production from applications of 2, 4, 8, 16 and 32 tons/a.

Sea urchin shells and viscera are composted at the IROC Company. The liquid part of sea urchins, from the processing floor and tables, is dumped on a bed of sawdust in the hauling truck, and the shells are loaded on top of this mixture for delivery. Shells and liquid are unloaded and covered with semidry manure solids from a manure separator.

Composting continues until the pile cools. Odor and flies are kept to a minimum. No problems have been encountered after 30 days of this operation. Field trials are planned to determine crop responses to the product.

Sea urchin viscera and body fluids are hydrolyzed in yet another project. Phosphoric acid is added to the urchin fluid until a pH of 3.0-4.0 is obtained. The product is stored in plastic pails and can be used in two weeks. This product can be used as a foliar spray or top dressing (sprayed on the ground) for growing plants. Early trials on house plants indicate that sea urchin hydrolysate could be used as an all-purpose house plant fertilizer. Further tests are needed to substantiate this.

Nutrients of Fisheries By-Products and Their Potential Use in Feed and Compost Formulations

by Fereidoon Shahidi, Memorial University of Newfoundland
Department of Biochemistry

Abstract

By-products of cod (*Gadus morhua*), queen crab (*Chionoecetus opilio*) and pink shrimp (*Pandalus borealis*) were studied with regard to chemical composition and nutrient value as possible compost and/ or animal/aquaculture feed ingredients.

Cod by-products were found to contain 2.29% N, 0.41% of which was due to collagen content. The total lipid content was 4.30%, and mineral constituents accounted for 3.95% of total weight. The calculated protein efficiency ratio, PER values, based on amino acid scoring methods, was 1.88-2.36 as compared with 2.86-3.24 for cod muscles. The total omega-3 fatty acid content was 26.6% of total lipid content. Thus, cod by-products could serve as a potential nutrient component in any formulated feed or compost. For use in feed formulations, a sterilization or acidification process could be required to prevent possible microbial contaminations.

By-products of queen crab and pink shrimp contained 1.14%-1.76% N, 0.5%-1.1% lipid and 17.0%-26.0% chitinous materials. The shells contained 0.20%-0.25% K and 1.66%-2.88% P; however, Ca was present at 14.90%-15.30%. While the amino acid and lipid fatty acid levels of shells were quite adequate for utilization in feed formulations (calculated PER values 2.30-2.88), use of shells for agricultural purposes has the potential advantage of providing an excellent K/N/P nutrient and could also serve as a lime substitute. Chitinous materials of shells have the added advantage of binding nutrients such as proteins, minerals, etc., around the roots and bulbs of plants, thus increasing product yield and quality. Use of chitinous materials as seed coating has been shown to decrease fungal attack and to have a similar yield-enhancing effect. In addition, use of shell chitosans as a protein flocculent for wastewater treatment and subsequent use as a compost or animal feed ingredient could have practical significance. Work towards realization of these objectives is part of our ongoing research program, or is planned.

Introduction

While commercial exploitation of cod has been practiced for many decades, the commercial exploitation of crustaceans, particularly queen crab in the Canadian Atlantic, started in 1960 with landings in the Gaspe area of Quebec. By 1983, the total value of the queen crab fishery surpassed the $50 million mark. The total catch in Newfoundland coastal areas amounts to nearly 25% of the total Canadian catch in the Atlantic region. Pink shrimp is the major shrimp species harvested in the Labrador area, and this again is an important source of income for fishers and processors in the region.

By-products of fish and shellfish account for up to 80% of the original weight of raw material (Shahidi et al. 1991). While the major components of fish by-products are proteins, the main components of shellfish by-products are proteins, chitin and minerals. Small amounts of flavorant proteins and carotenoid pigments are also present in shellfish by-products. Unfortunately, most of the by-products of fish and shellfish are not presently utilized. Furthermore, by-products have become a problem to seafood processors as environmental restrictions are enforced. Thus, further processing not only serves as a means of producing value-added products, it also resolves many of the environmental concerns facing the seafood industries.

The present study is part of a program to evaluate the feasibility of establishing a by-products facility in the Newfoundland-Labrador region. Thus, proximate and amino acid compositions of proteins, fatty acid composition of lipids as well as chitin, pigment and mineral contents of shellfish discards were investigated.

Materials and Methods

Raw Materials

By-products of cod were obtained from Bay Bulls, Newfoundland. They were then comminuted in a Hobart industrial grinder, model 4146 (The Hobart MFG. Co., Ltd., Don Mills, Ontario). Different parts of shells separated during the commercial processing of queen crab at Quinlan Brothers Plant, Bay de Verde, Newfoundland, and by-products of pink shrimp obtained from Fisheries Products International (St. John's, Newfoundland) were used as starting materials. The shells were ground using a Waring blender (Model 33 BL 73, Dynamics Corp., New Hartford, United States), vacuum packed in plastic bags and kept frozen at -20°C until use.

Methods

Moisture content in by-products was determined by oven drying of about 2 g. of the sample at 105°C overnight or until a constant weight was obtained (AOAC 1990). Total N and ash contents were determined using AOAC (1990) methods.

For shells, protein content was determined after a two-hour extraction of a known amount of discard with 2.5% KOH solution at 90°C. The protein extract was then separated from insoluble matters in KOH, using a coarse glass-sintered funnel, and was subsequently diluted to 250 ml. with water. The protein content of the solution was determined according to the Kjeldahl (AOAC 1990) or biuret (Snow 1950) method of analysis. In the latter case, bovine serum albumin (BSA) was used as a standard. The content of amino acids was assayed in proteins extracted from shells by 2% KOH solution (20°C, two hours) and then precipitated with 10% acetic acid solution, pH 4.5. The individual amino acids in freeze-dried samples were generally determined after hydrolysis with 6% HCl for 24 hours at 110°C (Blackburn 1968). The amino acids were then separated and identified using a Beckman 121 MB amino acid analyzer. Tryptophan was determined separately according to the method of Penke et al. (1974).

The content of chitin in the by-products was determined by demineralization of 0.5-1.0 g. of shells, deproteinized with a 5% KOH solution for 2 hours at 100°C, in 20 ml. 5% HCl for two hours at room temperature. Chitin was separated on a coarse glass-sintered funnel, washed with water to neutral pH and then with 3 x 25 ml. of acetone followed by oven drying at 105°C.

Total lipids were extracted from by-products according to the method of Bligh and Dyer (1959) using a chloroform-methanol-water mixture. Fatty acid composition of lipids, extracted according to Bligh and Dyer (1959), was determined as methyl esters, by gas chromatography using a Perkin Elmer Model 8500 gas chromatograph.

Total carotenoids in the by-products were determined in the lipid fraction isolated according to Bligh and Dyer (1959) by the method of Saito and Regier (1970). Carotenoid fractions were then separated using a thin-layer chromatographic method as described elsewhere (Shahidi and Synowiecki 1991). The absorbance of carotenoids was read on a Beckman DU-8 spectrophotometer. Concentration of carotenoids was then calculated using linear equations of standard curves prepared for individual carotenoid solutions in chloroform.

Results and Discussion

The proximate compositions of cod, pink shrimp and queen crab by-products are given in Table 1. The moisture content of pink shrimp by-products was 72.10±0.20%. The moisture content of cod by-products was 77.61±0.35%, while that for queen crab shells was 29.7%-69.4%, depending on shell segment and sample lot tested. The protein content, on dry basis, of pink shrimp shells exceeded that of queen crab shells from different segments. Cod by-products had the highest protein content, averaging at 14.30±0.61%. The water-extractable proteins with potent flavor characteristics accounted for 1.4±0.20% and 1.58±0.11% of the total proteins for queen crab shoulder and pink shrimp by-products, respectively. The lipid content of

TABLE 1

Proximate composition of fish and shellfish by-products (%)

Discard/Segment	Moisture	Protein	Lipid	Ash	Chitin*
Cod	77.61±0.35	14.30±0.61	4.30±0.78	3.95±0.25	---
Shrimp	72.10±0.20	12.31±0.18	2.34±0.14	8.10±0.12	17.02±0.23
Crab	42.50±0.31	10.97±0.12	0.49±0.03	17.64±0.18	18.71-32.20

*on a dry basis

pink shrimp shells also exceeded that of queen crab shell segments; however, the ash content of pink shrimp shells was lower than that of queen crab shells (Table 1). Cod by-products had the highest lipid, 4.30±0.73%, and the lowest ash, 3.95±0.25%, contents.

The content of chitin in the shells, on a dry basis, was 17% for pink shrimp and varied 18.7%-32.2% for queen crab (Table 1). Backs and claws had a lower content of chitin. Furthermore, the content of chitin in soft-shelled queen crab by-products from back segments was higher than that of hard shells.

The essential amino acid compositions of the proteins recovered from pink shrimp and queen crab shells is summarized in Table 2. Results indicate that pink shrimp shell proteins are well balanced in amino acid composition and, as such, could be used as an excellent component for starter feed for animals and for aquaculture industry. The queen crab shell proteins, however, were of lesser quality and contained much smaller amounts of lysine, leucine and isoleucine. Essential amino acid contents for cod by-products were comparable or

TABLE 2

Essential amino acid composition of fish and shellfish by-products proteins (%)

Amino Acid	Cod	Shrimp	Crab
Histidine	1.79±0.12	2.24±0.09	3.58±0.01
Isoleucine	3.30±0.30	5.78±0.13	2.67±0.02
Leucine	6.18±0.50	7.01±0.02	5.14±0.02
Lysine	6.53±0.49	6.58±0.07	2.51±0.07
Methionine	2.78±0.24	2.41±0.08	1.93±0.01
Phenylalanine	3.18±0.73	5.13±0.07	5.98±0.01
Threonine	4.15±0.37	4.14±0.20	4.75±0.02
Tryptophan	1.01±0.10	1.19±0.07	0.77±0.01
Valine	3.80±0.27	5.95±0.06	7.07±0.10

lower than those in queen crab by-products. Thus, the calculated PER values, obtained as described elsewhere (Shahidi et al. 1991), of cod by-products and queen crab by-products were 1.88-2.42 as compared with those of 2.79-2.88 for pink shrimp shells and 2.88-2.99 for cod muscles (Table 3).

TABLE 3

Calculated PER value for fish and shellfish by-products

Discard	PER Value
Cod	1.88-2.36
Cod muscle	2.86-2.99
Shrimp	2.79-2.88
Crab	2.30-2.42

The major fatty acids of lipid components of cod by-products and shells from pink shrimp and queen crab are shown in Table 4. Monounsaturated fatty acids were the major components of shell lipids. While the contents of eicosapentaenoic acid (EPA) for pink shrimp and queen crab shells were similar, pink shrimp lipids had a larger content of docosahexaenoic acid (DHA). Cod by-products had much less C20:1, C22:1 and C20:5. However, the content of DHA was much higher in cod by-products than in pink shrimp and queen crab by-products. The minerals of queen crab and pink shrimp by-products were dominated primarily by Ca, and to a lesser extent by P. Other minerals, mainly N, K, Mg and Sr were present at less than 1% (Table 5).

TABLE 4

Some major fatty acids of fish and shellfish by-products lipids (%)

Fatty Acid	Cod	Shrimp	Crab
16:0	11.0	11.88	9.36
18:1	20.3	21.82	25.76
20:1	7.4	10.00	13.33
22:1	5.1	7.63	7.38
20:5	8.9	13.16	12.72
22:6	13.3	10.57	5.59

TABLE 5

Contents of major minerals of shellfish by-products

Mineral (%)	Shrimp	Crab
Ca	15.30	14.95
Na	2.05	0.95
K	0.20	0.25
Mg	0.95	0.92
P	1.66	2.88
Sr	0.22	0.23

The carotenoid pigments were a minor, but important, component of shells. Pink shrimp and soft-shelled queen crab backs had the largest content of carotenoids. Hard-shelled queen crab backs as compared with soft-shelled queen crab backs contained about 20% less pigments (Table 6). Inclusion of isolated carotenoids in the diets of salmonids and subsequent uptake in flesh and skin of fish has been successfully accomplished.

TABLE 6

Carotenoids of shellfish by-products

Discard	Total Carotenoids, µg/g
Shrimp	147.7
Crab Backs, hard	119.6
Crab Backs, soft	139.9

In conclusion, nutrient composition of seafood by-products shows adequate quality characteristics for inclusion in feed and also for composting purposes. Studies in these areas, including growth parameters of selected agricultural products, are either ongoing or are planned. Utilization of chitin and chitosans in seed coatings and in prevention of plant diseases, and of chitinous compounds as possible food preservatives are being and/or to be investigated.

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Composts for Nursery Production

by Todd A. Herrick, Evergreen Nursery Company, Sturgeon Bay, Wisconsin

Background

Evergreen Nursery utilizes 2,000 cu. yd. of bark compost annually as a potting mix for both evergreen and deciduous plant species. In 1989, the potting mix was reformulated in order to improve plant growth. Analysis of the problems encountered with the "old" mix and the solutions used to improve it illustrate the requirements of composts for use as potting media.

Prior to 1989, the compost consisted of a blend of several types of "hardwood" bark:

30% Ash	pH = 7.4
30% Soft Maple	pH = 6.4
20% Hard Maple	pH = 5.8
10% Birch	pH = 7.1
5% Elm	pH = 7.0
5% Beech	pH = 5.9

This combination of barks was windrowed, watered as needed to maintain 50% moisture by weight, fertilized with 4 lb. of urea and 1 lb. superphosphate/cu. yd., and allowed to compost for six months to a year (turning as needed to maintain adequate aeration). The composted material was then ground down or screened to achieve a uniform particle size.

Problems experienced with this compost:

1) pH-induced Fe chlorosis. The post-composting pH of this medium was 7.5-8.0. Ideal growing medium pH for nutrient availability is about 5.5. Organic media tend to bind micronutrients at higher pHs.

Options to reduce pH:

a) Use NH_4SO_4 (21-0-0) instead of urea (46-0-0).

b) Use MAP (11-48-0) instead of TSP.

c) Remove ash, birch and elm, substituting oak (5.4), cherry (6.0) and other more acidic barks.

d) Add S after composting.

2) Odor problems in containers caused by anaerobic fermentation of the bark during composting. The poor physical structure caused low aeration porosity of 7%-10% and high water retention porosity of 25%-30%. "Ideal" aeration porosity for optimum plant growth is 20%-30%, and "ideal" water retention porosity is 15%-25%.

Options to alter physical properties:

a) Discontinue grinding to retain a larger particle size.

b) Amend to increase aeration porosity (e.g., with pea gravel, perlite, etc.).

3) Poor growth and lack of vigor in both deciduous and evergreen species.

Options to improve plant growth:

a) Evaluate the influence of heat stress and black posts.

b) Evaluate the nutrition program and potting mix.

4) High cost of final product. Raw material cost was $5-$10/cu. yd., but due to high labor input and rapid shrinkage, the final product cost averaged $20-$30/cu. yd.

Options to reduce cost:

a) Compost without labor.

b) Find barks that resist decomposition.

The solution to the problems associated with this compost was to modify the base mix by using pine barks rather than "hardwood" barks. The new compost consisted of a blend of the following:

35% White pine	pH = 4.1
35% Red pine	pH = 3.9
10% Hemlock	pH = 4.7
10% Hardwoods	pH = 7.5
5% Peatmoss	pH = 3.5
5% Sand	pH = 8.2

The improvements as a result of modifying the mix with pine bark were several-fold, including:

- A post-composting pH averaging 6.1.
- Porosity enhancement. The high lignin content in pine barks resists decomposition, and the composted material retains good structure without excessive breakdown. Aeration porosity rose to 30%, and water retention porosity decreased to 20%.
- Reduced cost. Less composting labor meant a less expensive product.
- Vigorous growth!

General Requirements of a Potting Mix

The requirements for specific plant species vary, but the following factors are important when developing a potting mix:

- Stability (bulk density).
- Ability to retain and supply nutrients.
- A degree of water-holding capacity.
- Water retention porosity.
- Adequate drainage as aeration porosity (necessary for exchange of O_2 and CO_2 and for nutrient uptake).
- Provision for optimal growth.
- Reasonable cost.
- Aesthetics.

"Compost" Areas of Concern

If the end goal is a quality product, the following areas of concern should be addressed during the composting:

- pH.
- Soluble salts (measured as conductivity).
- Heavy metals.
- Adequate availability.
- Stability, uniformity and consistency (general physical properties).
- Residuals (e.g., herbicides on grass clippings).
- Cost.
- Maturity (allelopathic toxins and toxic organic acids).
- Anaerobic metabolites resulting from improper composting (acetic, propionic and butyric acids; methane and alcohols; localized O_2 depletion and N immobilization).

Measurements of maturity include:

- Water soluble extracts applied to germ seedlings.
- Analysis for starch/cellulose content, CEC, organic C to N ratio and the presence of indicator microorganisms or humic substances.

Key Factors for Successful Composting

1) Nutrient balance.

   a) C to N ratio (30:1-35:1 is considered ideal, less than 20:1 results in N loss and volatilization of NH_3, greater than 40:1 results in a reduced rate of decomposition).

Wood	700:1
Sawdust	200-500:1
Straw	80:1
Leaves	60:1
Cornstalks	60:1
Fruit waste	35:1
Horse manure	25:1
Grass clippings	15-20:1
Cow manure	18:1
Poultry manure	15:1
"Food waste"	15:1
Alfalfa hay	12:1
Soil	6-10:1

   b) C to P ratio (75:1 to 150:1 is considered ideal).

2) Availability of trace elements in a usable form.

3) Adequate moisture (target range is 50%-60% by weight, becomes limiting below 50%, composting activity ceases at 10%).

Sawdust	75%-90%
Rice hulls	75%-85%
Straw	75%-85%
Manures	55%-65%
Lawn clippings, wet wastes	50%-55%

4) Adequate (but not excessive) aeration.

   a) Excessive — prohibition of the thermophilic stage.

   b) Inadequate — odors and fermentation.

5) Temperature of 50°-60°C (optimum).

The Composting Process

There are four general phases in the composting process, each characterized by different temperature ranges and microbial populations.

1) Mesophilic stage.
   a) pH drops to 4.5-5.0. Organic acids produced as polysaccha rides are metabolized.
   b) Temperature increases to 45°-50°C.
   c) Bacteria, actinomycetes and fungi predominate.

2) Thermophilic stage (greatest microbial activity).
   a) pH increases to 8.0-9.0.
   b) Liberation of free NH_3 as proteins decompose.
   c) Temperature increases to 60°-70°C (above 60°C fungi shut down).
   d) Spore-forming bacteria, actinomycetes and fungi.
   e) Degradation of most sugars, fats, starches and proteins.
   f) Destruction of plant/human pathogens and weed seeds.

3) Cooling down stage.
   a) Temperature decreases to 25°C.
   b) pH decreases.
   c) NH_3 production ceases.
   d) Thermophilic fungi reinvade.
   e) Hemicellulose/cellulose decompose.

4) Maturation stage.
   a) Slightly alkaline.
   b) Little heat generation.
   c) Intense competition for lignin (mesophiles).
   d) Long-term stabilization and colonization.

The Evaluation of Peat-Based Fisheries By-Products Composts for Use as Horticultural Container Substrates

by Kurt W. Johnson, Thomas J. Malterer and Thomas E. Levar, University of Minnesota Natural Resources Research Institute

Abstract

As composting becomes a more acceptable method of disposing of fisheries by-products, there is need to find suitable end uses for the material. As part of the composting and value-added horticultural peat products program at the University of Minnesota Natural Resources Research Institute, research is being conducted to develop high value products from compost. This research focuses primarily on the characterization of these composts in terms of their physical, chemical and biological properties. Three peat-based fisheries by-products composts with initial C to N ratios of 18 to 1, 14 to 1 and 8 to 1 were produced from salmonid fisheries by-products in combination with sphagnum moss peat, utilizing a static aerated pile composting method. These composts were tested to determine the following physical properties: bulk density, total pore space, air capacity, container capacity, available water and particle size distribution. Chemical analyses included: pH, soluble salts and nutrient concentrations. Several compost maturity tests (e.g., cress seed germination bioassay) were also performed on the composts. The result of these characterizations gives a wide range of values for each property, related primarily to the initial C to N ratios and the time allowed for curing of the composts. One commercial mix was also analyzed as a comparison. These data were compared to horticultural substrate guidelines. These sphagnum moss peat-based fisheries by-products composts, particularly those with higher initial C to N ratios, have potential for use as horticultural container substrates.

Introduction and Background

This research was completed as part of the Value-Added Horticultural Peat Products Project funded by the Greater Minnesota Corporation (GMC) in fiscal year 1990-1991. Cooperators in the project were William Fonteno of the North Carolina State University Substrates Laboratory and William McElhannon of Fafard Analytical Services. This project addressed the development of value-added horticultural peat products from materials originating from Minnesota sources.

These materials included a number of peat-based composts. The composts were developed as part of another 1990-1991 GMC-funded project, Peat as a Bulking Agent for Composting. These composts consist of combinations of sphagnum moss peat with salmonid fisheries by-products, utilizing a static aerated pile composting method (Mathur et al. 1986).

Considerations in Horticultural Substrate Selection

Horticultural substrates should be chosen based on their physical, chemical, biological and economic characteristics (White 1974).

Some of the desired physical characteristics considered in substrate selection included: low bulk density, high water-holding capacity, stability and aeration. A material with the proper combination of these attributes will result in a substrate with ideal physical properties for plant growth.

The chemical characteristics of a substrate are particularly important for plants growing in containers because of the relatively small volume of material the plant has to grow in. One important overall consideration regarding the chemical properties of the selected components is the level of toxic substances, such as heavy metals or organics. The use of chemically clean, nontoxic components in the development of substrates and other products allows unlimited end use and improved market potential.

From a biological standpoint, substrates should be free of weed seeds, insects, and plant and human pathogens. The composts analyzed in this study were heated during processing by thermophilic microorganisms to eliminate biological pests. The temperatures required to kill weed seeds and pathogens (130°-150°F) are not detrimental to the microorganisms beneficial to plant growth.

Economic considerations are also very important in selecting substrates. Substrates should be readily available at all times of the year at reasonable cost and should be within close proximity to minimize shipping costs (White 1974). The composts in this study were produced from fisheries by-products that have an associated disposal cost. This makes their use in substrates very economical and also beneficial for the environment.

Perhaps the most important consideration in selecting a substrate is consistency of the material (McElhannon pers. comm. 1990). Because of the liability involved with producing substrates for commercial growers, substrates need to be very consistent from year to year, and the use of the substrate must yield predictable plant growth. The retail market is less stringent, yet quality control is still important.

Research Objective

The objective of this research was to evaluate selected peat-based fisheries by-products composts for use as horticultural container substrates based on analysis of their physical, chemical and biological characteristics.

Materials and Methods

Materials

The fisheries by-products were acquired from the Minnesota Aquafarms aquaculture facility in Chisholm, Minn. Commercial grade horticultural sphagnum moss peat was obtained from Minnesota Sphagnum, Inc., located near Floodwood, Minn. Three sphagnum moss peat-based fisheries by-products composts and a commercial mix were analyzed to determine physical, chemical and biological characteristics to assess potential use as horticultural container substrates. Following is a list of the materials analyzed for this paper:

- W.R. Grace forestry mix
- fisheries by-products 18 to 1 compost (78% sphagnum moss peat)
- fisheries by-products 14 to 1 compost (54% sphagnum moss peat)
- fisheries by-products 8 to 1 compost (28% sphagnum moss peat)

The numbers following the compost type are the initial C to N ratios for each compost. The percentage sphagnum moss peat listed is the sphagnum moss peat included in each compost on a weight basis.

Physical Characterization of Substrates

The specific physical parameters that describe the air and water relationships of a substrate within a container are total porosity, container capacity, air space, unavailable water and available water. These five parameters make up a "substrate fingerprint" that is specific for each material (Fonteno 1988). Particle size distribution and bulk density are also useful in describing the physical characteristics of a substrate.

Total porosity is defined as the total volume of a substrate not occupied by the solid fraction (Bunt 1976). Approximately 10%-15% of the volume in a container is occupied by media, the rest is pore space (Fonteno 1990). In practice, these pores can be filled with air or water. Total porosity is a function of the substrate and is not dependent on the size of the container.

Container capacity is defined as the percentage volume of water retained by a substrate in a container after the substrate has been saturated and allowed to drain (White 1964). The amount of water retained will be greater than that present in an agricultural soil at "field capacity." Container capacity is a function of the substrate and the container, and therefore varies with the container size (Bunt 1976).

Unavailable or hygroscopic water is that percentage volume of water still retained in the substrate at soil moisture tensions greater than 15 bars. The 15-bar level is also known as the permanent wilting point, at which plants are unable to extract sufficient water to regain turgidity even when placed in an atmosphere saturated with water vapor (SSSA 1984). The percentage unavailable water is also known as the permanent wilting percentage (Bunt 1976).

Air space is the percentage volume of a substrate that contains air after the substrate has been saturated and allowed to drain (Bunt 1976). Air space is equal to the difference between total porosity and container capacity.

Available water is the percentage volume of water retained in a substrate that is available for plant growth. Available water is equal to the difference between container capacity and the permanent wilting percentage (Bunt 1976).

Total porosity and unavailable water are specific for each substrate and do not vary with container size. Container capacity, air space and available water change with different substrates and container sizes.

Given a known volume of moist substrate, bulk density is defined as the oven dry weight per that known volume (g./cu. cm.). Bulk densities for container substrates are relatively low as compared to field soils but must be high enough to physically support the plant.

NCSU Quick Unit

The NCSU Quick Unit was developed at the North Carolina State University Substrates Laboratory by William Fonteno for the physical analysis of container substrates (Fonteno pers. comm. 1991). The unit measures total porosity, container capacity and air space of a substrate quickly and with a high degree of precision. Bulk density is also determined in the process.

15-Bar Determination

As previously mentioned, unavailable water is that volume of water still retained in the substrate at soil moisture tensions greater than 15 bars. To duplicate these tensions and to determine the percentage unavailable water, a soil pressure plate extractor is required. The soil pressure plate extractor simulates soil moisture tension or suction by applying gas pressure of 15 atmospheres to saturated substrate cores placed on a porous ceramic plate. This creates an equilibrium tension of 15 bars in the sealed vessel. Substrate moisture flows out of the sample and through the porous plate until the system reaches equilibrium. The cores can then be removed and weighed.

The specific method used to complete the 15-bar determination for this project is the one developed by Fonteno at the North Carolina State University Substrates Laboratory. This determination is usually done in conjunction with the NCSU Quick Unit analysis, resulting in a complete "substrate fingerprint."

Particle Size Distribution

Particle size analysis is a measurement of the size distribution of individual particles within media samples (Gee and Bauder 1986). Results of this analysis are usually presented in a particle size distribution curve. This information can be useful in predicting water-holding capacity and bulk density, and can also be used as a guide for combining several materials to achieve a desired particle size distribution.

The method used for particle size distribution in this study was the one used by William McElhannon at Fafard Analytical Services.

Chemical Characterization of Substrates

The chemical analysis of substrates was performed primarily by Fafard Analytical Services under McElhannon's direction. The method of chemical analysis employed at Fafard is the saturated media extract procedure developed at Michigan State University primarily for the testing of container substrates (Warncke and Krauskopf 1983). An advantage of this method is that a single set of fertility guidelines can be established, since the amount of water at saturation is directly related to the water-holding characteristics of the individual substrate. The saturated media extract method removes only water-soluble nutrients.

The sphagnum moss peat and fisheries by-products used to produce the composts were previously tested to determine PCB and heavy metal concentrations. These concentrations were all within acceptable limits.

The pH Determination

The pH is a measure of hydrogen ion concentration or acidity of a material. The pH of a substrate affects nutrient availability and, therefore, plant growth and health. Excesses and deficiencies of plant nutrients are influenced by the pH of the substrate and affect plant dry matter accumulation, growth habit, height and leaf conditions. The acceptable pH range for container substrates is 5.3-6.5 with an optimum range of 5.6-5.8 (McElhannon pers. comm. 1990).

The pH measures for all samples in this study were performed according to the saturated media extract method at Fafard Analytical Services using a pH meter.

Soluble Salts

Ions or nutrients in solution such as nitrate, ammonium, K, Ca, Mg, chloride and sulfate all contribute to the soluble salt content of a substrate (Warncke and Krauskopf 1983). High soluble salts can adversely affect plant growth through specific ion toxicities, such as B or Mn, or by generally high salinity levels, which affect the availability of water to plants (Bunt 1976). Soluble salt levels are determined by measuring electrical conductivity, which is directly dependent upon the level of soluble salts in a solution. The soluble salt levels for this project were determined by Fafard Analytical Services on a saturated media extract solution using an Agri-meter electrical conductivity meter.

Nutrient Analysis

A balance of essential nutrients in a substrate is required for optimum plant growth. Excesses or deficiencies of nutrients can cause poor germination, abnormal growth or death of the plant.

Analyses to determine the concentration of essential plant nutrients were performed for each of the substrates. The nutrient determinations included nitrate N, ammonium N, P, K, Ca, Mg, Fe, Mn, B, Cu, Z and Mo. All plant nutrient analyses were performed by Fafard Analytical Services. Three replications of each material were submitted for analysis.

Compost Maturity

In addition to the physical and chemical characterization, several additional tests relating to the maturity or stability of the compost were performed.

Compost maturity is a measure of the degree of decomposition and the stability of a compost. In a mature compost, the chemical compounds present in the fisheries by-products have been degraded to basic forms by microorganisms; the biological activity, which was quite high during the early stages of composting, is relatively low; and organic nutrients have been mineralized into plant available forms. A mature compost does not contain phytotoxic substances and should benefit plant growth (Zucconi and De Bertoldi 1987).

The degree of maturity required is dependent on the expected end use for the compost. A high level of maturity is needed if the compost is to be used as a container substrate because of the small volume of material available for the plant to utilize. Other uses, such as land application as a soil amendment, require a lesser degree of maturity because the compost will be further diluted and degraded in the soil.

There are numerous methods for determining compost maturity (Jiminez and Garcia 1989). However, no one method works well for a variety of composts. To achieve an accurate assessment of maturity, several different tests in combination should be performed. Three maturity tests were conducted as part of this project:

self-heating, nitrate accumulation and the cress seed germination bioassay.

Self-Heating Test

A compost is considered biologically unstable or immature if upon turning and rewetting a significant temperature increase (usually 10°C) is noted. The renewed biological activity is an indication that further degradation is occurring. A compost is not mature until this degradation is complete.

In this project, all composts were thoroughly mixed and rewetted (to approximately 60% moisture content), then placed in uncovered barrels to determine the extent of self-heating. Temperatures were recorded on a daily basis until the compost temperatures returned to ambient. The composts were quite dry before rewetting, suggesting the maturing process had been impeded by dehydration.

Nitrate Accumulation Test

The accumulation of nitrates in a compost occurs in the final stages of the curing process. This buildup of nitrate can be a good measure of compost maturity and indicate when a compost can be used as a plant substrate without detrimental effects.

Samples were collected when the compost was first mixed and rewetted, and then once every 30 days for the next three months. Three replicates of each compost were sent to Fafard Analytical Services for analysis to determine nitrate levels.

Cress Seed Germination Bioassay

The cress seed germination bioassay developed by Zucconi et al. (1981) was included in this study as another measure of compost maturity. Three concentrations (100%, 30% and 10%) of each compost extract were tested. In this bioassay, the compost extract is incubated with cress seed (*Lepidium sativum*) at 27°C for 24 hours. The germination and root elongation of the seeds is measured and recorded. The product of the germination and root elongation for the compost extract is expressed as a percentage of a tap water control to give a germination index. This method is particularly useful for assessing the phytotoxicity of the compost, a vital concern when the end use is as a substrate for plant growth. Detailed procedures for the cress seed germination bioassay were provided by Harry Hoitink of Ohio State University (Hoitink pers. comm. 1991).

Results and Discussion

Physical Characterization of Substrates

The physical characterization of the three fisheries by-products composts and the commercial forestry mix resulted in values for total porosity, container capacity, air space, unavailable water, available water, bulk density and particle size distribution. Air and water relationships must be expressed on a volume basis rather than a weight

TABLE 1

Average physical characteristics of substrates[1]

basis when dealing with soilless mixes in containers because of the relatively low bulk densities and small volumes present as compared to field soil conditions (Biernbaum 1990). The results of these physical analyses are presented in Table 1.

Substrate	Total Porosity[2]	Container Capacity[2]	Air Space[2]	Unavailable Water[3]	Available Water[4]	Bulk Density[2]
	percentage					g./cu. cm.
W.R. Grace mix	84.70 ± 0.86	69.80 ± 0.85	14.90 ± 0.86	18.20 ± 0.26	51.60	0.09 ± 0.00
Fisheries by-products 18:1 compost (78% peat)	84.70 ± 1.70	68.80 ± 1.72	16.00 ± 1.33	19.50 ± 1.02	49.20	0.10 ± 0.00
Fisheries by-products 14:1 compost (54% peat)	85.20 ± 2.28	71.80 ± 2.19	13.40 ± 0.99	23.90 ± 0.64	47.90	0.12 ± 0.00
Fisheries by-products 8:1 compost (28% peat)	81.60 ± 1.96	71.80 ± 1.40	9.80 ± 1.02	42.70 ± 1.58	29.10	0.19 ± 0.01

1 Table contains arithmetic mean values ± standard deviation
2 Sample size = 7
3 Sample size = 5
4 Available water = mean container capacity - mean unavailable water

Total Porosity

The values for total porosity for the materials tested ranged from a high of 85.2% for the fisheries by-products 14 to 1 compost to a low of 81.6% for the fisheries by-products 8 to 1 compost. A value of 84.7% was recorded for the commercial mix. All of the compost materials had total porosity values within 5% of the commercial mix. The total porosity did not appear to be significantly affected by the initial C to N ratio; however, the value for the fisheries by-products 8 to 1 compost was slightly lower.

Container Capacity

Container capacity values for all materials tested ranged from a high of 71.8% for both the fisheries by-products 14 to 1 and 8 to 1 composts to a low of 68.8% for the fisheries by-products 18 to 1 compost. 69.8% was recorded for the commercial mix. The values for container capacity were not affected by the initial C to N ratio.

Air Space

The resulting air space values for the tested materials ranged from a high of 16.0% for the fisheries by-products 18 to 1 compost to a low of 9.8% for the fisheries by-products 8 to 1 compost. The air space value for the commercial mix was 14.9%. The composts with a higher initial C to N ratio (more sphagnum moss peat) had higher air space values than those with a lower initial C to N ratio.

Unavailable Water

The unavailable water values for the materials tested ranged from a high of 42.7% for the fisheries by-products 8 to 1 compost to a low of 18.2% for the commercial mix. The unavailable water was generally lower for composts with a higher initial C to N ratio than for those with a lower initial C to N ratio. This inverse relationship is especially evident for the fisheries by-products 8 to 1 compost, which had the highest unavailable water content for the lowest initial C to N ratio. All the compost materials had values higher than the commercial mix.

Available Water

The available water content for all the materials tested ranged from a high of 51.6% for the commercial mix to a low of 29.1% for the fisheries by-products 8 to 1 compost. Available water is a function of container capacity and unavailable water, therefore materials with low container capacity and/or high unavailable water resulted in low values for available water as in the case of the fisheries by-products 8 to 1 compost.

Bulk Density

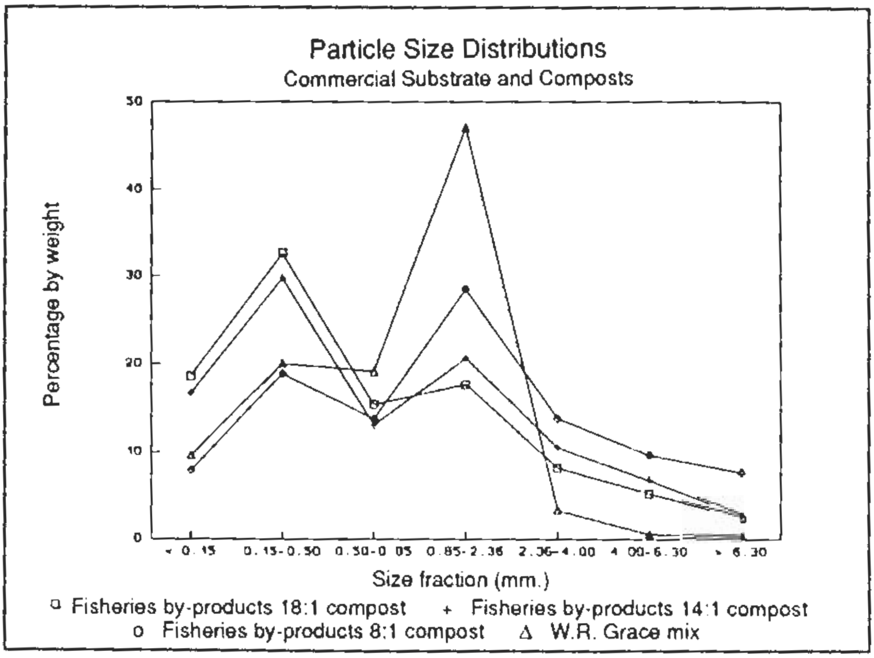
The bulk density values for the materials tested ranged from a high of 0.19 g./cu. cm. for the fisheries by-products 8 to 1 compost to a low of 0.09 g./cu. cm. for the commercial mix. The bulk density values were highest for the composts with the lowest initial C to N ratio. All of the composts had bulk density values higher than the commercial mix.

Particle Size Distribution

Particle size distribution curves were developed for the commercial mix and each of the three fisheries by-products composts. These curves are presented in Figure 1. The vermiculite in the commercial

FIGURE 1

Average particle size distributions for a commerical substrate and peat-based fisheries by-products composts (sample size = 5)



mix resulted in a greater percentage of particles in the 0.85-2.36 mm. range than that observed in the composts. The composts had particle size distributions that contained a considerably higher percentage of fines than the commercial mix contained. This could be alleviated by screening to remove fines or by the addition of coarser materials.

The fisheries by-products 18 to 1 and 14 to 1 composts had physical properties quite similar to the commercial mix. The fisheries by-products 8 to 1 compost had the undesirable characteristics of low available water content and low air space. The physical properties of composts can be adjusted to within acceptable ranges by the addition of sphagnum moss peat, vermiculite, perlite or other components.

Chemical Characterization of Substrates

Chemical analysis was performed on the three composts and the commercial mix to determine pH, soluble salts and nutrient concentrations. These analyses were completed by Fafard Analytical Services according to the saturated media extract method developed at Michigan State University (Warncke and Krauskopf 1983). General nutrient and soluble salt guidelines for samples tested using the saturated media extract method are presented in Table 2 (Warncke and

TABLE 2

General nutrient guidelines for substrates analyzed using the saturated media extract (SME) method (Warncke and Krauskopf 1983; McElhannon 1990)

Analysis	Low	Acceptable	Optimum	High	Very High
pH	<5.3	5.3-6.5	5.6-5.8	>6.5	-
Soluble Salt, mS/cm	0-.75	.75-2.0	2.0-3.5	3.5-5.0	5.0+
Nitrate-N, ppm	0-39	40-99	100-199	200-299	300+
Ammonium-N, ppm	-	-	0-20	-	-
Phosphorous, ppm	0-2	3-5	6-9	11-18	19+
Potassium, ppm	0-59	60-149	150-249	250-349	350+
Calcium, ppm	0-79	80-199	200+	-	-
Magnesium, ppm	0-29	30-69	70+	-	-
Iron, ppm	-	-	0.30-3.00	-	-
Manganese, ppm	-	-	0.10-3.00	-	-
Boron, ppm	-	-	0.05-0.50	-	-
Copper, ppm	-	-	0.01-0.30	-	-
Zinc, ppm	-	-	0.10-0.30	-	-
Molybdenum, ppm	-	-	0.01-0.10	-	-

Krauskopf 1983; McElhannon pers. comm. 1990). The results of the analysis of the composts and the commercial mix are presented in Table 3. The compost materials were sampled and analyzed at 0-, 30-, 60- and 90-day intervals during the curing stage to monitor the maturing process. Only the 90-day data are included in this discussion of chemical characterization because the nutrient values were closest to acceptable levels at this point in time. The commercial mix was sampled at one point in time, as received. Each of these materials was compared to the guidelines in Table 2 to determine chemical suitability as substrate.

The pH values for the materials tested ranged from a high of 8.70 for the fisheries by-products 8 to 1 compost to a low of 4.26 for the commercial mix. The only substrate in the optimum pH range of 5.6-5.8 was the fisheries by-products 18 to 1 with a value of 5.80. The composts with lower initial C to N ratios had higher pH readings.

The soluble salt levels ranged from a high of 12.03 mS/cm. for the fisheries by-products 8 to 1 compost to a low of 1.37 mS/cm. for the fisheries by-products 18 to 1 compost. The exceptionally high reading for the fisheries by-products 8 to 1 compost is likely a result of the low initial C to N ratio. The rest of the composts and the commercial mix had soluble salt readings close to the acceptable optimum ranges.

TABLE 3

Average chemical analyses of the commerical substrate and composts at 90 days curing time[1]

		mS/cm.	ppm				
Substrate	pH	EC	NO_3	NH_4	P	K	Ca
W.R. Grace mix	4.26 ± 0.06	2.33 ± 0.15	63.26 ± 1.83	25.91 ± 3.31	4.95 ± 1.57	198.57 ± 6.96	233.87 ± 33.34
FBC 18:1 (78% peat)	5.80 ± 0.20	1.37 ± 0.07	5.64 ± 0.01	190.76 ± 5.75	104.19 ± 4.73	44.65 ± 1.57	13.04 ± 1.11
FBC 14:1 (54% peat)	7.06 ± 0.06	3.73 ± 0.38	5.57 ± 1.64	513.55 ± 55.36	193.21 ± 17.69	129.99 ± 13.17	21.73 ± 2.41
FBC 8:1 (28% peat)	8.70 ± 0.00	12.03 ± 0.68	1.54 ± 2.67	1033.08 ± 5.41	607.46 ± 30.52	477.85 ± 21.56	70.04 ± 9.86
	ppm						
Substrate	Mg	Fe	Mn	B	Cu	Zn	Mo
W.R. Grace mix	139.27 ± 11.14	1.37 ± 0.01	2.73 ± 0.26	0.06 ± 0.01	0.00 ± 0.00	0.26 ± 0.01	0.04 ± 0.01
FBC 18:1 (78% peat)	1.58 ± 0.26	6.22 ± 0.49	0.22 ± 0.02	0.04 ± 0.00	0.03 ± 0.01	0.32 ± 0.02	0.01 ± 0.01
FBC 14:1 (54% peat)	3.18 ± 0.36	12.08 ± 1.12	0.48 ± 0.05	0.03 ± 0.00	0.15 ± 0.02	1.67 ± 0.24	0.06 ± 0.01
FBC 8:1 (28% peat)	3.66 ± 0.42	31.64 ± 3.12	0.97 ± 0.13	0.06 ± 0.00	0.91 ± 0.12	11.11 ± 1.04	0.13 ± 0.01

[1] Table contains arithmetic mean values ± standard deviation. Sample size = 3. FBC = fisheries by-products compost

Nitrate levels ranged from a high of 63.26 for the commercial mix to a low of 1.54 for the fisheries by-products 8 to 1 compost. The compost values were all low, with the composts with the highest initial C to N ratios having the lowest nitrate levels. This could be a result of the high ammonium concentrations limiting nitrification. The nitrate concentration for the commercial mix was in the acceptable range.

Ammonium levels ranged from a high of 1,033.08 ppm for the fisheries by-products 8 to 1 compost to a low of 25.91 ppm for the commercial mix. All of the composts had high ammonium readings, while the commercial mix value was close to optimum. The composts with the highest pH readings and lowest initial C to N ratios had the highest concentrations of ammonium. Moderately high ammonium levels are acceptable as long as the pH is less than 7. If the pH is over 7, there is a chance of toxic free ammonia being formed from the ammonium (Bunt 1976). Both the nitrate and ammonium forms of N are available to plants.

P readings ranged from a high of 607.46 ppm for the fisheries by-products 8 to 1 compost to a low of 4.95 ppm for the commercial mix. P levels were very high for all the composts analyzed in this study, with the highest values for those composts with a low initial C to N ratio. The only material with a P level in the acceptable range was the commercial mix.

The range of K values varied from a high of 477.85 ppm for the fisheries by-products 8 to 1 compost to a low of 44.65 ppm for the fisheries by-products 18 to 1 compost. All K readings were in the low to optimum ranges except for the fisheries by-products 8 to 1 compost, which had a K concentration in the very high range.

Ca and Mg values were low for all of the composts and optimum for the commercial mix. The Ca concentrations ranged from a high of 233.87 ppm for the commercial mix to a low of 13.04 ppm for the fisheries by-products 18 to 1 compost. The Mg readings ranged from a high of 139.27 ppm for the commercial mix to a low of 1.58 ppm for the fisheries by-products 18 to 1 compost. Ca and Mg values were highest for composts that had lower initial C to N ratios.

The concentration of Fe was high in all of the composts. The values ranged from a high of 31.64 ppm for the fisheries by-products 8 to 1 compost to a low of 1.37 ppm for the commercial mix. Fe values were highest for composts that had lower initial C to N ratios.

All of the composts and the commercial mix had Mn levels in the optimum range. B and Cu levels for most of the composts were also close to the optimum range except for a high Cu concentration for the fisheries by-products 8 to 1 compost. The commercial mix had an optimum B level and a low Cu level.

Z levels were high for all of the composts and optimum for the commercial mix. Z levels increased as the initial C to N ratio of the composts decreased.

All the composts and the commercial mix had optimum levels of Mo except for the fisheries by-products 8 to 1 compost, which had a high level.

The compost with the most potential for use as a container substrate, when compared to the commercial mix on the basis of pH, soluble salts and nutrient concentrations, is the fisheries by-products 18 to 1. In general, composts with higher initial C to N ratios had chemical analyses most similar to that of the commercial mix and within horticultural guidelines. Nutrient concentrations were highest for composts that had lower initial C to N ratios. These composts could possibly be diluted by the addition of other inert or low nutrient materials to bring nutrient levels into an acceptable range.

Compost Maturity

Self-Heating Test

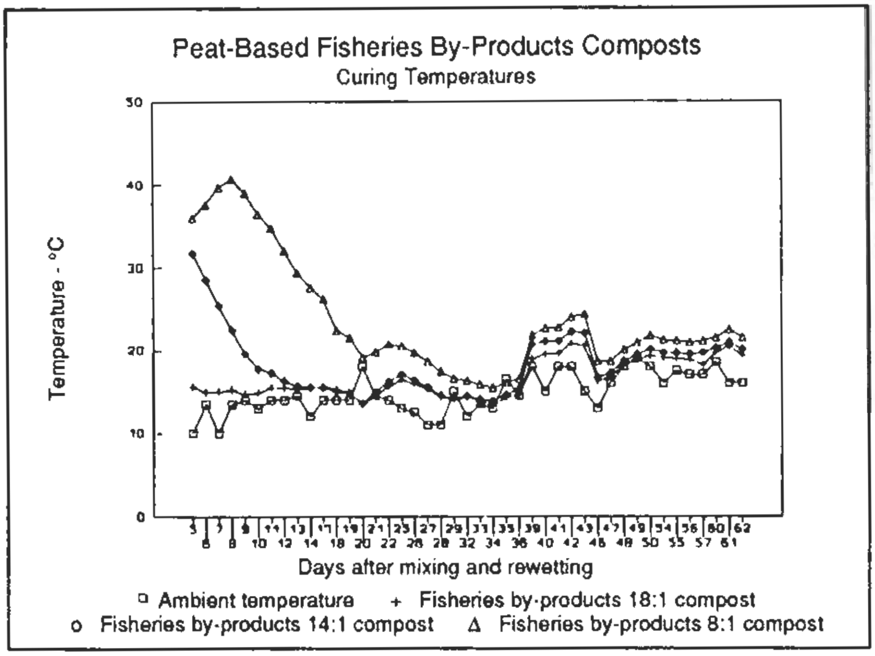
A compost is considered biologically unstable or immature if upon turning and rewetting a significant temperature increase (usually 10°C) is noted. In this project, all three composts were thoroughly mixed and rewetted (approximately 60% moisture content), then placed in uncovered barrels to determine the extent of self-heating. Temperatures were recorded on a daily basis until the compost temperatures were tracking ambient. These temperatures were then plotted graphically. Only two of the composts, fisheries by-products 8 to 1 and 14 to 1 composts, showed any significant heating after mixing and rewetting. The temperature plots for these two composts, along with the plot for the fisheries by-products 18 to 1 compost and ambient temperature are presented in Figure 2. Dehydration, influenced by low initial C to N ratios could have prematurely halted the degradation process. This test could be used as a rough estimate of maturity but should be used in combination with other tests that take into account other factors that directly influence plant growth. The temperature peak occurred within a week after mixing and rewetting for each of the two composts.

Nitrate Accumulation Test

The accumulation of nitrates in a compost can be a good indicator of maturity (Finstein and Miller 1984). Nitrate is the N form that is most available to plants. In the mineralization process, organic N is converted to ammonium, then to nitrite and finally to nitrate. This relationship is presented graphically in Figure 3 (Bunt 1976). This figure represents the changes in N forms and pH over time when organic fertilizer has been added to a sphagnum moss peat-based substrate.

FIGURE 2

Average peat-based fisheries by-products compost curing temperatures after mixing and rewetting (sample size = 5)



Compost also proceeds through these three stages of N conversion as part of the curing process. In Stage 1, the organic N is converted to ammonia, which combines with soil acids to form the ammonium ion with a resulting rise in pH. In Stage 2, the pH continues to rise as maximum ammonium accumulation occurs. The presence of ammonium is an indication of unstabilized materials (Zucconi and De Bertoldi 1987). It is at this stage, under alkaline conditions, when free ammonia can be present. Nitrite also exists at this stage. Free ammonia is toxic to plants, and the high pH can also cause micro-nutrient deficiencies. This toxicity gradually diminishes in Stage 3 as the pH falls below neutral and ammonium is converted to nitrite and nitrate through the nitrification process. Therefore, the accumulation of nitrate and the resulting drop in pH indicates a mature compost that can be used as a plant substrate without detrimental effects.

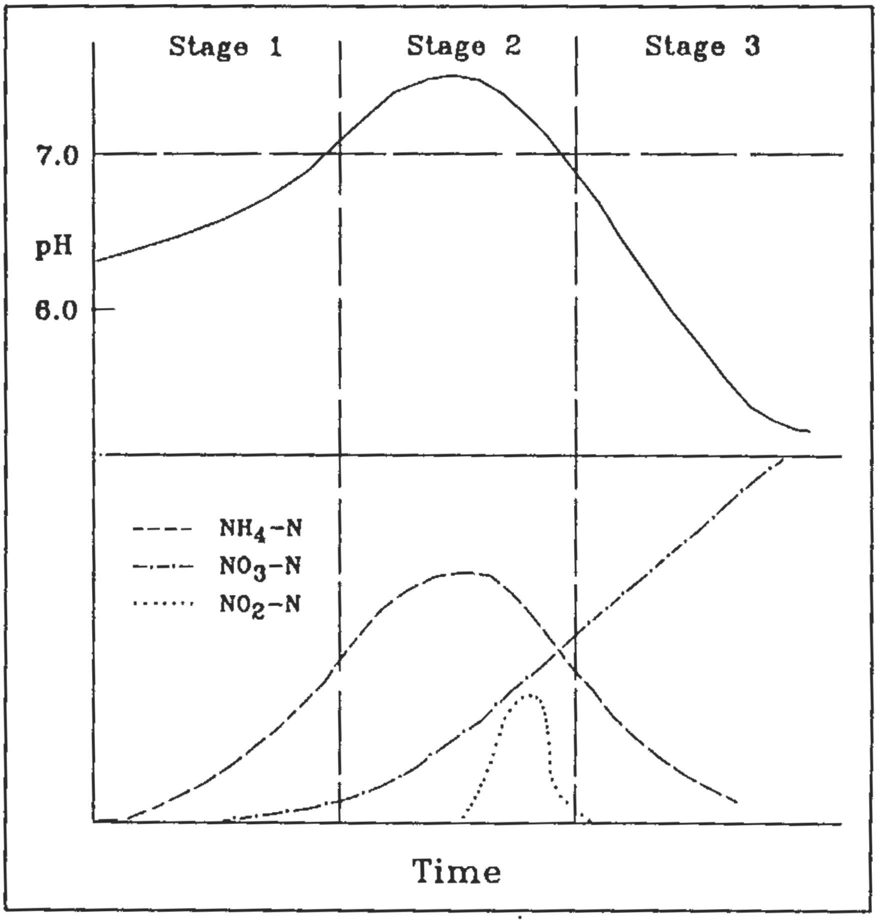
Table 4 includes the nitrate and ammonium concentrations, pH and germination index values for the composts. There was very little nitrate accumulation for any of the composts; therefore, the nitrate concentrations of the composts did not correlate well with the results of the germination index. The ammonium and pH values must also be taken into consideration.

Cress Seed Germination Bioassay

The cress seed germination bioassay developed by Zucconi et al. (1981) was included in this study as another measure of compost maturity. This test is particularly useful in determining the suitability of a

FIGURE 3

The changes in N forms and pH over time when an organic fertilizer is added to a peat-based substrate (Bunt 1976)



compost for use as a plant substrate in that it is a direct measure of the phytotoxicity of the material. During the composting process, toxins harmful to plant growth are produced. This test determines this toxicity at one point in time. It works best for regular monitoring of composts that are under optimum conditions for degradation and not merely stabilized by sterilization or dehydration. Composts that have been stabilized through dehydration can show a favorable germination index upon initial testing but can resume production of toxins as conditions again become favorable for degradation. An advanced test that takes into account this "latent toxicity" must be used to determine the maturity of composts that have been stabilized by means other than biological degradation and humification (Zucconi et al. 1984). Optimal conditions for microbial degradation were maintained for the composts tested in this study; therefore, the basic germination test was used.

A compost is considered safe for use as a plant substrate if the compost has a germination index higher than 60% (Zucconi et al. 1981). The results of the cress germination bioassay for the three compost

TABLE 4

Average compost pH, nitrate, ammonium and germination index values at 90 days curing time[1]

materials tested after 90 days of curing appear in Table 4. The compost extracts at 100% concentration were used to determine the germination index. The 100% concentration was used over the 30% and 10% concentrations to simulate the use of these composts as container substrates without the addition of other materials.

Compost	pH[2]	Nitrate[2] (ppm)	Ammonium[2] (ppm)	Germination Index[3] (percentage)
Fisheries by-products 18:1 compost (78% peat)	5.80 ± 0.20	5.64 ± 0.01	190.76 ± 5.75	91.1 ± 10.4
Fisheries by-products 14:1 compost (54% peat)	7.06 ± 0.06	5.57 ± 1.64	513.55 ± 55.36	59.2 ± 6.5
Fisheries by-products 8:1 compost (28% peat)	8.70 ± 0.00	1.54 ± 2.67	1,033.08 ± 5.41	2.6 ± 5.6

[1] Table contains arithmetic mean values ± standard deviation
[2] Sample size =3
[3] Sample size =10

The data in Table 4 suggest that compost maturity, as reflected in the germination index, is a function of a number of factors including pH, nitrate and ammonium concentrations. The composts that exhibited a low germination index–fisheries by-products 14 to 1 and fisheries by-products 8 to 1–were characterized by a high pH and a considerable ammonium concentration as compared to the fisheries by-products 18 to 1 compost. Free ammonia can be present when the pH of a compost is above the neutral point. Although nitrate accumulation is an indicator of compost maturity, these data show that maturity is more a function of pH and ammonium concentration. In the case of the fisheries by-products 14 to 1 and fisheries by-products 8 to 1 composts, high pH and ammonium levels resulted in low germination indexes. On the other hand, the fisheries by-products 18 to 1 compost has a relatively low ammonium concentration and a pH well below neutral, resulting in a high germination index. This underscores the importance of performing several tests for determining compost maturity.

The compost that appears to be most suitable for use as a container substrate from a maturity standpoint is the fisheries by-products 18 to 1 with its high initial C to N ratio. The other composts can improve with an extended curing time or dilution with other materials, or could be used as is for a fertilizer product or as a soil amendment.

Conclusions

Physical Characterization

The fisheries by-products 18 to 1 and 14 to 1 composts had physical properties quite similar to the commercial mix. The fisheries by-products 8 to 1 compost had the undesirable characteristics of low available water content and low air space. The physical properties of composts can be adjusted to within acceptable ranges by the addition of sphagnum moss peat, vermiculite, perlite or other components.

Chemical Characterization

The compost with the most potential for use as a container substrate, when compared to the commercial mix on the basis of pH, soluble salts and nutrient concentrations, is the fisheries by-products 18 to 1 compost. In general, composts with higher initial C to N ratios had chemical analyses most similar to that of the commercial mix and within horticultural guidelines. Nutrient concentrations were highest for composts that had lower initial C to N ratios. These composts could possibly be diluted by the addition of other inert or low nutrient materials to bring nutrient levels into an acceptable range.

Compost Maturity

The compost that appears to be the most suitable for use as a container substrate from a maturity standpoint is the fisheries by-products 18 to 1 with its high initial C to N ratio. The other composts could be improved with an extended curing time or dilution with other materials, or could be used as is for a fertilizer product or as a soil amendment.

In general, the fisheries by-products 18 to 1 compost appears to be suitable for use as a horticultural container substrate. The fisheries by-products 14 to 1 compost can also be used for this purpose with some modifications. The fisheries by-products 8 to 1 compost should only be used as a small component in container substrates (less than 10%) or as a soil amendment or fertilizer.

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The Use of Aquaculture By-Products as a Fertilizer for Idaho Crops

by Gail L. Olson, Idaho National Engineering Laboratory Center for Environmental Monitoring and Assessment

Introduction

Along the Snake River, in the Thousand Springs area of southern Idaho, water from the Snake River Plain aquifer seeps out of cliffs at a fairly constant temperature of about 59°F. The constant flow of clean, cool water has attracted over 125 fish farms and hatcheries to concentrate within a 20-mi. stretch of the Snake River. These fish farms produce about 65% of the nation's rainbow trout (USDA 1990).

Solids from fish farms (consisting mostly of fish manure, silt and feed) are aquaculture by-products. Although most of the solids occur naturally in free-flowing systems, unnaturally high concentrations from fish farming can pose environmental threats. When flushed into waterways, the by-products can cause algal blooms, increased turbidity, decreased dissolved oxygen and nitrate pollution (Liao 1970).

Regulators and fish farmers have traditionally viewed aquaculture by-products as a waste management problem; however, agronomic value could qualify aquaculture by-products as a soil additive with market potential. In the Thousand Springs area, an estimated 22 million gal. of aquaculture by-products slurry are produced annually, enough to fertilize several hundred acres of crops. Aquaculture by-products contain moderate amounts of essential plant nutrients (compared to other organic fertilizers), are easily land-applied in liquid form and are a practical fertilizing option for organic farmers.

Collection of aquaculture by-products varies from fish farm to fish farm, but generally involves vacuuming raceways and transferring the aquaculture by-products to collection basins. Some smaller fish farms with earthen rearing ponds allow aquaculture by-products to accumulate within ponds until fish harvest, then the aquaculture by-products are generally dried somewhat, backhoed and transferred to disposal areas. Some fish farms pump aquaculture by-products slurry through irrigation pipes.

For this study, aquaculture by-products from four fish farms were characterized for metals and nutrients. Three of the fish farms used separate collection basins, and the fourth was a small fish farm that allowed aquaculture by-products to accumulate in earthen rearing areas. Aquaculture by-products from one of the large facilities were used in field and greenhouse plant fertility studies, with favorable results. The aquaculture by-products performed equivalently to lower application rates of commercial fertilizer.

Study Methods

Aquaculture By-Products Characterization

At least three composited aquaculture by-products samples were collected from each of four fish farms. Three fish farms had concrete settling basins, and the other fish farm had earthen fish ponds where the aquaculture by-products accumulated on the bottom.

At three fish farms, subsamples were collected from the surface, subsurface, inlet and outlet of concrete settling basins (where practical) with a plastic measuring cup attached to an 8-ft. pole. Then, five to seven subsamples were thoroughly mixed in a lined bucket for a sample. One 500-ml. aliquot was containerized in a brown Nalgene bottle, labeled and stored on ice in a cooler for shipping. A clean plastic liner was used for the bucket for each sample.

The fourth fish farm consisted of four earthen fish ponds. Most of the aquaculture by-products collected at the downstream end of the ponds, so samples were collected there. Each pond was sampled. All samples were sent to Ward Laboratories in Kearney, Neb., for analysis of nitrate, ammonium, organic N, total N, P, K, pH and electrical conductivity.

Characterization of the aquaculture by-products for metals content was conducted in 1990, and a different method for collection was employed. For that, two samples from each of four fish farms were collected with a plastic cup attached to an 8-ft. pole. One of the two samples was collected at the collection basin inlet, and one at the outlet. No earthen ponds were sampled during 1990.

Fertility Studies

Greenhouse and field studies were conducted to compare aquaculture by-products to commercial fertilizer and a control. Aquaculture by-products slurry was used to grow sweet corn in the field study. Dried aquaculture by-products were used to grow spring wheat in the greenhouse study.

Greenhouse Study

In the first year study, dried aquaculture by-products at N application rates of 100, 200 and 300 lb./a. were compared to a control (nothing added) and to commercial fertilizer (16-16-16), which was also applied at rates of 100, 200, and 300 lb./a. There were seven replicates of each of the seven treatments, for a total of 49 pots (12-gal. pots). Each treatment was applied to the surface and incorporated to a depth of about 4 in. The growing medium was a Cornell mix, which consists of a mixture of sand, peat moss and vermiculite (1/3 each by volume). Three rows of Borah spring wheat were planted per pot, to a depth of about 1 in. Moisture meters were implanted in three different treatments to ensure that plants were receiving adequate moisture.

Results from the first-year study indicated that commercial fertilizer at rates of 200 and 300 lb./a. were excessive, so in the second-year study, rates of 50, 100 and 200 lb./a. were used instead. Aquaculture by-products were maintained at N application rates of 100, 200 and 300 lb./a. Results from the second-year study are not yet available.

Yield and biomass production were determined at the end of the growing season.

Field Study

In the first-year field study, sweet corn was grown on a sandy loam in a farmer's field near one of the fish farms. Plots were 6 rows wide by 30 ft. long. Treatments were: N application rates of 100 and 200 lb./a. using urea, once and twice over the plots with aquaculture by-products slurry (using a spreader truck), and a control. There were six replicates of each treatment. Each application was surface applied. When the aquaculture by-products were sufficiently dry (about two days), all plots were plowed to a depth of about 8 in. Plots were planted and sprinkler irrigated at the same time as the rest of the farmer's field.

Rates of total N application for the aquaculture by-products were about 600 and 1,200 lb./a. About 1/3 of this N in the aquaculture by-products is available the first year. Much of the ammonium N (which accounts for about 10%-14% of the total) is lost through volatilization. Most of the rest of the N is in the organic form, and only about 1/3 of that is available for plant uptake in the first year.

All plots accidentally received a starter fertilizer, which amounted to application of N at a rate of 40 lb./a.

Results

Aquaculture by-products contain essential nutrients for plant growth and do not contain high levels of metals commonly seen in municipal sludge. The consistency of aquaculture by-products slurry, similar to muddy water, allows for easy application with a spreader bar. Then, if allowed to dry before tilling, the aquaculture by-products are easily incorporated into the soil.

The fertility studies indicate that aquaculture by-products perform well as a fertilizer and add organic N to soil. Unlike manures, aquaculture by-products do not contain weed seeds and do not contain residuals from hormone treatments or vaccinations common to feedlot operations. Organic farmers can use aquaculture by-products without concern about these sources of contamination.

Results from Aquaculture By-Products Characterization

Nutrient concentrations of aquaculture by-products vary markedly by fish farm (Table 1). This variation is due to several factors, including type of fish feed and feeding system, type of pond, collection system and how long the aquaculture by-products were in the pond or basin. The longer aquaculture by-products are in the pond, the more nutrients are lost through volatilization and outflow.

The aquaculture by-products from earthen ponds contained lower nutrient levels than the aquaculture by-products from concrete settling basins, due to a larger proportion of low-nutrient sediments. Soluble salts were lower, and pH was higher. Aquaculture by-products from fish ponds were also lower in moisture content, due to the larger proportion of sediments and because the liquid portion that was collected with the solids was drained off when samples from the earthen ponds were collected.

Table 2 compares trace element concentrations in Thousand Springs area aquaculture by-products to sludge from a nearby wastewater treatment plant and with cow manure. The aquaculture by-products are considerably lower in all measured trace elements than the municipal sludge and slightly lower than the cow manure for all measured trace elements except Z. Aquaculture by-products generally are higher in N and P than most other manures are, except poultry manure (Figures 1 and 2).

TABLE 1

Results from nutrient analyses of Idaho aquaculture by-products, reported on a dry weight basis. Fish farms #1-3 contained isolated settling basins. Fish farm #4 consisted of earthen ponds with no settling basins

	Fish Farm #1	Fish Farm #2	Fish Farm #3	Average for Settling Basins	Fish Farm #4 - No Settling Basin
Total N (%)	5.49	3.76	3.15	4.13	0.87
NH_4 (%)	0.73	0.18	0.23	0.38	0.03
NO_3 (%)	0.0006	0.0009	0.0006	0.0007	0.0001
P (%)	3.51	1.34	1.60	2.15	0.70
K (%)	0.29	0.30	0.43	0.34	0.36
SO_4 (%)	0.40	0.2	0.40	0.34	0.16
Moisture (%)	88	92	83	88	54
Dry Matter (%)	12	8	17	12	46
Sol. Salts (mmho/cm)	3.9	2.3	1.6	2.6	1.3
pH	5.2	4.6	6.2	5.3	6.3

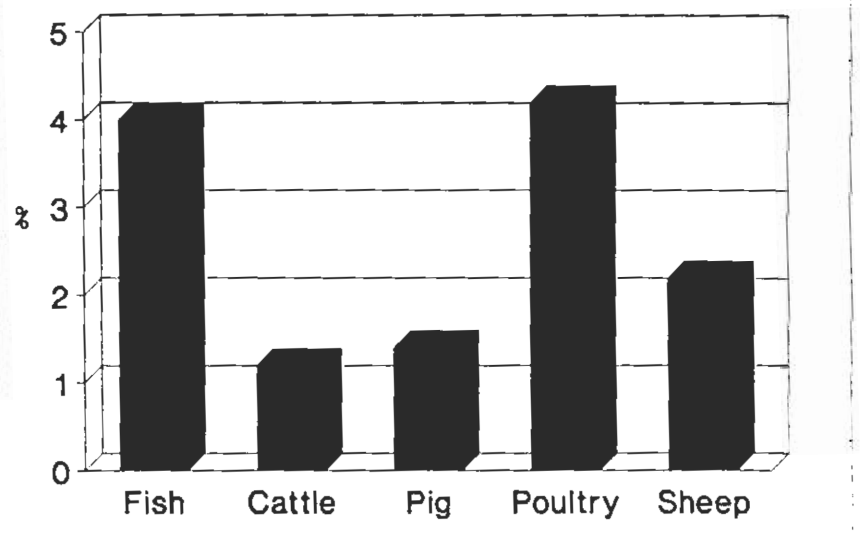
TABLE 2

Concentrations of toxic metals in Thousand Springs Area aquaculture by-products, municipal sludge from a nearby town and cow manure

Element	Aquaculture By-Products (ppm)	Municipal Sludge (ppm)	Cow Manure (ppm)
Cadmium	<2	7.9	2.5
Arsenic	< Detection Limit	24.2	6.1
Chromium	13	42.3	180.0
Copper	47	482.0	55.0
Nickel	7	23.4	28.0
Lead	5	80.4	17.5
Zinc	450	1,460.0	298.0

FIGURE 1

Percentage N in animal manures



Results from Fertility Studies

The greenhouse experiment demonstrated that yields from pots fertilized with aquaculture by-products at a N application rate of 300 lb./a. were not different than yields from pots fertilized with commercial fertilizer at 100 lb./a. (Figure 3). Yields from pots fertilized with aquaculture by-products at N application rates of 200 and 300 lb./a. were significantly higher than those from pots with comparable rates of commercial fertilizer ($p \leq 0.001$). Aquaculture by-products must be applied at higher rates in order to produce comparable results to commercial fertilizer, since most (about 90%) of the N in aquaculture by-products is in the organic form and is not available during the first year of production. Since it takes three times the aquaculture by-products to produce yields comparable to those of commercial fertilizer, it is hypothesized that about 1/3 of the total N in aquaculture by-products is available the first year of application.

FIGURE 2

Percentage P in animal manures

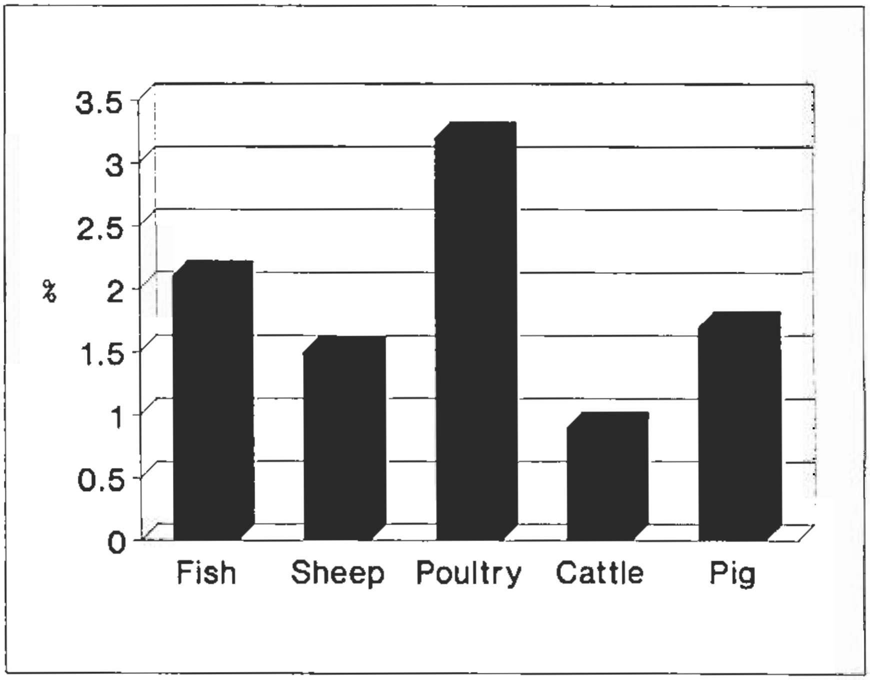
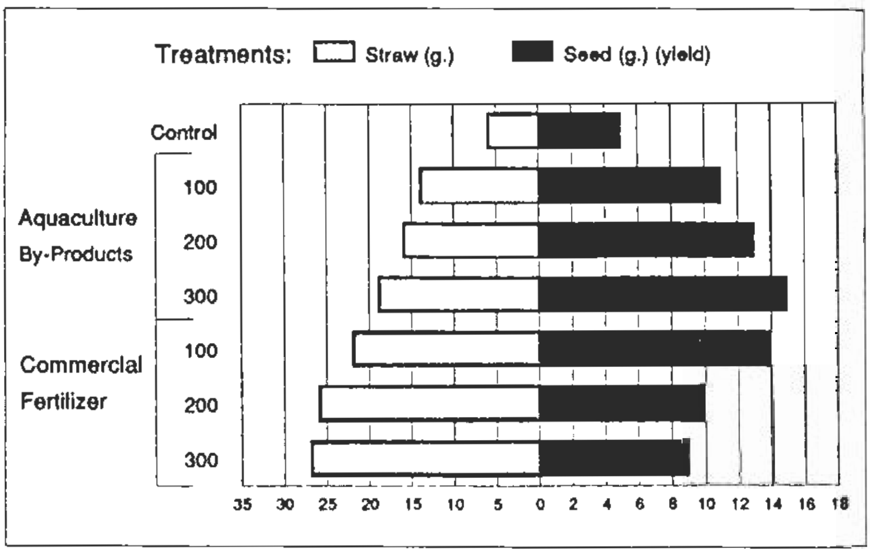


FIGURE 3

Greenhouse experiment: wheat seed and straw production by treatment



Yields from pots fertilized with aquaculture by-products increased with increasing rates of N application (M100 > M300, $p \leq 0.002$). Yields from pots fertilized with commercial fertilizer decreased with increasing rates of N.

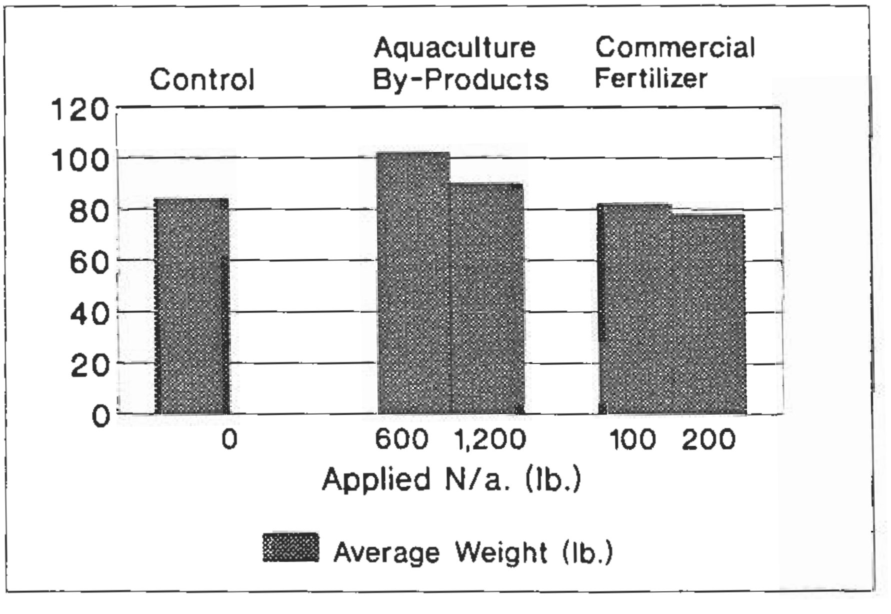
Straw production increased with increasing rates of N in both types of fertilizer treatments, but was substantially greater in the pots fertilized with commercial fertilizer (Figure 3). Treatments N200 and N300 exhibited signs of over-fertilization. Plants that are over-fertilized increase vegetative matter production at the expense of seed production. The harvest index (seed weight/total weight) indicates whether a plant is functioning efficiently. For spring wheat, a harvest index of 30%-45% is normal. The harvest indexes for the N200 and N300 treatments were below 30%. The N100, all the aquaculture by-products treatments and the control were within expected harvest indexes.

In the field experiment, the plots fertilized with one layer of aquaculture by-products (M1) performed better than all of the other treatments (Figure 4). The p-values for M1 versus the other treatments were as follows:

Treatment	p-value
Two layers of manure	$p \leq 0.01$
Urea (N 200 lb./a.)	$p \leq 0.03$
Urea (N 100 lb./a.)	$p \leq 0.09$
Control	$p \leq 0.07$

FIGURE 4

Field experiment: corn yields from different treatments



None of the other treated plots produced statistically higher yields than the control plots. This suggests that all plots were amply fertilized and that plots receiving high rates of nutrients were likely over-fertilized.

Limitations of Using Aquaculture By-Products in Agriculture

Although aquaculture by-products are easily spread with a spreader bar from the back of a tanker truck, there are some limitations associated with their use. Most obvious is that aquaculture by-products are malodorous. Although not a problem in the Thousand Springs area, which supports many cattle operations, odors could be problematic in more populated areas. Slurry injection is a technical solution to the odor problem, but it can be cost-prohibitive.

In slurry form, aquaculture by-products contain about 85% solids, of which 4% is N. Consequently, it takes a substantial amount of aquaculture by-products to fertilize a field. Trucking the aquaculture by-products can be costly, so it is usually only feasible to use aquaculture by-products on crops when the field is close to the source. Thousand Springs is surrounded by cropland, which makes aquaculture by-products fertilizing convenient. Another problem with using aquaculture by-products slurry is that it can crust over. Although it is normally plowed under after it dries, it can impede germination.

Composted aquaculture by-products form hard aggregates. For our greenhouse experiment, we had to grind the aquaculture by-products prior to applying and incorporating them into the soil. Under field conditions, the aggregates can remain relatively intact, and it can be several years before N in the aggregates would become available for plant uptake.

Most of these limitations apply to aquaculture by-products as the sole source of fertilizer. Some farmers in the Thousand Springs area have used aquaculture by-products as a supplementary fertilizer source on several crops for many years with no adverse effects.

Conclusions

Aquaculture by-products are a viable source of fertilizer for agricultural crops. Mixtures contain about 10% solids. Nutrient levels are variable by fish farm, but the average total N content is about 3.5%-4.0%. About 90% of total N is in the organic form, and about 1/3 of that is available during the first year of application. The rest carries over to the next year or is lost through leaching, volatilization or run-off. Aquaculture by-products do not contain elevated levels of heavy metals and in slurry form are easily applied to cropland with a tanker truck with a spreader bar.

Limitations to using aquaculture by-products are odor and a propensity to form a crust when dry. If aquaculture by-products are not thoroughly plowed into the soil, some plants could be unable to push through the crust.

In field and greenhouse fertility studies, aquaculture by-products performed as well as commercial fertilizer in the production of sweet corn and spring wheat. Spring wheat yields from aquaculture by-products were comparable to yields from commercial fertilizer applied at 1/3 the rate of N application. This is presumed to support the hypothesis that 1/3 of the N in aquaculture by-products is available during the first year. In the field study, plots with aquaculture by-products at low application rates did better than all other plots. High application rates of aquaculture by-products and both treatments with urea did not produce more sweet corn than the control plot.

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Fisheries By-Products Utilization in British Columbia: A Case Study

by Niels E. Holbek, University of British Columbia Research Farm; E. Lam, Malaspina College Aquaculture and Fisheries Department, British Columbia; K.V. Lo, University of British Columbia Bio-Resource Engineering Department; M.A. McDonald, University of British Columbia Forest Sciences Department, and J.C. Willow, Ministry of Agriculture, Fisheries and Food, British Columbia

Introduction

The Province of British Columbia, like many other jurisdictions in North America, has over the past few years implemented strategies to reduce, reuse or recycle. These policies and other external factors have had a direct impact on the provincial fish production and processing sectors. In 1990-91, Industry Science and Technology Canada, a federal agency, and the Province of British Columbia Ministry of Agriculture, Fisheries and Food (MAFF) funded the British Columbia Aquaculture Research and Development Council to assess the magnitude of fisheries by-products generation, current utilization and potential future options for enhancing utilization.

The study found quantification difficult due to inconsistent data, proprietary concerns related to production information and insufficient data collection. Using the most recent information, the following profile was developed. In 1988, British Columbia produced approximately 109,000 T. of offal and 1,600 T. of fish mortalities. The offal was derived from ground-fish processing (41%), from the herring roe fishery (27%) and from salmon processing (17%), with the balance made up from a number of other species (Ming 1991). Of the total, 21,000 T. were rendered into meal and oil, 5,000-10,000 T. were sold commercially for animal feed and approximately 700 T. were composted. The balance, 80,000 T., was dumped in landfill sites.

The fisheries by-products problem in British Columbia has been aggravated over the past few years for a number of reasons. Pollution control regulations and odor abatement objectives for rendering plants have resulted in higher quality standards for offal received. Limited plant capacity during seasonal fisheries, when the tonnage caught is high, can restrict accessibility. Remote processing plants, lacking rendering capability, have been particularly impacted as quality standards, fluctuating volumes and transportation costs have made the rendering option economically unattractive. Although new technology allows improved recovery and a higher quality product to be produced, investment in new capital has been limited. Other portions of the industry have appeared more profitable than rendering. This is particularly true for fisheries-based reduction plants, which are frequently attempting to service high capital costs on a seasonal basis. Competition with the historically inexpensive landfill option has also been an inhibiting factor.

A portion of fisheries by-products volume, such as dogfish, is unsuitable or unacceptable for rendering for various reasons. This portion has traditionally been destined for landfill.

The introduction of fish farming to British Columbia began in the early 1970s. Aggressive industry development focused on site selection and production issues and failed to give adequate attention to the problems associated with the disposal of fish mortalities. During the early years of fish farming, the farmers were permitted by the Ministry of Environment to dispose of the mortalities in "mort" pits. This practice has subsequently fallen into disfavor due to poor management practices and government policies designed to reduce land filling and to recycle suitable portions of the waste stream. The limitations placed on "mort" pits and the quality standards imposed by rendering plants have left the fish-farming industry with very limited options. Ocean dumping has not been permitted.

Since 1989, the University of British Columbia and MAFF have been challenged to assist in arriving at solutions to the fisheries by-products utilization problem. The focus areas have been the production and utilization of acid-ensiled fisheries by-products and the composting of ensiled fish mortalities and fresh offal. The objective of this paper is to give a brief overview of the activities of these two agencies over the past few years. The work carried out to date includes scientific studies, extension publications, operational experience and project development, including insights into the public reaction to a proposed compost facility.

Acid Ensiling of Fisheries By-Products

Acid ensiling relies on autolytic digestion to provide liquefaction. Optimal rates of liquefaction are a function of temperature, mixing, particle size, enzyme quantity, pH, and the nature and condition of the substrate being digested. Biological decomposition is inhibited through the addition of organic or inorganic acids. The result of successful acid ensiling is a stable product, which can be stored for extensive periods of time and handled with relative ease as a liquid. This process was viewed as a waste management technique that could be utilized by remote fish farms with limited disposal options to store fish mortalities prior to composting or other utilization options.

In 1990, MAFF published an extension document entitled *Ensiling Salmon Mortalities: Suggested Guidelines for B.C. Salmon Farmers*

(Carswell et al.). This booklet is currently being revised with new information, based on laboratory work and field experience. Of recent interest is the use of citric acid either as the sole acidifier or in combination with other acids.

Composting Ensiled Fish Mortalities

The work on ensiling techniques was undertaken, at least in part, with the assumption that silage could be effectively composted. This assumption was evaluated in 1991 (Lo 1991) with a laboratory scale trial conducted by the University of British Columbia Bio-Resource Engineering Department in Vancouver.

Six 55 l. PVC reactors, insulated with RSI-1.4 fiberglass were used for the study. The reactors were divided into three groups of two reactors. One group of reactors was inoculated with 0.23 kg. of swine manure, the other was composted without any swine manure. An equal amount of fish silage (6.8 kg.) was added to each reactor. Varying quantities of three bulking agents were employed to achieve a suitable moisture content for composting. Wood shavings (4.5 kg.), hog fuel (11.4 kg.) and wood chips (15.9 kg.) were used to give corresponding moisture contents of 62%, 67% and 58%.

Lime was added at the time of mixing to achieve a pH of approximately 7, and continuous aeration was supplied at a fixed rate of 0.2 l./minute/kg. of volatile matter. The composting process was evaluated by monitoring temperature, moisture content, C content, total N, C to N ratio and pH. The initial conditions of the raw materials can be seen in Table 1, and the parameters monitored in the trial are summarized in Table 2. Temperature profiles are shown in Figure 1. Temperature was monitored using Precision Centigrade Temperature Sensors (LM35) and the results recorded on an AD-5312 Multi-Logging Meter. Samples were dried in an oven at a temperature of 105°C for 24 hours, and moisture was then calculated. After drying for moisture content analysis, the samples were burned at 550°C for 25 minutes. C content was then calculated on the basis of ash residue as follows (on a dry weight basis): $C\% = (100\text{-Ash})/1.8$. Total N was analyzed on a FP-228 Nitrogen Determinator (LECO). The pH was determined by adding 50 ml. of deionized water to a 10 g. sample. The contents were stirred several times in the first half hour, then left standing for an additional hour. Thereafter, pH was measured using a Good Digital pH/mV/Temp meter (Model 201ATC).

All treatments attained thermophilic conditions and remained at or above 55°C for more than three days. The addition of swine waste to provide a starter culture was not necessary. It is assumed that the bulking agent or the silage provided sufficient inoculum for the process to proceed. The addition of the swine waste inoculum does not appear to have affected the rate of biological activity.

TABLE 1

Initial conditions of the raw materials

	MC, %	C, % (d.b.)	TN, % (d.b.)	pH
Fish silage	88.8	54.5	17.6	3.6
Pig manure	80.5	53.7	3.3	7.6
Wood shavings	51.4	55.4	0.3	4.1
Hog fuel	63.4	55.1	0.2	5.0
Wood chips	57.5	53.7	0.0	4.8

TABLE 2

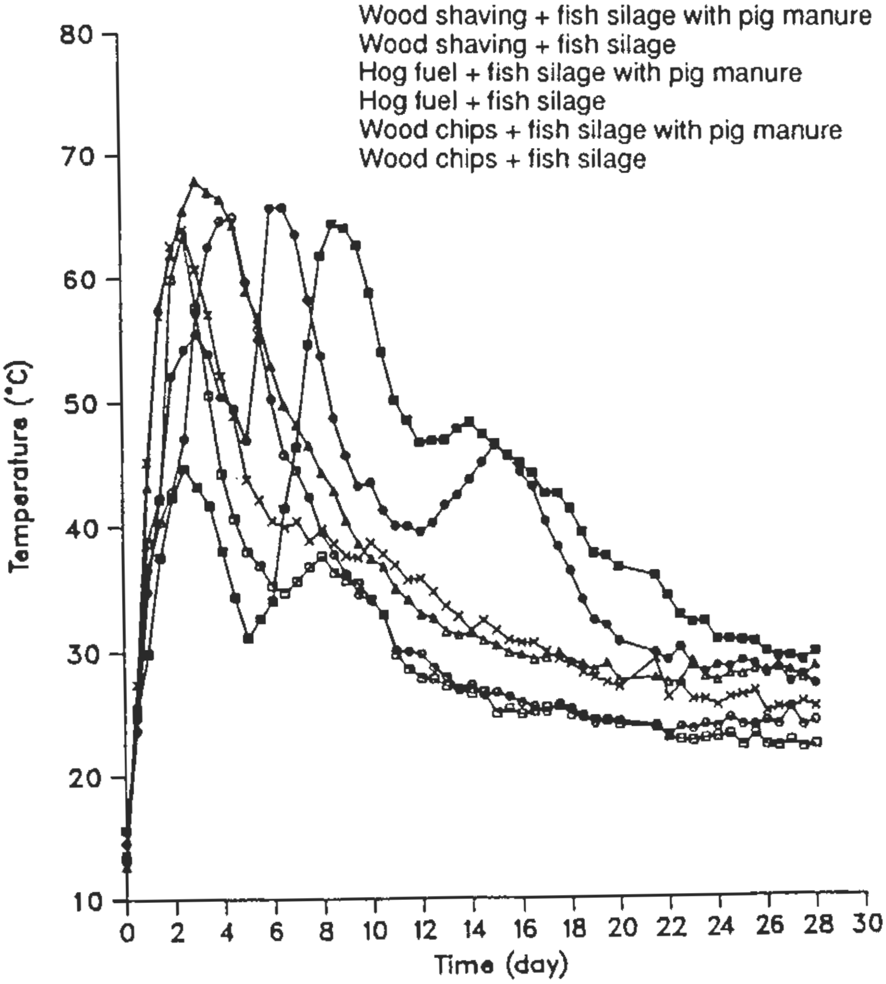
Parameters monitored in fish silage composting

Treatment	A1		A2		B1		B2		C1		C2	
Time, day	0	31	0	31	0	31	0	31	0	31	0	31
MC, %	61.8	31.4	62.5	35.5	67.6	62.3	66.2	66.3	58.8	55.5	58.0	54.7
MC change, %		49.5		43.2		7.8		-0.2		5.6		5.7
C, % (d.b.)	53.7	51.9	53.8	51.8	54.2	53.9	54.1	52.8	54.6	54.2	54.4	54.3
C loss, %		3.4		3.7		0.6		2.4		0.7		0.2
TN, % (d.b.)	2.37	1.75	2.61	1.62	1.63	1.58	1.84	1.65	0.97	0.59	0.92	0.48
TN loss		26.2		37.9		3.1		10.3		39.2		47.8
C/N	23.2	29.7	20.6	32.0	33.3	34.1	29.4	32.0	56.3	91.9	59.1	113.0
pH	7.5	8.1	7.2	8.1	7.0	8.0	6.9	8.9	7.7	8.0	6.9	8.1
P, % (d.b.)	0.43	0.56	0.43	0.48	0.35	0.38	0.36	0.42	0.28	0.33	0.24	0.26
K, % (d.b.)	0.36	0.60	0.37	0.49	0.28	0.45	0.31	0.41	0.27	0.31	0.23	0.32

NOTE: A1: 10 lb. of wood shavings and 15 lb. of fish silage with inoculation of 0.5 lb. of pig manure
A2: 10 lb. of wood shavings and 15 lb. of fish silage
B1: 25 lb. of hog fuel and 15 lb. of fish silage with inoculation of 0.5 lb. of pig manure
B2: 25 lb. of hog fuel and 15 lb. of fish silage
C1: 35 lb. of wood chips and 15 lb. of fish silage with inoculation of 0.5 lb. of pig manure
C2: 35 lb. of wood chips and 15 lb. of fish silage

FIGURE 1

Temperature profiles



The study concluded that the pH of the fish silage should be adjusted to approximately 7 for optimal microbiological activity. Low moisture bulking agents, such as paper, should be considered in order to achieve a moisture content near 60%. Optimal aeration in the experimental reactors should take place for 50 minutes every four hours at a rate of 0.2 l./minute/kg. of volatile matter. The hog fuel compost produced, conserved the most N with a ratio of N to P to K at 4 to 1 to 1.

The composting of fish silage has raised some concern about the impacts of antibiotic therapy on fish silage and compost generated from fish silage. A recent report (Karreman and Klotins 1991) concluded that potential antibiotic residues/metabolites in compost are not considered an issue. Plant uptake of possible residues/metabolites is not considered a concern as plants do not translocate these substances through roots. No explicit testing of potential residues appears to have been done to date.

Survival of Potential Salmon Pathogens in Acid-Supplemented Fish Silages

The transfer of potential pathogens through the transport and disposal/utilization of fish mortalities was viewed with concern. The antimicrobial properties associated with ensiling as reported in the literature (Bylund and Wiklund 1987) was viewed as a positive characteristic of the process. In order to affirm the results in the literature and evaluate the survival of potential salmonid pathogens of concern in British Columbia, a trial was undertaken by Lam and Holbek (1991) to assess pathogen survival in salmon silage. The microbiological work was conducted at Malaspina College Aquaculture and Fisheries Department.

Silages were prepared using fresh fish mortalities. A formic acid silage (3% wt/wt, pH 3.6), a sulfuric acid silage (3% wt/wt, pH 2.1) and a combination sulfuric/formic silage (6 to 1, 3% wt/wt, pH 2.7) were produced per MAFF recommendations (Carswell et al. 1990).

The silages were inoculated with the following pathogens: *Y. ruckeri, A. salmonicida, V. anguillarum, V. ordalii, R. salmoninarum, M. fortuitum*, IPN virus and IHN virus. All the pathogens, except IPN virus and *M. fortuitum* were isolates from fish mortalities in British Columbia. The cultures of IPN and *M. fortuitum* were provided by the Pacific Biological Station, Nanaimo, Department of Fisheries and Oceans.

Aliquots (90 ml.) of each silage were inoculated with 10 ml. of each of the pathogens in log phase growth (Table 3). Estimates of pathogen concentration in each aliquot were made by doing serial 10-fold dilutions and plating .025 ml. drops of each dilution on solid media. Tryptic soy agar was generally used for plating, but salt (1.5%) was added to enhance the culture of vibrios. The other exceptions were the use of KDM-2 for the culture of *R. salmoninarum* and a Lowenstein-Jensen selective medium (PML Microbiologicals) for the culture of *M. fortuitum*.

After four hours, 24 hours and, where required, four days and 30 days incubation at 15°C , a 4.5 ml. sample was removed from each pathogen-inoculated silage, diluted to 50% with 4.5 ml. sterile tryptic soy

TABLE 3

Size of inoculum added to each aliquot of silage

Pathogen	Inoculum (CFU/ml.)
V. anguillarum	2.6 x 10 ^8
V. ordalii	4.8 x 10 ^6
A. salmonicida	7.2 x 10 ^8
Y. ruckeri	6.8 x 10 ^8
M. fortuitum	4.4 x 10 ^7
R. salmoninarum	3.2 x 10 ^5
IHN	1.2 x 10 ^6
IPN	3.9 x 10 ^5

broth and neutralized (pH 6.8) with filter-sterilized 5 N sodium hydroxide. With sterile tryptic soy broth as a diluent, serial 10-fold dilutions were made for each sample and all dilution tubes were incubated at 15°C.

Four days later, each dilution in the series was examined for cloudiness, an indicator of possible bacterial growth. From each suspect (cloudy) dilution tube, a loopful of material was removed and inoculated on tryptic soy agar. Any resulting colonies were confirmed biochemically and serologically as being identical to the pathogen inoculated, using the procedures described in the Manual of Compliance to the Canadian Fish Health Protection Regulations.

Exceptions to these procedures were made for evaluating the survival of *R. salmoninarum* and the two viral pathogens, IHN and IPN. *R. salmoninarum* was diluted with sterile KDM-2 and incubated at 15°C for six weeks. The survival of IPN and IHN was evaluated by taking 1 ml. samples from the pathogen inoculated silage and diluting to 10% with MEM-10 containing antibiotic-antimycotic and HEPES buffer. Serial 10-fold dilutions were made, and from each dilution a 1 ml. sample was inoculated, in duplicate, on preformed monolayers of EPC and CHSE-214 cells. The cells were subsequently checked every other day for cytopathic effects, which would indicate the presence of virus.

M. fortuitum survived four hours of incubation in all of the silage mixtures. *Y. ruckeri* survived only in the 3% (wt/wt) sulfuric (pH 2.1) silage for four hours.

No confirmed growth of any of the inoculated pathogens could be detected beyond 24 hours of incubation in any of the three silage mixtures tested. It appears that the ensiling process effectively renders the pathogens tested innocuous within 24 hours, provided that the ensiling is properly conducted. The use of ensiling technology on fish farms appears to be an appropriate method to reduce the risk of potential pathogen transfer from fish mortalities.

The Use of Acid-Supplemented Fish Silage as a Forest Fertilizer

The University of British Columbia Forest Sciences Department (McDonald et al. n.d.) is currently involved in a major study with the Greater Vancouver Regional District examining the environmental impacts and effects on forest productivity of using anaerobically digested sewage sludge as a forest fertilizer. As a satellite trial to this study, plots were established in a nine-year-old western red cedar plantation on Northern Vancouver Island to examine the efficacy of ensiled fish mortalities as a forest fertilizer. Clarifier sludge from the Western Pulp Ltd. mill at Port Alice has been added to both sewage sludge and fish mortalities in an attempt to slow the release of N available from these organic materials.

Two replicated blocks including the following treatments were established: (1) control, (2) ash, (3) fish silage/ash/pulp mill sludge, (4) inorganic fertilizer, (5) sewage sludge/pulp mill sludge, (6) fish silage/ash and (7) sewage sludge. The plots treated with fish silage/ash and fish silage/ash/pulp mill sludge were 15 m. by 15 m., totaling 225 sq. m. All plots, with the exception of the inorganic fertilizer, were treated to provide the equivalent of 500 kg./ha. N. The inorganic fertilizer was applied at a rate 225 kg./ha. N in the form of ammonium nitrate and 75 kg./ha. P in the form of triple superphosphate. The fish silage contained 2% N and was applied at the rate of 562.5 kg. of silage on 225 sq. m. for a rate of 25,000 kg./ha. Ash from the pulp mill was added to the silage at a rate 112.5 kg./225 sq. m. in order to raise the pH of the silage mixture. The soils in this area are podzolic with a pH in the 3-4 range. The fish silage treatments incorporating pulp mill sludge included sludge at an equivalent 1 to 1 rate, 562.5 kg./225 sq. m. The fish silage treatments were applied by mixing the constituents in a tank and applying the mixture by pump and fire hose.

The effects on tree height and diameter increment, foliar nutrient uptake, soil water nutrient movement and forest floor decomposition rate are being monitored. The first data were collected in August 1991. The results of height and diameter growth were the only data available at the time of publication. These results are presented in Table 4. While the height growth for the inorganic fertilizer is significantly greater than the other treatments, this could not be maintained over time as the other treatments release organically bound N.

Preliminary data indicate that the fish silage/ash treatment contributed to significantly improved height growth over the control and that the fish silage/sludge/ash treatment contributed to both a significantly higher height and diameter over the control.

TABLE 4

First year tree growth

Treatment	Height Growth (cm.)	Diameter Growth (cm.)
Inorganic fertilizer	208.2	35.0 *
Fish/ash	203.0 *	31.7 **
Sewage sludge	202.0 *	35.9 *
Sludge/pulp	199.4 *	29.8 **
Fish/ash/pulp	193.6	34.9 *
Control	187.1	30.7 **
Ash	179.7	28.8

* means with the same asterisks are not significantly different ($p < 0.05$)

** because of differences in the original height of the trees on different blocks, analysis of covariance was used. These are adjusted means.

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Fish Composting Facility

Several years ago the University of British Columbia Research Farm at Oyster River on Vancouver Island was approached by a local fish farmer seeking an alternate disposal option for his fish mortalities. The Research Farm is principally a dairy operation with 350 head of cattle on a 600-ha. land base. The initial reaction to the fish dilemma was to attempt to assist with the problem. The plant nutrient constituents of the fisheries by-products, the organic matter content and the opportunity to participate in a solution to an environmental problem through recycling was more than sufficient justification for participating in developing solutions.

The initial approach to dealing with the fish mortalities was simply to incorporate the fisheries by-products into the solid manure handling system and permit a static composting process to proceed. The solid manure from the cow and calf pens is stored outside on a well-drained site. While this approach worked reasonably well, handling problems and odors from untreated fish mortalities, particularly at the time of delivery, raised concerns among staff and nearby neighbors.

In due course, it became apparent that one fish farmer's problems were shared by many and word of university involvement spread rapidly. The Research Farm was surprised by inquiries from local processors who were also plagued with a number of difficulties in utilizing or disposing of fish by-products. The Research Farm agreed to accept this additional volume. It soon became clear that the volume of bulking agent generated in the livestock operation would be inadequate for the quantity of fisheries by-products being delivered. Abundant precipitation, normally experienced during the fall and winter months, aggravated this deficiency.

The Research Farm manages most of the manure volume in a liquid form. Manure scraped from the barns undergoes solid-liquid separation, and the liquid portion is stored in a large manure pit with a capacity exceeding one year. A strategy was developed to incorporate fisheries by-products into this system. The methodology pursued was to incorporate fisheries by-products into the manure system prior to separation. A ramp was constructed to allow bulk unloading, and a tote invertor was borrowed to permit facilitated handling of fish mortalities arriving in totes. A finisher/shredder was purchased to grind the fish and was installed at the receiving area. Fish were dumped into a hopper, then chopped and deposited by gravity into the manure receiving channel. Subsequently, the slurry and fish mixture was passed over the solid-liquid separation devise. The solids were stockpiled, and the liquid was stored in the pit.

Unfortunately, the system did not work well. Chopping the fisheries by-products took much more power than initially imagined. The 25-horsepower finisher/shredded intake was reduced significantly in size to permit a continuous flow through the device. However, when this problem was overcome, the fish oils created ongoing problems with two solid-liquid separation devices. The fish oils plugged the screens. In addition, we became concerned about additional odors generated at the site — beyond the odors from dairy manure, which already troubled neighbors from time to time. This approach was abandoned in the early spring of 1990. We continued temporarily with our static pile composting; however, this activity was also suspended when it became clear that we were not in a position to effectively accommodate the volume of fisheries by-products in the region. As many processors and fish farmers had come to rely on the Research Farm as the only disposal or utilization option available to them, a meeting of all interested paries in the region, including relevant government agencies and a regional community group, was called to review the problem.

The result of the meeting was that MAFF took a lead role in arriving at a solution to the problem. Short- and long-term solutions were identified as critical. One-year approvals were provided by the British Columbia Ministry of Environment to two existing wood waste landfill permits, resolving the immediate problem.

MAFF concluded that whatever solutions to the problem were contemplated, on-farm acid ensiling of fish mortalities offered a potentially desirable method of on-farm handling, storage and pathogen control. Furthermore, an ensiled product increased utilization options and was expected to be compostable. The British Columbia Salmon Farmer's Association and individual farmers expressed serious interest in the ensiling option, and MAFF initiated development work (Carswell et al. 1990).

Proposals for a long-term solution to the problem were invited by MAFF. MAFF indicated that funding assistance from the Sustainable Environment Fund might be available to the successful proposal. The University Research Farm, with previous experience handling fisheries by-products, a keen interest in "waste management" and a large, suitable land base submitted a proposal to construct an agitated, open, in-vessel composting system capable of handling regional volumes estimated at 2,500 T./year. This proposal was selected following industry review, technical assessment and regional consideration. The research component, technology transfer, technical merit and user involvement in the operation of the facility were cited as the reasons that the university's proposal was selected.

The capital budget for the project was estimated at $955,000. The Provincial Sustainable Environment Fund provided an initial contribution of $300,000. The Mt. Washington Community Futures Committee, with access to federal funding through the Initiatives program of Immigration and Employment, Canada, was successful in securing $430,000. Accessing these funds was based, at least in part, on the project's employment generation, employment preservation and import substitution merits. Fifteen industry members representing fish processors and fish farmers each contributed $10,000, and the University of British Columbia provided the $75,000 balance. The funding package was completed in a six-month period with excellent cooperation among the funding principals. An initial operating loan was also secured. The business plan for the facility projects financial self-sufficiency in the third year of operation. Operating costs will be recovered through tipping fees and compost sales. Any surplus revenues will be used for education and research purposes.

During the funding drive, the Pacific Bio-Waste Recovery Society (PACBIO) was incorporated to oversee the operation of the facility. The nonprofit society consists of directors representing industry, the Mt. Washington Community Futures Committee, MAFF and the university.

PACBIO decided in the early stages of the project that all regulatory requirements would be addressed. This was critical, as there were questions about the need to acquire a waste management permit since no regulations were in place for this type of facility and no waste was being discharged. In addition, it appeared questionable as to whether land zoned agricultural required rezoning. A waste management permit, regional rezoning and approval from the Agricultural Land Commission were all pursued.

Upon confirmation of funding, a community information meeting was held on March 27, 1991, to advise local rural residents of the nature of the project. Some opposition was expected; however, the level of emotion among a portion of the community opposed to the project was surprising. PACBIO erroneously assumed that this type of environmentally friendly project would be well accepted in a community that tends to view itself as green. Subsequently, on May 16, 1991, an open house to discuss the project was held at the Research Farm.

A public hearing required for rezoning was held May 21, 1991. The proponents were ill-prepared for the emotional outcry that was precipitated, based largely on poor information. Local concerns included odors, leaching, traffic, disease transfer, rodents, property values and composting of other organic wastes. The regional government decided not to make a decision on the rezoning as new information came to light from other agencies following the public hearing. Instead, the regional government hosted two days of public information meetings and scheduled a second public hearing.

Due to the complexity of the project, the acceptability of the site to regulatory agencies and the benefits of an agricultural environment, PACBIO determined that alternative locations would not be desirable and could result in the project being compromised. At this point, PACBIO recognized the need to address the absence of accurate information in the community. Therefore, a qualified individual was hired to undertake community liaison activities, prepare an information package, assess the level of community concerns and organize the society's response to the next public hearing. The second public hearing was held on September 9, 1991. This hearing was dramatically more positive and included residents who originally opposed the proposal speaking in favor of it.

The role of the community in these type of projects should not be underestimated. Suggestions and concerns from the public have resulted in a number of improvements. Among the changes are a minor relocation, a totally contained system of wastewater management, a composting toilet, and a fully enclosed mixing and composting area complete with an air-conditioning system comprised of a scrubber and a bio-filter.

During the public process, PACBIO proceeded with the preliminary engineering work.

Conclusions

A number of conclusions can be drawn from the British Columbia experience as it relates to fisheries by-products composting.

Large quantities of fisheries by-products are destined for landfills in British Columbia — an estimated 80,000 T. (Ming 1991) in 1988. Composting is a viable method, albeit a low end use, for fisheries by-products.

The fisheries by-products compost market for British Columbia is estimated to be 10.4 million l./year or approximately 5% of the total soil conditioner market for the province (Ferrence 1991). Given a constant demand across Canada, the national market would be 69.9 million l./year.

While alternative or improved technologies for handling fisheries by-products are being explored, dramatic changes do not appear imminent. Improved returns for fish meal would undoubtedly result in new investment in this area; however, there do not appear to be good reasons to expect such changes. The potential for specialty products and pharmaceuticals from fisheries by-products holds future promise. Such extraction is not expected to reduce fisheries by-products volumes substantially.

Should higher and better uses for fisheries by-products become economical in British Columbia, many other portions of the organic waste stream have potential for composting.

The ability of the various agencies to work in concert to arrive at solutions to the fisheries by-products problem has been very productive. Acid-ensiling techniques provide fish farmers with an economical and effective method to process fish mortalities. Potential pathogen transfer is inhibited through this process. Fish silage has demonstrated compost efficacy as a forest fertilizer.

The Pacific Bio-Waste Society, a consortium of community, industry, government and university interests, has successfully secured capital funding to construct an agitated, open, in-vessel composting facility to address a regional fisheries by-products problem. Community concerns should not be underestimated and must be appropriately addressed to the extent reasonably possible when dealing with change and wastes locally.

Many people and organizations are interested in learning more about fisheries by-products composting. Several composting initiatives in British Columbia have experienced start-up problems in attempting to compost fisheries by-products. The Pacific Bio-Waste Recovery Society looks forward to the opportunity to work and associate with other organizations involved in composting activities.

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Use of Extracts from Fisheries By-Products and Peat Compost in Fermentation Processes

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Abstract

Extracts of a compost of fisheries by-products and sphagnum peat were utilized as a substrate source in the growth of microorganisms in submerged fermentation processes. It is expected that the production of compost utilizing sphagnum peat and fisheries by-products should be an easy and inexpensive process. Because of this, it was thought that extracts of this compost could provide economical culture media in coastal areas where there are limitations in the availability of other by-products generally utilized in fermentation processes. Experiments were conducted growing species of fungi and yeast that could be used as sources of microbial biomass protein for the feeding of animals. These experiments included the feeding of cultivated fish, in which the protein produced by fermenting fisheries by-products and sphagnum peat compost extracts was incorporated successfully into the diet.

Introduction

Sphagnum peat has a high adsorptive and absorptive capacity (Fuchsman 1980), and it is claimed that the ammonia liberated during the process of composting sphagnum peat with fisheries by-products is absorbed by the sphagnum peat fibers. Sphagnum peat composting could be a commercially viable operation (Mathur et al. 1988). It has been reported that the final product fulfills the criteria established for a good quality compost, including earthy odor and appropriate concentrations of nutrients (Mathur et al. 1986).

Liquid extracts from sphagnum peat produced by acid hydrolysis have been tested as a source of fermentation substrates (LeDuy 1979; Fuchsman 1980; Martin 1983 a,b; Manu-Tawiah and Martin 1987). As is the case with many other fermentation substrates, sphagnum peat hydrolysates basically provide carbohydrates for microbial metabolism, acting as a source of C and energy. Generally, those substrates need to be supplemented with other nutrients, such as sources of N, to be effective in supporting high concentrations of microbial growth and the production of associated metabolic products. In general, those supplements constitute an important part of fermentation process costs.

The production of fisheries by-products and sphagnum peat compost is an easy and inexpensive process, and the concentrations of nutrients such as N and P are higher in the product than in the original sphagnum peat. Therefore, it was considered that extracts from the compost could provide a more economical, nutrient-enriched fermentation medium than nutrient-supplemented sphagnum peat extracts. This work presents results of growing the fungus *Scytalidium acidophilum*, which is a promising source of microbial biomass protein, in fisheries by-products and sphagnum peat compost extracts. Preliminary information about the cultivation of the yeast *Candida utilis*, another good microbial protein source, in the compost hydrolysates, is also presented.

Materials and Methods

Materials

The fisheries by-products and sphagnum peat compost was supplied by the St. Shott's Rural Development Association, Newfoundland, and by the Land Resource Research Institute, Agriculture Canada, Ottawa, Ontario. The sphagnum peat moss was obtained from Peat Products Ltd., St. John's, Newfoundland.

Production of Sphagnum Peat and Compost Extracts

Sphagnum peat and compost, individually, were mixed with dilute sulfuric acid and autoclaved at 121±1°C (15 psig) for approximately two hours. The extracts were separated from the solid portion of the autoclaved product by pressing and were then filtered.

Microbial Cultures

The cultures of *S. acidophilum* ATCC 26774 fungus and the yeast *C. utilis* were purchased from the American Type Culture Collection (Rockville, Md.).

Culture Conditions

The microbial cultures were maintained on potato dextrose agar slopes at 4°C until required for inoculation.

Following the general method of fermenting sphagnum peat and compost extracts developed in our laboratories, the extracts were sterilized and then inoculated at a ratio of 5% (v/v). The inoculum had been grown in an adaptation step with sphagnum peat or compost extracts as the main nutrient source (Martin and White 1985). The operational parameters for the fermentation processes were those previously optimized for these organisms in sphagnum peat hydrolysate. Table 1 shows those parameters for the growth of *S. acidophilum* fungus (Martin and White 1986). For the fungus, the cultivation time should be approximately eight to 10 days. For yeasts, it should be approximately 24 to 48 hours. Laboratory experiments were conducted in 250-ml. Erlenmeyer flasks, with 50 ml. of culture media, incubated in a Gyrotory water-bath shaker (Model G76D, New Brunswick Scientific Co., Inc., Edison, N.J.). A scale-up of the processes to 2- and 10-l fermenters have also been conducted.

TABLE 1

Growth parameters for the growth of *Scytalidium acidophilum* fungus in fisheries by-products and sphagnum peat compost extracts

Parameter	Value
pH	2 ± 0.1
Temperature (°C)	25 ± 0.1
Agitation speed (RPM)	150

Analytical Methods

Total lipids content was determined by the method described by Folch et al. (1957); the total N, by the modified micro-Kjeldahl Method 47.021 (Horwitz 1980); the ash contents, by AOAC Method 14.006 (Horwitz 1980) and the moisture contents of the compost and sphagnum peat, by AOAC Method 7.003 (Horwitz 1980). Total carbohydrate concentration was determined by the anthrone reagent method (Morris 1948). Biomass concentrations were determined per Martin and Chintalapati (1989).

Results and Discussion

Table 2 presents the composition of the compost. The N content of the compost was approximately four times the N content of the sphagnum peat. The ash content of the compost was also higher, which indicates higher amounts of mineral nutrients in it. The compost hydrolysate also showed good concentrations of N and minerals (Table 3), indicating the hydrolysation process employed had extracted them efficiently. The compost had a lower proportion of carbohydrates than the sphagnum peat, due to its content of fish, and the total carbohydrate concentration in the compost hydrolysate was also lower.

TABLE 2

General composition of fisheries by-products and sphagnum peat compost[a]

Component	Concentration (percentage, dry weight)[b]
Ash	19.5 ± 2.8
Moisture[c]	27.07 ± 0.77
Lipids	0.9 ± 0.04
N	2.5 ± 0.1

[a] From Martin and Chintalapati 1989
[b] Mean values of three determinations ± standard deviations
[c] Percentage of wet weight

TABLE 3

Composition of fisheries by-products and sphagnum peat compost extracts[a]

Component	Concentration (g./l.)[b]
Ash	13.85 ± 0.56
Carbohydrates	14.45 ± 0.89
Lipids	1.93 ± 0.21
N	2.70 ± 0.50

[a] See Table 2
[b] See Table 2

The dry biomass concentrations, yields (g. of biomass produced / g. of substrate consumed) and efficiencies (g. of biomass produced / g. of initial substrate) were not statistically different ($P > 0.05$) for the fungus *S. acidophilum* grown in hydrolysates of either sphagnum peat or compost. However, the compost hydrolysate possessed additional nutrients, which allowed it to sustain enhanced mycelial growth when additional carbohydrates were added to it. It is not possible to obtain this result with the sphagnum peat hydrolysate unless additional amounts of other nutrients are also added.

Regarding the yeast *C. utilis*, it was successfully adapted to grow in fisheries by-products and sphagnum peat compost extracts. Ongoing experiments have shown that it attains a high protein content. Preliminary tests have been conducted in feeding cultivated fish with this source of microbial protein, without any deleterious effects on the fish health, growth and reproduction.

Conclusions

a) Fisheries by-products and sphagnum peat compost extracts possessed higher concentrations of nutrients than those present in sphagnum peat hydrolysate.

b) The acid-tolerant fungus *S. acidophilum* and the yeast *C. utilis* were adapted to grow in fisheries by-products and sphagnum peat compost hydrolysate.

c) Fisheries by-products and sphagnum peat compost hydrolysates seem to have the potential for utilization as an inexpensive substrate for fermentation processes.

d) In addition, fisheries by-products and sphagnum peat compost has been successfully employed in our laboratories at Memorial University of Newfoundland as a growth medium for the edible mushroom *Pleurotus ostreatus* (Martin and Bassler 1989). The flavor of this exotic mushroom is highly appreciated, and it attains high prices.

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Ensiled Fisheries By-Products and Crop Residues as Feeds for Ruminants

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Abstract

Large amounts of fisheries by-products result from seafood processing. Only about 10% of the total weight of processed crabs is used for human food, and by-products are approximately 50% from fish filleted or dressed for human consumption. These fisheries by-products can present a disposal problem due to odor, high water content, and federal, state and local statutes.

Some fisheries by-products are used to produce dried meals, which are used as animal feed. The value of fish meal and crab meal as supplemental sources of protein is documented (NRC 1982), but large amounts of fossil fuel are required for producing these meals. An alternative method of processing is ensiling of fisheries by-products. Fish silage has been traditionally a liquid product made by the addition of acid to whole fish or parts of fish (Tatterson 1982). Liquefaction proceeds by action of enzymes in the fish (Summer and James 1977). Low levels of this type of material have been fed to swine (Cameron 1962) and poultry (Poulter et al. 1980).

Research was conducted during several years on ensiling of finfish and crab by-products with crop residues for use as ruminant feed.

Chemical Composition

The chemical composition of finfish and crab by-products is given in Table 1 (Samuels et al. n.d.a). The crude protein contents are 60% and 44%, respectively. Both fisheries by-products are high in Ca and P.

Ensiling of Fisheries By-Products

Finfish and crab by-products were ensiled in different proportions to give dry matter levels of 40%, 50% and 60% with corn stover or peanut hulls, alone or with addition of 5% dry molasses or 1% formic acid (Samuels et al. n.d.a). The mixtures of finfish by-products and crop

TABLE 1

Chemical composition of seafood-processing by-products[a]

Item (dry matter basis)	Seafood-Processing By-Products (percentage)	
	Finfish	Crab
Dry matter	26.4	40.2
Crude protein	60.4	44.1
Ash	28.0	34.5
Ca	7.3	14.2
P	4.2	1.8
Mg	0.23	0.11

[a] Adapted from Samuels et al. (n.d.a)

residues plus 5% dry molasses ensiled satisfactorily. The pH of the silages averaged 5.6. Satisfactory ensiling of the crab by-products and crop residues, alone or with additives, was not achieved. The pH of the silages was 8, and the mixtures had a very pungent smell, apparently due to high levels of trimethylamine. Acidifying mixtures of 60 to 40 or 40 to 60 crab by-products and straw to a pH of 4.5 with glacial acetic acid resulted in desirable silage with a pleasing aroma. However, the cost of adding the high level of acetic acid (16%) would not be economically feasible. Including 20% dry molasses in a 1 to 1 mixture of crab by-products and wheat straw resulted in a silage with a desirable aroma and a pH of 5.3 (Abazinge et al. 1986a). The trimethylamine level was 8.4, compared to 20.6 mg./100 g. dry matter basis for the control silage. Satisfactory silage was produced with 15% dry molasses.

Nutritional Value of Ensiled Mixtures

Metabolism trials were conducted with sheep that were fed finfish and crab by-products ensiled with different proportions of wheat straw (Samuels et al. n.d.b). The fisheries by-products supplied 23% and 45% of the dry matter in the silages. Dry molasses was included at 5% in all mixtures. Glacial acetic acid was added at 16% to the crab by-products with straw mixtures.

The apparent digestibilities of the ensiled fisheries by-products with straw mixtures are given in Table 2. Dry matter digestibilities of the finfish by-products with straw silages was higher ($P < .01$) than for the crab by-products with straw silages. The digestibility of dry matter was higher ($P < .01$) for finfish by-products silage containing the high level of by-products and tended to be higher for the silage containing the higher level of crab by-products, compared to the lower levels.

A metabolism experiment was conducted with sheep to compare the digestibility of crab by-products with straw silage containing 16% glacial acetic acid or 20% dry molasses alone or with silage inoculant

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A metabolism experiment was conducted with sheep to compare the digestibility of crab by-products with straw silage containing 16% glacial acetic acid or 20% dry molasses alone or with silage inoculant

TABLE 2

Apparent digestibility[a] of fisheries by-products and straw silages by sheep[bc]

Component	Finfish By-Products : Straw		Crab By-Products : Straw		Straw Silage	SE
	70:30 silage	51:49 silage	60:40 silage	40:60 silage		
DM[d,e,f]	51.0	42.8	47.3	43.7	23.0	2.19
CP[d,e,f]	83.6	63.8	55.0	49.2	23.3	3.41
Ether extract	113.8	100.6	92.8	96.8	80.0	9.42
NDF	41.2	34.2	40.0	39.8	16.9	2.75
ADF	36.5	28.4	44.7	34.3	10.4	6.11
Cellulose	76.8	62.6	73.5	68.3	44.0	5.57
Hemicellulose	53.8	49.4	61.1	50.3	36.1	4.96

[a] Calculated by difference, using value for ensiled plus basal and basal diet. Values for individual sheep within the same block, fed the basal and basal plus given silage were used

[b] Six animals/treatment

[c] Adapted from Samuels et al. (n.d.b)

[d] The fisheries by-products silages differ ($P<.01$)

[e] The fisheries by-products silages differ from straw silage ($P<.01$)

[f] The finfish by-products silages differ from crab by-products silages ($P<.01$)

(Abazinge et al. 1986b). Digestibilities of dry matter, crude protein and most cell wall components were higher for the silages with 20% molasses, compared with 16% acetic acid (Table 3).

A feeding trial was conducted with fattening cattle fed finfish by-products with straw silage to supply 25% or 50% of the dry matter of the ration (Abazinge 1986). Daily gain was similar for cattle fed 0% or 25% finfish by-products with straw silage (Table 4). Rate of gain was reduced when 50% of the ration was composed of finfish by-products with straw silage, dry matter basis, due to lower feed intake. However, feed efficiency was similar for the cattle fed the three rations. Carcass quality was similar for the cattle fed the two levels of silage and those fed the control ration. The taste of the meat was not adversely affected by feeding finfish by-products with straw silage.

Crab by-products with straw silage containing 16% molasses was fed to fattening steers at 0%, 15% and 30% of the ration, dry matter basis (Ayangbile 1989). Daily gain was similar for the cattle fed 0% and 15% crab by-products with straw silage and tended to be higher for those fed 30% silage (Table 5). Dry matter/gain was similar for cattle fed 0%, 15% and 30% crab by-products with straw silage. Carcass quality and taste of the meat were not affected by feeding the crab by-products with straw silage.

The results of these experiments indicate that finfish and crab by-products can be ensiled satisfactorily with crop residues, and the resultant silages can be used in livestock rations.

TABLE 3

Apparent digestibility of diets by sheep[a]

Component	Basal (percentage)	Additives to Mixtures[b] (percentage)			Ensiled Wheat Straw (percentage)	SE[d]
		10% acetic acid	20% molasses	20% molasses + 0.1% inoculant		
Dry matter[e,f,g,h]	61.98	51.05	54.20	57.74	44.37	1.09
Crude protein[f,g,h]	70.17	64.75	70.34	74.36	66.90	1.20
Neutral fiber[e,f,g,h]	59.79	39.47	42.07	49.06	49.67	1.76
Acid fiber[e,f,g]	60.10	41.74	47.34	53.76	55.73	3.28
Cellulose	54.59	46.78	45.54	52.61	53.32	2.82
Hemicellulose[e,f,g,h]	59.34	17.03	26.03	34.57	35.25	2.90
Lignin[e,f,g,h]	64.24	42.77	44.69	50.23	57.04	2.35

[a] Adapted from Abazinge et al. (1986a)

[b] Crab by-products and wheat straw (1:1, wet basis)

[c] *S. faecium* and *L. plantarum*

[d] Standard error of means

[e] Basal diet and silages differ ($P<.01$)

[f] Acetic acid treatment and 20% molasses and inoculant treatments differ ($P<.01$)

[g] Molasses treatment and inoculant treatment differ ($P<.05$)

[h] Wheat straw and crab by-products silages differ ($P<.05$)

TABLE 4

Performance and carcass characteristics of cattle fed finfish by-products and straw silage[a]

Item	Finfish By-Products and Straw (percentage, dry matter basis)		
	- 0 -	- 25 -	- 50 -
Initial weight (kg.)	271	264	268
Final weight (kg.)[b,c]	400	392	365
Daily gain (kg.)[c]	1.16	1.15	0.88
Dry matter/day (kg.)[b,c]	7.70	7.32	5.79
Dry matter/kg. gain (kg.)	6.64	6.36	6.58
Carcass weight (kg.)[b,c]	227	220	201
Dressing percentage	56.2	56.0	54.8
Quality grade[d]	9.3	9.5	9.2
Backfat (cm.)[b,c]	0.61	0.56	0.33
Ribeye muscle area (sq. cm.)[c]	61.3	62.6	53.5
Kidney-pelvic-heart fat (percentage)	1.75	1.95	1.75
Yield grade	1.9	1.8	1.8

[a] Adapted from Abzinge (1986)
[b] Control and fisheries by-products cattle differ ($P<.05$)
[c] Low and high fisheries by-products cattle differ ($P<.05$)
[d] Code: 8 = high standard, 9 = low good, etc.

TABLE 5

Performance of steers fed two levels of crab by-products silage[a]

Item	Crab By-Products and Straw Silage[b,c] (percentage)			SE
	- 0 -	- 15 -	- 30 -	
Performance				
Initial weight (kg.)	373.9	379.1	378.3	10.0
Final weight (kg.)	529.0	533.1	545.9	15.9
Average daily gain (kg.)	1.43	1.42	1.55	.1
Dry matter intake (kg./day)	11.7	12.3	12.0	.5
Dry matter/gain	8.1	8.7	7.8	.4
Carcass characteristics				
Carcass weights (kg.)[f]	303.6	304.1	319.4	10.2
Marbling[d]	4.6	4.7	5.1	.3
Quality grade[e]	12.4	12.6	12.9	.3
Dressing percentage	57.4	57.1	58.5	.6
Ribeye area (sq. cm.)	76.1	78.7	81.9	.4
Backfat (cm.)	1.2	1.0	1.2	.1
Kidney-pelvic-heart fat (percentage)[g]	2.3	2.5	2.1	.1
Yield grade	2.4	2.1	2.3	.2

[a] Adapted from Ayangbile (1989)

[b] Crab by-products, straw, molasses, water (32:32:16:20, wet basis) plus 0.1% microbial inoculant

[c] Dry matter basis

[d] Code: 3 = slight, 4 = small, 5 = modest, etc.

[e] Code: 11 = high good, 12 = low choice, 13 = average choice, etc.

[f] Linear effect (P<.05)

[g] Quadratic effect (P<.05)

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Utilization of Blue Crab By-Products Compost to Suppress Meloidogyne javanica *on Tomato*

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Abstract

Three greenhouse pot experiments were conducted to determine the effects of compost made of blue crab (*Callinectes sapidus*) by-products and cypress (*Taxodium distichum*) sawdust on the reproduction of the root-knot nematode *(Meloidogyne javanica).* The first two tests were factorial designs. In these tests, one factor was mixtures of air-dried blue crab by-products compost and fine sand soil. The other factor was inoculation of *M. javanica.* Test 1 was replicated six times in 10.0-cm. diameter pots, while test 2 was replicated eight times in 12.7-cm. diameter pots. After inoculation with *M. javanica*, one "Homestead" tomato (*Lycopersicon esculentum*) was transplanted into each pot. Tomatoes were allowed to grow 56 and 59 days, respectively, in tests 1 and 2. At experiment conclusion, fresh root and foliar weight, root gall index and egg masses/plant were recorded. The third greenhouse test was conducted to compare the influence of dried, ground, raw blue crab by-products and blue crab by-products compost on the population development of *M. javanica.* The test was conducted utilizing air-dried fine sand soil, and treatments were replicated six times in 12.7-cm. diameter pots. A tomato seedling was transplanted into each pot and allowed to grow 60 days before harvest. Data collection was conducted as in the two other tests. In test 1, all levels of blue crab by-products compost (10%, 20% and 100%, w/w) significantly ($P > 0.05$) increased fresh root and foliar weight, and decreased root gall indices and number of egg masses/plant, compared to the control treatment. In test 2, the 20% and higher levels of compost increased plant weight and significantly reduced root galling and egg masses/plant. In test 3, root gall indices and number of egg masses were significantly reduced by both the raw blue crab by-products (0.05% w/w) and blue crab by-products compost (20%) treatments, compared to the control. The raw blue crab by-products treatment showed significantly less root galling and number of egg masses than the blue crab by-products compost treatment.

Introduction

Twenty-two processing plants in northwest Florida process over 3.4 million kg. of blue crab annually (Andree 1988). The disposal of by-products from these plants is problematic due to the increasingly high costs of the current practice of land filling the material. Recently, an alternative method of disposal, composting, has been successfully tested in a pilot program and shows promise of becoming a standard practice for treating these by-products (Woods End Research Laboratory 1990). Through composting, the blue crab by-products are transformed into a stable, nonputrescent material that could have agricultural applications similar to other currently available composted products.

Both composted and noncomposted organic materials have been added to soil since very early times to improve plant growth. Some of these materials have been shown to provide suppression of plant-parasitic nematodes in soil, but use of these materials in developed countries has been limited due to the availability of effective nematicides (Mankau and Das 1974; Rodriguez-Kabana 1986). Because of the cancellation or use restrictions on several effective nematicides, scientists have developed an increased interest in studying organic materials for nematode suppression. Materials containing chitin, such as blue crab by-products, have been shown to suppress plant parasitic nematode populations and subsequently increase plant growth (Godoy et al. 1983; Mankau and Das 1974; Mian et al. 1982; Rodriguez-Kabana 1986; Rodriguez-Kabana et al. 1984; Rodriguez-Kabana et al. 1989). The process of composting is known to break down complex molecules such as chitin. It is unclear, therefore, whether the composted blue crab by-products would result in nematode suppression similar to chitin. The studies reported herein, thus, were conducted to determine the effects of compost made from 36% blue crab by-products and 64% cypress sawdust on nematode populations and associated plant growth response.

Materials and Methods

Three greenhouse pot experiments were conducted using "Homestead" tomato inoculated with the Javanese root-knot nematode *M. javanica*. Tests 1 and 2 were arranged in a factorial design with test 1 replicated six times and test 2 replicated eight times. In test 1, one factor was blue crab by-products compost (Woods End Research Laboratory 1990) at 0%, 10%, 20% and 100% (w/w) mixed with a fine sand soil (93% sand, 4% silt, 3% clay, less than 1% organic matter and pH 5.7). The other factor was *M. javanica* applied at 0 or 10,000 eggs/pot. In test 2, one factor was blue crab by-products compost at 0%, 5%, 10%, 20%, 40%, 80% and 100% (w/w), and the other factor was *M. javanica* at 0 or 15,000 eggs/pot. In test 3, treatments included soil alone, 0.05% w/w raw blue crab by-products and 20% w/w blue crab by-products compost inoculated with 15,000 eggs/pot of *M. javanica.* Test 3 was arranged in a randomized complete block design with six replicates.

Prior to experiment initiation, soil was fumigated with methyl bromide at 0.6 kg/a.i. cu. m. The blue crab by-products compost and soil were air-dried and sieved by passing through a screen containing 0.3 mm. diameter openings. The raw blue crab by-products were freeze-dried, ground and sieved as above. The treatment mixtures were placed in 10-cm. diameter plastic pots in test 1 and 12.7-cm. diameter pots in tests 2 and 3. Water was then added to bring the mixtures to field capacity, and pots were allowed 4, 6 and 13 days before inoculation with nematode eggs in tests 1, 2 and 3, respectively. Eggs of *M. javanica* were extracted from "Homestead" tomato roots using the sodium hypochlorite method (Hussey and Barker 1979). After inoculation, one tomato was transplanted immediately into each pot in tests 1 and 3, while in test 2 transplanting occurred eight days later. Plants were fertilized biweekly with 40 ml. of a 60 g./l. solution of 20-20-20 (N-P_2O_5-K_2O) for the duration of the experiments.

Pots were arranged on a greenhouse bench in a randomized complete block design, and tomatoes were allowed to grow 56, 59 and 60 days, respectively, in tests 1, 2 and 3. At experiment conclusion, fresh top weight, fresh root weight and root gall index were recorded. Root gall index ratings were made on a 0-4 scale where 0 was 0%, 1 was 1-25%, 2 was 26-50%, 3 was 51-75% and 4 was 76% or more of the root system galled. Plant roots were stained in phloxine B, and the number of egg masses was counted (Taylor and Sasser 1978). Additionally, *M. javanica* eggs were extracted with sodium hypochlorite and counted from 2 g. of root tissue from each replicate in test 1.

Results

In test 1, all levels of blue crab by-products compost significantly ($P > 0.05$) increased both foliar and root weights of tomato, and reduced root gall indices, compared to the control treatment (Table 1). Numbers of eggs/g. root and egg masses/plant similarly were reduced significantly by addition of 10%, 20% and 100% blue crab by-products compost. Comparatively little additional suppression of root galling and nematode reproduction was observed between the 20% and 100% compost levels.

In test 2, significant increases in foliar weight were observed at the 20%, 80% and 100% blue crab by-products compost levels as compared to the control treatment (Table 2). Fresh root weights were increased significantly at the 80% and 100% blue crab by-products compost levels. Root galling and number of egg masses/plant were reduced significantly at 20% and higher levels of compost. Little additional suppression of root galling and nematode reproduction was observed at levels higher than 20% compost.

TABLE 1

Influence of crab by-products compost on plant growth, root gall index and *Meloidogyne javanica* egg production on tomatoes in greenhouse test 1

Percentage of Crab By-Products in Compost[x,y]	Foliar Weight	Root Weight	Root Gall Index	Eggs/ g. Root	Egg Masses/ Plant
0	4.32	5.81	4.00	93,927	606
10	22.17	12.54	3.00	16,937	328
20	26.86	10.65	1.00	2,233	35
100	26.60	11.64	0.40	2,644	1

[x] Air-dried crab by-products compost mixed on weight for weight basis with an air-dried fine sand soil

[y] Foliar weight and root weight data include pots with and without *M. javanica*

TABLE 2

Influence of crab by-products compost on plant growth, root gall index and *Meloidogyne javanica* egg production on tomatoes in test 2[z].

Percentage of Crab By-Products in Compost	Fresh Top Weight	Fresh Root Weight	Root Gall Index	Egg Masses/ Plant
0	31.7	11.7	4.0	1,610
5	32.1	14.5	4.0	1,680
10	34.0	13.8	4.0	1,340
20	56.8	15.9	3.0	761
40	41.0	13.0	1.8	171
80	60.4	18.1	2.0	451
100	58.6	19.6	2.2	441

[z] Fresh foliar and root weights include both those pots that were and were not inoculated with *M. javanica*

TABLE 3

Comparative influence of raw crab by-products and crab by-products compost on plant growth, root gall index and *Meloidogyne javanica* egg production on tomatoes in test 3.

Treatment	Foliar Weight	Root Weight	Root Gall Index	Egg Masses/ Plant
Control	14.4*	11.5	4.0	218
Crab by-products compost (20%)	20.1	5.6	2.2	134
Crab scrap (0.05%)	15.2	7.6	1.3	21

*Waller Duncan K-Ratio T-Test ($P \leq .05$)

In test 3, root weight was reduced significantly by both the raw blue crab by-products and the blue crab by-products compost treatments, while foliar weights were not affected (Table 3). Root gall indices and number of egg masses/plant were significantly reduced by both the raw blue crab by-products and the blue crab by-products compost treatment compared to the control. The raw blue crab by-products treatment showed significantly less root galling and number of egg masses than the blue crab by-products compost treatment.

Discussion

Addition of blue crab by-products compost was shown to suppress root galling and number of egg masses/plant and generally increase tomato growth. Minimum levels of 10%-20% blue crab by-products compost were observed to suppress root galling and egg mass production. These results coupled with those from test 3 indicate that while blue crab by-products compost suppresses populations of *M. javanica*, the compost is not as effective as raw blue crab by-products (Godoy et al. 1983; Mian et al. 1982).

The mode of action of chitin on nematodes has been hypothesized to be the production of ammoniacal N and enhanced chitinous fungal activity (Mian et al. 1982). The depletion of nitrogenous compounds and reduction of energy sources through composting probably reduced chitin concentrations (Brinton and Seekins 1988), and thus the nematode suppressive characteristics of the blue crab by-products compost.

The 10% level of blue crab by-products compost represents an application rate of over 100 T./ha., which could be uneconomical for nematode control in large-scale agriculture. The blue crab by-products compost utilized in these tests had a C to N ratio of 24 with N content of 0.36%. Data from these tests indicate that blue crab by-products compost has the same limitations for nematode control as many other materials containing high C to N ratios (Rodriguez-Kabana 1986). Additions of large quantities of these materials have been found necessary to inhibit nematode reproduction. Seemingly, the greatest potential for use of blue crab by-products compost for nematode suppression would be in container grown plants and organic production systems. In these situations, high loading rates are normal practices.

The ability of blue crab by-products compost to increase organic matter, soil water retention and provide/retain soil nutrients could be more important than the ability of the blue crab by-products compost to suppress nematodes. Further greenhouse and microplot tests need to be conducted to verify and extend results of these experiments.

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Production and Testing of Composts Containing Fisheries By-Products and Sawdust

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Abstract

Seafood processing in coastal Washington regions generates a substantial volume of by-products that could be converted into useful fertilizer by composting with sawdust. In this study, ground bottomfish by-products and shrimpshell sludge generated from the production of chitin were composted with red alder or a mixture of western hemlock and Douglas fir sawdusts to produce four composts: red alder with ground bottomfish by-products (AGF); western hemlock/fir with ground bottomfish by-products (HGF); red alder with shrimpshell sludge (AP); and western hemlock/Douglas fir with shrimpshell sludge (HP). The resulting AGF was 1.9% N and had a C to N ratio of 18, as opposed to 1.3% N and C to N ratios of about 26 for the other three composts. Approximately 20%-30% of the total N in the AGF, HGF and HP composts was in mineral forms, as opposed to 2% in the AP compost. Red alder sawdust contains less lignin and is more easily decomposed, which favors N retention or immobilization during the composting process. Except for the AP, all composts were comparable or superior to the commercially available sewage sludge and cow manure composts used in this study in promoting dry matter production of corn or a mixture of orchardgrass/perennial ryegrass in a greenhouse study. The C to N ratio was not a reliable parameter to predict N availability of the fisheries by-products composts.

Introduction

Seafood processors in the Pacific Northwest are weighing alternatives for the disposal of large volumes of fisheries by-products because of increasingly constraining environmental regulations. Composting, a recycling process, is an attractive option because it not only converts organic by-products into more benign products (Mathur et al. 1988; Frederick et al. 1989) but also because it has the potential to add economic value to the fisheries by-products.

Refinements in methodologies for composting in recent years are due in large measure to extensive experience from composting municipal sewage sludge. Much of this experience has been valuable for composting other materials such as animal manures, yard waste, municipal refuse and food-processing waste. Indeed, nearly any organic substance or mixture that has a moisture content between 40% and 65%, a pH between 5 and 12, and sufficient volatile solids for temperature elevation and pathogen destruction can be successfully composted (Haug 1980; Willson 1989).

Composting nitrogenous materials with high moisture contents requires both a bulking agent to absorb moisture and increase the porosity for aeration as well as a carbonaceous amendment to provide an energy source to sustain microbial activity. C to N ratios in the composting mixture are closely associated with N mineralization and immobilization. Well balanced nutritional conditions of microbial biomass are met by supplying a substrate with a C to N ratio of about 25. If the ratio is appreciably higher, immobilization of N by microbial growth could decrease the supply of inorganic N available for plant use. It is generally recommended that composts should have C to N ratios of 20-25 to have good N fertility value.

Shredded bark, wood chips, shredded brush and sawdust are often used to provide a C source and facilitate aeration. The choice of bulking agent is based on availability and cost as well as performance characteristics for composting. The extensive tracts of forest land throughout the coastal regions of the Pacific Northwest support a timber industry that generates large volumes of sawdust annually. If the sawdust has relatively small and uniform particle sizes, it can be effective as a C amendment as well as a bulking agent. The rate of decomposition of woodwastes increases with increased surface area as the particle size decreases (Bollen 1969). The smaller particle size breaks up the lignin network that protects the cellulose polymers from being attacked by cellulases (Neal et al. 1965). Because the composition of wood tissue from different tree species varies, the decomposition rates of sawdusts could vary considerably (Frankos et al. 1982). Allison et al. (1963) incubated sawdusts from 28 tree species in soil and found that hardwood sawdusts are generally more degradable than softwood sawdusts. Red alder is a hardwood and Douglas fir and western hemlock are softwood tree species that are extensively harvested for timber products in the Pacific Northwest. Red alder sawdust and a mixture of Douglas fir and western hemlock sawdusts were composted with two fisheries by-products that constituted 87% of fisheries by-products in the coastal region of Washington in 1985-87 (Bonacker et al. 1989). The purpose of this study was to evaluate the feasibility of composting as an alternative for the disposal of fisheries by-products and to determine the nutrient contents of the composts and their availability to plants. The two fisheries by-products used were from ground bottomfish, which was a mixture of several species, and a shrimpshell sludge, which was generated from the deproteination process in the production of chitin and chitosan.

The objectives were to: (1) produce composts from combinations of each of the fisheries by-products with each of the two sawdusts according to commonly used procedures, (2) determine the physical and chemical characteristics of the composts and (3) evaluate the nutrient availability and plant growth effects of the composts in a greenhouse trial.

Methods and Materials

Compost Production

The composting was initiated March 6 and 7, 1990, at the Port of Willapa Harbor in Raymond, Wash. Since the compost was made during the rainy season in a greater than 200 cm./year rainfall zone, the pile was made in a covered shed with open sides and a packed earth floor. Since there was no finished compost to use as inoculum, an attempt was made to build up the microbial population and enzyme concentration by aging some sawdust for inoculation of the fresh sawdust. In mid-December 1989, 9.2 cu. m. each of western hemlock/Douglas fir and red alder sawdusts were delivered to the site. Then, 125 kg. of NH_4NO_3 fertilizer (43 kg. N) was added to the western hemlock/Douglas fir sawdust and 64 kg. of NH_4NO_3 (22 kg. N) was added to the red alder sawdust and mixed with a front-end loader to reduce the C to N ratio into a range of 15-40. The sawdusts were covered and aged until composting was initiated. At the time the compost mixtures were made, 1.5 cu. m. of this aged sawdust was mixed with 10.7 cu. m. of fresh sawdust.

The bottomfish by-products were ground and delivered to the site in 0.75-cu.-m. fiberglass bins that could be poured with a forklift into furrows in the windrowed sawdust. The shrimpshell sludge was generated at a plant adjacent to the composting site. The desired range of C to N ratios for the compost mixtures of 15 to 40 was the basis for determining the proportions of sawdust and fisheries by-products to be used in the mixture (Willson 1989). The constituents were analyzed for organic C by the Walkley and Black (1934) titrimetric method, total N in a H_2SO_4 and H_2O_2 digestion by the Kjeldahl method (Bremner and Mulvaney 1982) and moisture content by gravimetry. The shrimpshell sludge contained only 2.3% solids. Ferric chloride was added at a rate of 0.12% to 60 cu. m. of the sludge to flocculate the suspended organic solids and left overnight in a settling tank. The following morning, about 10 cu. m. of sludge was drained from the bottom of the settling tank into a 19-cu.-m. tanker, which was pulled to the composting site. After an additional two to three hours of settling, the sludge was drained from the bottom of the tanker as needed for mixing into the sawdust.

The sawdust component of each mixture was spread out in a dish-shaped pile so that the fisheries by-products could be poured into the center. About 2,270 kg. of sludge were slowly mixed into 7,200 kg. of red alder sawdust and 5,500 kg. of western hemlock/Douglas fir sawdust. About 3,400 kg. of ground fisheries by-products were mixed into the same quantities of red alder and western hemlock/Douglas fir sawdusts. The compost constituents were mixed and windrowed with a 0.75-cu.-m. front-end loader. The resulting windrows were trapezoidal; 1.2 m. high, 0.9 m. and 3.0 m. wide at the top and base, respectively, and 6 m. long. Each time the pile was turned, a light coating (3-5 cm.) of fresh sawdust was sprinkled on the pile and the ground around the pile for odor reduction. Temperatures in the windrows were recorded in Datapods at two-hour intervals to monitor microbial activity. The composts were mixed and rewindrowed as often as twice daily when windrow temperatures exceeded 60°C. Beginning about 12 weeks after compost initiation, weekly samples were taken and analyzed for pH, organic C and total N as described above, inorganic N (NH-N and NO-N) by steam distillation (Bremner and Mulvaney 1982) and moisture content. Water was added as needed to maintain moisture content of the compost near 50%. This was continued until declining windrow temperatures and total N contents indicated that stabilization was occurring.

On June 19, 15 weeks after composting was initiated, the compost was transported to the Washington State University Research and Extension Center, Puyallup, Wash., for greenhouse evaluations. Subsamples of the composts were digested in H_2SO_4 and H_2O_2 at 400°C for total N, P and K analyses. Characterization of the finished compost was extended to include total K and neutral 1 M NH_4OAc-extractable K by flame photometry; total Zn, Cu and Cd contents in HNO_3 and $HClO_4$ digestions by atomic absorption spectrophotometry; total P and 0.5 M $NaHCO_3$-extractable P (Olsen and Sommers 1982) by colorimetry (Murphy and Riley 1962); soluble salts in a 1 to 5 compost to water ratio by electrical conductivity; and bulk density. Water retention was determined by soaking 25 g. of compost in water overnight, followed by draining and the gravimetric determination of the water content.

Greenhouse Experiment

Available levels of N, P and K and plant growth response were evaluated as measures of the quality of the composts for use as fertilizer. The growth trials were conducted using silage corn (Northrup King 9903, 85-day maturity) and a mixture of orchardgrass and perennial ryegrass in identical experiments. Compost was used at a 100% rate in both the corn and grass experiments for greenhouse evaluation of the compost N availability to plants. A Puyallup fine sandy loam soil (coarse loamy, mixed, mesic Fluventic Haploxeroll) was used for the fertilizer control comparison. Each treatment was replicated three times in 15-cm. pots that were completely randomized. Uniform application of P (KH_2PO_4) and K (KCl) was made in a band 2.5 cm. deep at rates equivalent to 44 kg. P/ha. and 224 kg. K/ha., respectively. N was applied to the soil as NH_4NO_3 at a rate of 112 kg. N/ha. The grass mixture was seeded on Aug. 2, 1990, at a rate of 100 seeds/pot. Four corn seeds/pot were planted on Sep. 6 and thinned to two plants after germination. Daylight was supplemented with metal halide lights for 16 hours/day. Water was applied through an overhead mist system. The grass was clipped weekly after establishment, and the clippings were accumulated until Oct. 8. The corn was harvested Oct. 2. Dry matter yields were determined, and the plants were ground for analysis of N, P and K contents after digestion in H_2SO_4 and H_2O_2 at 400°C. Subsamples of soil and compost were refrigerated for later determination of inorganic N (NH-N and NO-N) and total N. An additional experiment to evaluate P availability was conducted by uniformly adding N and K at rates of 112 kg. N/ha. and 224 kg. K/ha. to the compost treatments along with a fertilizer control treatment in the soil of 44 kg. P/ha.

The fisheries by-products composts were also compared at a 100% rate with three commercially available composts, including two sewage sludge composts and one cow manure compost. The two sludge composts and the cow manure compost were characterized for total N, inorganic N (NH_4^+-N and NO_3^--N), $NaHCO_3$-extractable P and total Zn, Cu and Cd, using procedures described above. Experimental procedures and growth measurements were the same as described above.

Results

Composting Process

Table 1 illustrates the chemical composition of the sawdusts and fisheries by-products components of the compost mixtures. The solids content of the shrimpshell sludge was only 5% despite flocculation with $FeCl_3$. The 7,200 kg. of red alder sawdust and 5,500 kg. of western hemlock/Douglas fir sawdust used for composting, at 60% moisture, contained 4,300 and 3,300 kg. of water, respectively; the 2,270 kg. of shrimpshell sludge contained 2,160 kg. of water. The resulting moisture contents for the red alder and western hemlock/Douglas fir compost mixtures with the sludge were 68% and 70%, respectively. Some leachate trickled from the piles, indicating that the moisture content of the compost mixtures exceeded water retention capacities, especially at the bottom, which was under more pressure from the weight of the overlying compost mixtures. Despite being far short of the preferred quantity of sludge addition to obtain the desired C to N ratio, this high moisture content prohibited further addition. The total N content of the leachate was only 0.06%, but the volume lost is unknown.

TABLE 1

Physical and chemical characteristics of the fisheries by-products and sawdust used to make the four types of compost. All data are expressed on a dry matter basis.

	Total							Moisture Content
	C	N	P	K	Zn	Cu	Cd	
	(percentage)				(µg./g.⁻¹)			(percentage)
Alder sawdust	48	0.4	0.004	0.12	14	0.3	<0.5	60
Hemlock/fir sawdust	52	0.1	0.030	0.02	1	0.2	<0.5	60
Groundfish	43	8.3	3.070	0.51	36	0.2	<0.5	70
Shrimpshell sludge	27	6.6	0.810	0.63	74	6.4	<0.5	95

Early in the composting period, the ambient air temperature was quite cool (3°-8°C). The slow increase in temperature in both the AP and the HP compost windrows revealed low decomposition rates. The compost windrows were reformed into piles that minimized the surface to volume ratio to preserve heat and stimulate microbial activity. The AGF and HGF composts were left in the long windrows. Eventually all of the composts, with the exception of the HP, reached the thermophilic stage (> 50°C) for at least one week. Windrow temperatures did not exceed 70°C except in the AGF. By the twelfth week of composting, the pH in the AGF compost had risen to 8.6. While this pH is within the acceptable range for composting, pH levels that exceed 8, especially at high temperatures, can cause significant amounts of N loss by volatilization as NH_3 (Morisaki et al. 1989). The decline of total N for the two ground bottomfish by-products composts (Tables 2 and 3) could be attributed to NH_3 volatilization during composting. The required turning of the compost piles for aeration could enhance NH_3 loss. The decline of NH-N contents without a corresponding increase in NO-N values (Figure 1) suggests that NH_3 volatilization occurred. In order to minimize this NH_3 loss, dilute HCl (1 M) was mixed into the windrow, which reduced the pH to 6.7.

TABLE 2

C and N weights in the sawdust, fisheries by-products, and fertilizer used to make the four types of compost and the resulting compost C to N ratios.

(HGF=hemlock/fir-groundfish, AGF= alder-groundfish, HP=hemlock/fir-shrimpshell sludge, and AP=alder-shrimpshell sludge)

Compost	Sawdust	Seafood	Fertilizer	Total	C:N Ratio
	(kg.)				
HGF C	1,142	439	NA	1,581	16.8
N	2	85	7	94	
AGF C	1,386	439	NA	1,825	18.1
N	12	85	4	101	
HP C	1,142	31	NA	1,173	69.0
N	2	8	7	17	
AP C	1,386	31	NA	1,417	
N	12	8	4	24	59.0

TABLE 3

Characteristics of four finished fisheries by-products and sawdust composts.

Elemental analyses are presented on a dry matter basis.

(HGF=hemlock/fir-groundfish, AGF=alder-groundfish, HP=hemlock/fir-shrimpshell sludge, and AP=alder-shrimpshell sludge)

	Total							C:N	Moisture	Water Retention	Bulk	
	C	N	P	K	Zn	Cu	Cd	Ratio	Content*	Capacity**	Density	EC
	(percentage)				($\mu g.\ g.^{-1}$)				(percentage)		($g.cc.^{-1}$)	($mmhos\ cm.^{-1}$)
HGF	32	1.3	0.73	0.19	47	2.3	<0.5	27	41	382	0.20	3.0
AGF	35	1.9	0.84	0.19	67	3.2	<0.5	18	42	351	0.25	3.3
HP	34	1.3	0.35	0.16	76	3.2	<0.5	26	48	445	0.18	3.8
AP	33	1.3	0.29	0.15	59	3.2	<0.5	25	41	388	0.22	2.4

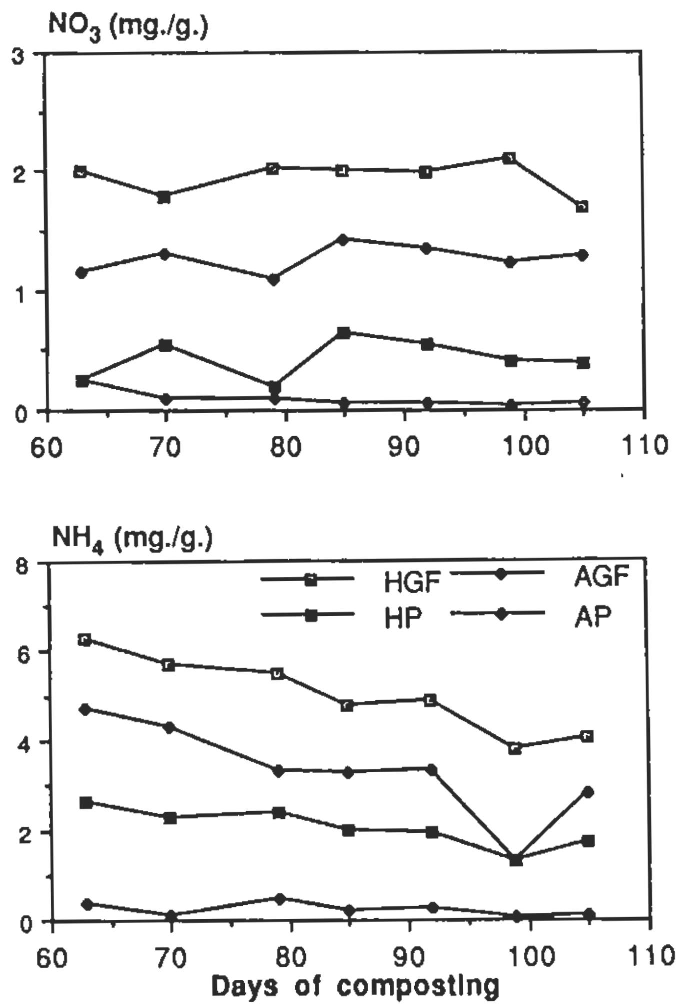
* Moisture content is expressed as a percentage of total weight of compost

** Water retention capacity is expressed as a percentage of dry matter weight

FIGURE 1

The effect of the length of composting time on N and concentrations of four fisheries by-products composts.

(HGF = hemlock/fir-groundfish, AGF = alder-groundfish, HP = hemlock/fir-shrimpshell sludge, AP = alder-shrimpshell sludge)



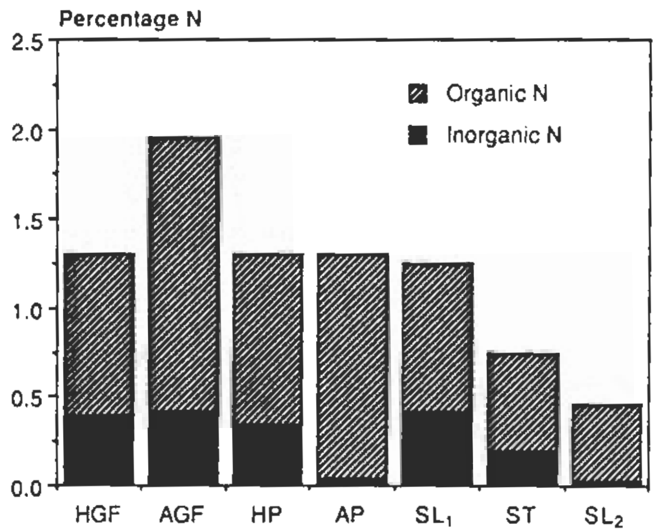
Although both flies and odor were reported to be somewhat objectionable early in the composting process, the light coating of fresh sawdust after each turning prevented any serious problems.

The C and N contributions from the compost mixture components along with the resulting mixture C to N ratios are shown in Table 2. Sawdust inputs were based on dry bulk densities of 0.18 and 0.24 g./cu. cm. for the western hemlock/Douglas fir and red alder sawdusts, respectively. N contributed from NH_4NO_3 that was added in the aged sawdust for inoculum was calculated with the assumption that there was no loss of N from the piles and no volume reduction during aging. The total N contents in the initial compost mixtures were quite variable (0.7%-2.7%). The HP was lowest because of the low N content of the sawdust and the small N contribution from the shrimpshell sludge. The HGF was highest because both sawdusts were added on a volume basis and the lower bulk density of the western hemlock/Douglas fir sawdust resulted in less mass being added. The high C to N ratios and low degradability of the solids in the HP and AP composts slowed the composting process.

At the completion of the composting period, the total N concentrations of the HGF and AGF had decreased, whereas the N concentrations of the HP and AP had increased (Table 3). A weight or volume loss of compost mixtures occurs during composting, with the extent of loss being dependent on the degradability of the mixture components. The increased N concentrations in the HP and AP probably resulted from volume reduction during composting, although N fixation could have contributed as well (Haug 1980). Assuming similar volume reductions in the HGF and AGF, the reduction in N concentrations from 2.5%-2.7% to 1.3%-1.9% at the completion of composting indicates that substantial quantities of N were lost during composting. This was partially a result of low initial C to N ratios since low C to N ratios enhance N loss (Ashbolt and Line 1982). However, the fact that more N was recovered in the AGF than in the HGF at comparable initial C to N ratios indicates that the quantity and decomposition rate of mineralizable organic C should be considered as well (Haug and Ellsworth 1991). Red alder contains more cellulose and less lignin (Neal et al. 1965) and decomposes at a faster rate than Douglas fir (Bollen 1969) so that a larger fraction of the C in the red alder is degradable during the composting period. In the AP, the higher degradability of the red alder was probably responsible for greater N immobilization, which resulted in the low inorganic N content (Figure 2). It can be assumed that the organic C remaining in the finished composts in the present study was derived primarily from the sawdusts, considering the high degradability of fisheries by-products. The reduction of C concentration in the two western hemlock/Douglas fir composts averaged 31.0% as compared to 34.5% in the two red alder composts. In terms

FIGURE 2

The organic and inorganic N concentrations of fisheries by-products composts. (HGF = hemlock/fir-groundfish, AGF = alder-groundfish, HP = hemlock/fir-shrimpshell sludge, AP = alder-shrimpshell sludge), sludge composts (SL_1 and SL_2) and steer manure compost (ST)



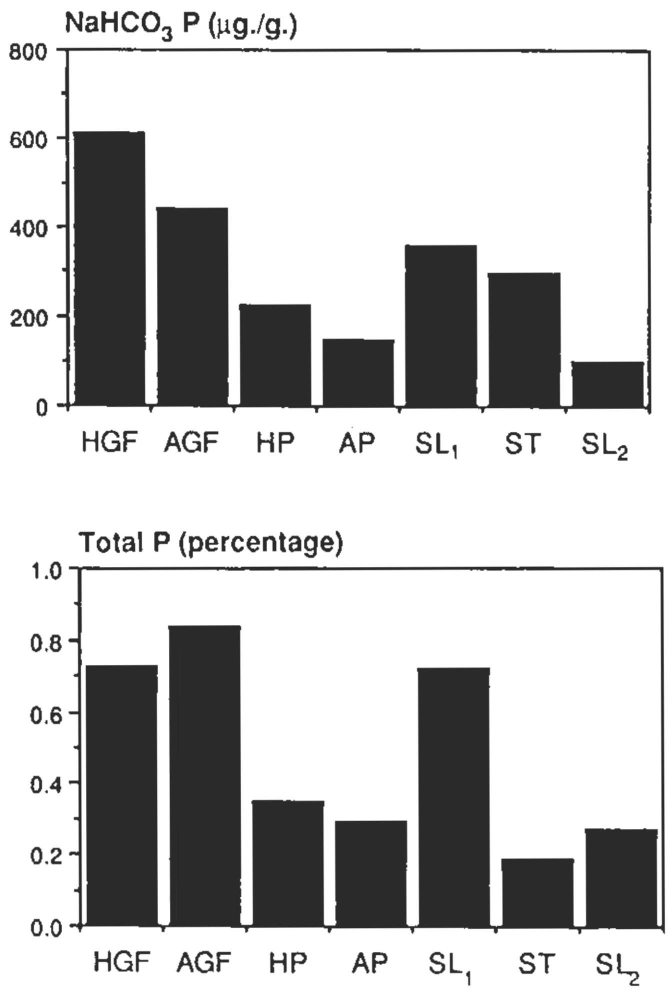
of N conservation, red alder sawdust is more conducive as a bulking agent than western hemlock/Douglas fir sawdust.

At the completion of composting in June, all composts appeared to have good consistency and had an earthy smell. Total N concentrations (Table 3) were comparable with those of municipal sludge and other fisheries by-products composts using sawdust as bulking material (Hay et al. 1988; Brinton and Seekins 1988). Approximately 20%-30% of the total N for HGF, AGF and HP as opposed to 2% for AP was in mineral forms (NH-N + NO-N) (Figure 2). Because of the low available inorganic N concentration, the AP compost could be of little value to supply adequate N for immediate plant use and could even aggravate N infertility through microbial immobilization. The total inorganic N levels in the HGF, AGF and HP were comparable with one of the commercially available sewage sludge composts (SL_1) and the cow manure compost (ST) but far superior to the other sewage sludge compost (SL_2). The total K concentrations in the composts were quite low (Table 3), but virtually all of it was exchangeable. With low Zn, Cu and Cd concentrations in the fisheries by-products and sawdusts (Table 1), the fisheries by-products composts contained heavy metals at much lower concentrations (Table 3) than sludge (Frederick et al. 1989) or municipal refuse composts (Terman et al. 1973) and are unlikely to cause excessive metal uptake by plants when applied to soil for crop production. The composts had relatively high salt contents (Table 3), which could impair plant growth for plant species with low salt tolerance. The high salt content in the ground bottomfish by-products composts was due to the large quantity of by-products added. In the shrimpshell sludge, the salts were derived mainly from the NaOH used in removing protein from the shrimpshell. When used as a soil amendment or mixed with other planting media, the composts will be unlikely to cause salt injury to plants as the salt content will be diluted.

The level of plant-available P estimated by $NaHCO_3$ extraction for the fisheries by-products composts was reasonably high (Figure 3) and comparable with those for the SL_1 and ST. A large quantity of P, representing 20%-30% of the total P for all the composts except the ST, could be removed by successive extractions with $NaHCO_3$, indicating that a considerable proportion of P in the finished compost was inorganic and plant available. About 70% of the total P present in the ST compost was extractable by $NaHCO_3$. The reason for such a high percentage is not clear.

FIGURE 3

The total and $NaHCO_3$-extractable P concentrations for fisheries by-products composts. (HGF = hemlock/fir-groundfish, AGF = alder-groundfish, HP = hemlock/fir-shrimpshell sludge, AP = alder-shrimpshell sludge), sludge composts (SL_1 and SL_2) and steer manure compost (ST)



Plant Growth Tests

Dry matter yields of corn grown in the fisheries by-products composts varied considerably (Figure 4). They responded positively to the HGF, AGF and HP but negatively to the AP. The total N uptake by corn in the HGF, AGF and HP was comparable with that in the SL_1 and ST, and the N fertilizer treatment (FC). These results confirm the fertilizer value of these three fisheries by-products composts. Like the SL_2, the AP compost had little or no immediately available inorganic N (Figure 2) and caused a severe N deficiency in the corn plants despite a comparable C to N ratio with the HP and HGF (Table 3). This indicates that the C to N ratio is not a reliable parameter to predict N availability in these composts, although the C to N ratio has been successively used to index N mineralization and bioavailability of other organic substances (Allison 1973; Iritani and Arnold 1960).

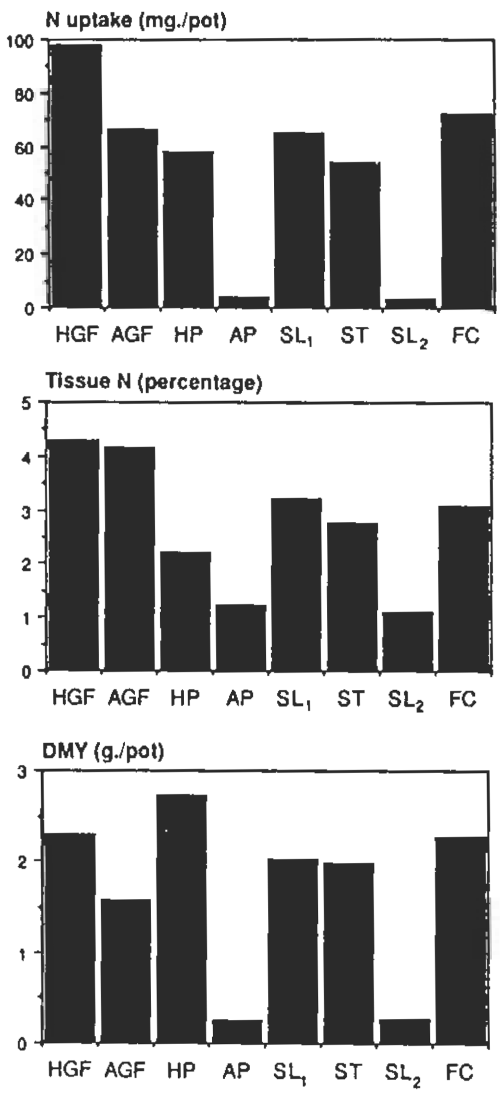


FIGURE 4

The dry matter yields (DMY), tissue N and N uptake by corn grown in fisheries by-products composts.

(HGF = hemlock/fir-groundfish, AGF = alder-groundfish, HP = hemlock/fir-shrimpshell sludge, AP = alder-shrimpshell sludge), sludge compost (SL_1 and SL_2), steer manure compost (ST) and soil fertilized with NH_4NO_3 (FC)

Grass yield in the fisheries by-products composts was higher than that in NH_4NO_3 fertilized soil, with the exception of the AP (Figure 5). The dry matter yields and N concentrations of grass did not respond to the AP or SL_2 compost. The AGF, HGF and HP enhanced dry matter yields and leaf N concentrations of grass and N uptake by grass to a greater degree than did the SL_1 and ST.

Phosphorus uptake by corn and grass grown in the HGF, AGF and HP was substantially higher than that in the soil receiving 44 kg. P/ha. (FC) (Figure 6). The HGF, AGF and HP were similar or superior to the SL_1 and ST in P availability to corn and grass. The AP and SL_2, which had low N availability as discussed earlier, had low P availability as well. Microbial assimilation of inorganic P could also be related to the low availability of the P in these two composts.

FIGURE 5

The dry matter yields (DMY), tissue N and N uptake by orchardgrass/ryegrass grown in the fisheries by-products composts.

(HGF = hemlock/fir-groundfish, AGF = alder-groundfish, HP = hemlock/fir-shrimpshell sludge, AP = alder-shrimpshell-sludge), sludge composts (SL_1 and SL_2), steer manure compost (ST) and soil fertilized with NH_4NO_3 (FC)

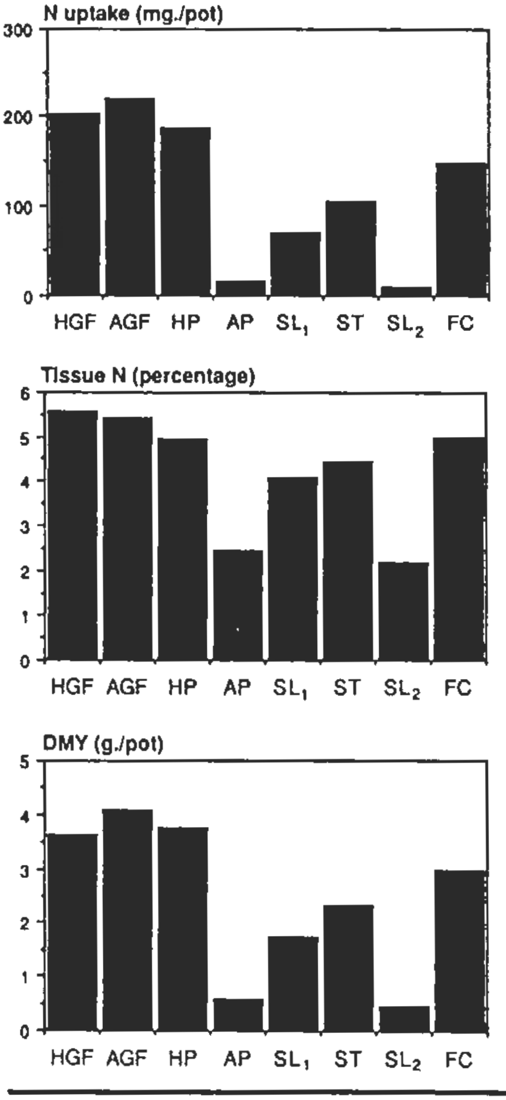
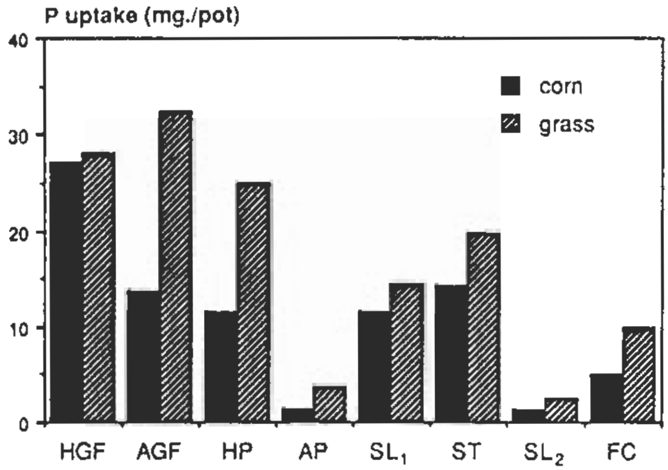


FIGURE 6

The P uptake by corn and grass grown in fisheries by-products composts. (HGF = hemlock/fir-groundfish, AGF = alder-groundfish, HP = hemlock/fir-shrimpshell sludge, AP = alder-shrimpshell-sludge, sludge composts (SL_1 and SL_2), steer manure compost (ST) and the fertilized soil (FC)



Conclusions

High quality compost can be made using ground bottomfish by-products combined with either red alder or western hemlock/Douglas fir sawdust. The high dry matter content of the ground bottomfish by-products presents no obstacles to proportioning the components to achieve a desired C to N ratio. The shrimpshell sludge, in contrast, was too wet to allow addition of sufficient quantities of solids to reach targeted C to N ratios. Although the HP compost performance in the plant growth experiments was quite good, the AP compost effects on plants were deleterious. Since the same amounts of sludge were mixed with both sawdusts, this difference relates to the variable characteristics of each sawdust. The western hemlock/Douglas fir sawdust is a more conducive bulking agent under these circumstances. However, unless the solids content of the shrimpshell sludge can be increased substantially, composting of this material is not a viable disposal option.

The low Cu, Zn and Cd concentrations and the high N and P availability in the AGF, HGF and HP composts made their quality and fertilizer value equal or superior to many municipal waste composts. Western hemlock/Douglas fir sawdust is more desirable than red alder sawdust for composting when the total organic N input from the fisheries by-products is low (e.g., in the shrimpshell sludge). However, when the quantity of N in the fisheries by-products is high (e.g., in the ground bottomfish by-products), red alder sawdust is preferable to western hemlock/Douglas fir sawdust because the relatively higher degradability enhances N recovery.

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Blue Crab By-Products for Garden Use

by George C. Henry, Jr., Cooperative Extension Service, Tallahassee, Fla.

Introduction

The production and preparation of seafood results in the accumulation of various by-products that could be discarded in some non-polluting manner. Unless handled properly, these by-products can become a nuisance, a hazard to human health and an environmental pollutant. Therefore, these by-products must be managed and disposed of in the proper manner.

The Florida seafood industry disposes of tons of fisheries by-products as waste materials. The question: Can this waste material be processed into a useful and worthwhile product? There were many other unanswered questions that troubled Florida's seafood industry.

The first hands-on demonstration introducing blue crab by-products compost to farmers, private industry and agricultural agents was conducted by Florida Sea Grant in late winter 1989, about 58 miles east of Tallahassee outside of the small town of Perry, Fla.

In spring 1990, the vegetable agent conducted a comparative study to evaluate blue crab by-products and mushroom compost as a soil amendment and its use as an organic fertilizer in vegetable gardens. Also, commercial fertilizer was used to compare plant response with that of organic sources used in this study.

Methods

There were four separate tracts involved in this study. Each tract consisted of 84 sq. ft. of garden area. Tract I contained mushroom compost. Tract III received equal fertilizer treatment. Tracts II and IV contained blue crab by-products compost.

The amount of compost applied to Tract I, Tract II (blue crab by-products with cypress bark) and Tract IV (blue crab by-products with pine bark) was 200 lb./tract or the equivalent of 40 tons/a. Tract III, commercial fertilizer (8-8-8), received a total of 7 lb., using split applications: 2 lb. were broadcast and incorporated into the soil, 2 lb. were banded at planting time and three sidedressings were included at 1 lb. each application (Table 1).

TABLE 1

Crab by-products compost fertilizer, spring 1990

Treatment	Amount	Application
Compost	40 tons/a. (200 lb./84 sq.ft.)	broadcast/incorporated
Crab by-products and cypress bark	40 tons/a. (200 lb./84 sq. ft.)	broadcast/incorporated
Crab by-products and pine bark	40 tons/a. (200 lb./84 sq. ft.)	broadcast/incorporated
Fertilizer 8-8-8	800 lb./a. (7 lb./84 sq. ft.)	broadcast/incorporated/ split application

Each tract contained these crops for testing: three tomato plants (fruiting crops), three 24-inch rows of beans (legumes), three collard plants (leaf crops) and three squash plants (yellow crookneck, cucurbit).

Results

There was no appreciable difference in time of seed germination of beans and squash planted in the four tracts.

From time of germination up to 25 days, plant response to blue crab by-products compost in Tract II and Tract IV was almost equal to that in Tract III and Tract I. However, Tract II and Tract IV showed early symptoms of P deficiency.

In order to obtain best results from Tracts I, II and IV, irrigation played a vital role in coagulation of soil particles and organic matter used in this study. Dry soils reduced microbial activity in the soil, and some friability of organic materials was lost through wind erosion. In Tract IV, the pine bark with blue crab by-products provided a 20% greater water-holding capacity than that in any of the other three tracts.

Trial plots were planted April 11, 1991 (Table 2).

TABLE 2

Crop response to crab by-products compost fertilizer treatment

Location: Tallahassee, Fla., 1990	Collards average plant height (in.)	Squash yield/plant (lb.)	Tomato yield/plant (lb.)	Beans yield/plant (lb.)
T-I mushroom compost	21	10.4	10.4	4.3
T-II crab by-products and cypress bark	18	5.4	18.0	2.4
T-III fertilizer	22	6.4	15.4	3.4
T-IV crab by-products and pine bark	17	4.3	9.0	2.4

T represents tracts

Tomatoes were harvested three times; squash was harvested twice. Average harvests are presented in Table 2. Collards were measured twice, and the average height was taken, while beans were a once-over operation.

Discussion

Results of this trial garden give strong indications that blue crab by-products are an effective soil amendment and organic fertilizer for vegetables grown in home gardens within the county and the Panhandle area. However, it is not clear from this study what exact amounts of organic materials to suggest for best results in various locations and with different cultural schemes. Most evidence shows a rate in the range of 40-50 tons/a. could be recommended for either blue crab by-products or mushroom compost treatments without additional fertilizer. An application of commercial fertilizer could be recommended when lower rates of organic sources are being used.

This study indicates that the utilization of blue crab by-products on home gardens and organic farms appears to be a most viable way to help solve the current problem of accumulation and disposal for blue crab by-products.

Large-Scale Composting of Blue Crab Processing By-Products in Florida: A Demonstration Project

by H. Clark Gregory, Soil and Water Conservation District, Fulton County, Ga.

Highly putrescible seafood processing by-products present a special opportunity and challenge to handlers. Blue crab by-products are rich in N, P and Ca, all primary plant nutrients. Coming from the sea, this material is also rich in micronutrients, trace elements so often lacking in sandy soils. On the other hand, blue crab by-products are smelly, runny and attract flies. Traditional blue crab by-products management practices call for getting the material buried in a landfill as quickly as possible.

Recognizing the problem and the opportunity, the Florida Sea Grant College Program, part of a national network of coastal state programs that assist marine fisheries, initiated this project. Sea Grant contracted with Woods End Research Laboratory of Mt. Vernon, Maine, to manage the project, based on Woods End Lab's experience on similar projects.

The project plan called for analyzing and inventorying the available compostable material in the seven-county study area in north central Florida. Researchers developed compost recipes based on available, compostable materials in the area. Taylor County officials cooperated by providing and preparing a 2-a. composting site. The county also provided labor, equipment and other support for the project, which will continue as a county-run compost production operation. Woods End staff planned and managed the project. Woods End staff handled materials delivery, compost mixing with a Wildcat compost windrow turning machine, compost testing and process monitoring.

The objectives of the project were: (1) to demonstrate that large-scale composting of blue crab processing by-products could be established in Florida as a viable, cost-effective alternative to continued land filling of the material and (2) to produce a high quality, nutrient-rich, potting soil-grade compost from blue crab processing by-products and other locally available materials. The Suwannee River Resource Conservation and Development (RC&D) Council, a local, nonprofit group, handled the compost market study and market development. The University of Florida Institute of Food and Agricultural Sciences (IFAS) is conducting field trials and growth studies using the blue crab-derived compost in order to determine best uses and optimal application rates for the compost product.

Through this project, otherwise wasted materials have found a home. There is no waste until it is wasted. Large-scale composting of food processing by-products prevents waste by converting the material into a rich humus, using simple farm technology. Involving the local, nonprofit RC&D Council and local soil and water conservation districts in market development gives the *Suwannee River Natural* brand of blue crab-based compost a competitive edge. Favorable growth results documented by IFAS will give the compost product added credibility. This project deals with high quality compost production, not waste disposal. Since most food processing residues are compostable, this project can serve as a model to others interested in converting an otherwise wasted resource into a rich, valuable and marketable compost.

Feasibility of Marketing Fisheries By-Products Compost

by Lynn Frederick, University of Wisconsin Sea Grant Institute

Introduction

Composting is a simple, inexpensive method of recycling organic by-products into valuable soil conditioner. Composting already has proven to be a technically viable alternative to direct land filling of fisheries by-products (Frederick et al. 1988; Mathur et al. 1988). In Wisconsin alone, commercial fish processing has yielded more than 3 million lb. of by-products annually (Stuiber, Lindsay and Vilstrup 1976), and sport fishery by-products probably equal that amount (Frederick et al. 1989).

Composts made of cow manure, sheep manure and sewage sludge are commonly sold throughout the United States. In Maine, 90,000-100,000 cu. yd./year of compost material are sold in bags and more than 130,000 cu. yd./year are sold in bulk (Commonwealth Marketing and Development 1988), suggesting a ready market for fisheries by-products compost.

Other studies have calculated the feasibility of turned-pile composting in scenarios that range from the cost of disposal by a fish processor to a large commercial composting and bagging operation (Brinton and Seekins 1988). The purpose of this study was to determine the economic feasibility of a small private enterprise that recycles fisheries by-products and waste brush into garden compost. Small business operations that have been documented and offer a basis for comparison and determining the potential of such a private enterprise include those involved in recycling newspapers into animal bedding (Powers and Widi 1983) and converting fisheries by-products into liquid fish fertilizer (Stuiber, Lindsay and Vilstrup 1976).

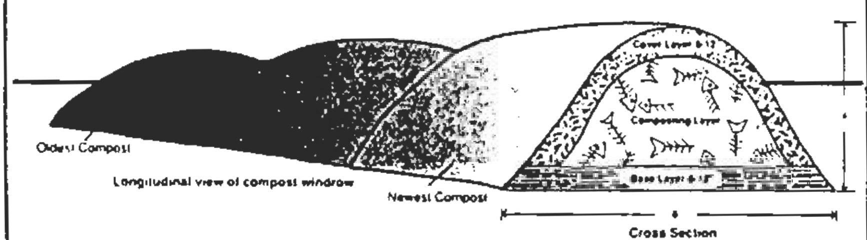
After the methodology for making fisheries by-products compost was developed, a pilot study was conducted on Washington Island, Wis., to: (1) determine the technology and financial costs of making fisheries by-products compost on a community basis, (2) determine the economic feasibility of a private composting business and (3) test the market for fisheries by-products compost.

Technical Aspects of Preparing Fisheries By-Products Compost for Market

Compost for the test market was prepared from fisheries by-products that were composted in the Washington Island pilot project using a static pile approach (Frederick et al. 1989). This method uses wood chips as a C source. The method first requires a base layer of wood chips. The material to be composted, consisting of one volume of fisheries by-products to three volumes of wood chips, is piled on top of the base layer. The entire pile is then covered with a mixture of wood chips and started compost to contain odors and keep vermin out of the composting material. The pile is constructed as a windrow approximately 8 ft. wide, 4-6 ft. high and as long as necessary (Figure 1).

FIGURE 1

The fisheries by-products composting process



Prior to being bagged, the raw compost must be chopped to create a uniform compost that can be readily tilled by the home gardener. Different kinds of equipment can chop compost to suit different applications: Forage choppers and soil shredders produce a relatively coarse compost suitable for mulching or tilling into gardens, while tub grinders and hammer mills produce a fine compost suitable for top dressing house plants, outdoor pots and small gardens.

Raw compost must be dry for chopping and bagging to avoid plugging up the machinery. In northern climates, the compost should be chopped in the fall, moved into a ventilated building and bagged throughout the winter for spring delivery. When a compost storage building is not available, the compost should be turned in the fall, covered with tarpaulins and chopped in the spring prior to bagging.

On Washington Island, fisheries by-products compost was prepared for test marketing from fisheries by-products composted in the pilot project during the summer of 1987. The trial pile was turned in the spring of 1988 in anticipation of test marketing but was not completely composted at that time, so the material was allowed to compost through the summer of 1988. That fall, the trial pile was chopped with a Gehl forage chopper, covered with tarpaulins and allowed to compost until spring. In spring 1989, the compost was chopped again and bagged for distribution at cooperating garden stores.

A major consideration in the test market — and probably in commercial operations as well — is the location of sales and service areas relative to the composting and bagging sites, because compost is bulky and transportation costs can be high. In the pilot study, compost was prepared and bagged on Washington Island, 40-250 mi. north of the targeted sales areas.

Because the compost had been chopped and stored outside under tarpaulins, the compost moisture content was still high and the compost was frozen on the planned April 15 delivery date. To meet project deadlines, it was necessary to re-chop the frozen compost and put it in perforated bags to enable the moisture to escape. Several cooperators who received this compost said the insides of the bags turned green with algal growth. In a commercial situation, the compost should be moved to a minimally heated, well-ventilated building in the fall so it can be turned, dried and packaged throughout the winter.

Packaged compost usually needs labeling approved by the agriculture department in the state where the product is sold. Although stipulations vary from state to state, they generally require labels to list the ingredients of the compost, its intended uses and the amount in the bag. Because composts gain and lose moisture depending on where they are stored, they can be sold either by weight or by volume. Most sphagnum peat products are sold by volume, while topsoil and manure composts are commonly sold in 40-lb. bags.

The compost used for the test market was labelled as "Door County Fish Compost" and bagged in 1-cu.-ft. packages that weighed approximately 25 lb. Each bag contained a consumer acceptance survey. The intent of the study was to find a market price for the fisheries by-products compost rather than to encourage direct price comparisons with similar products.

Test Marketing Compost from Fisheries By-Products

Test marketing was designed to: (1) determine product acceptability by both garden stores and consumers, (2) determine an appropriate price range for fisheries by-products compost and (3) determine if a market exists for potential entrepreneurs.

Altogether, 800 bags of compost were delivered for test marketing (Table 1). Deliveries began April 15, 1989, first to the most southerly locations. All deliveries were completed by May 20, 1989. Store managers were interviewed by June 15. Representing a variety of marketing situations, the garden stores included a small organic specialty store, a hardware store, locally owned garden centers that cater

TABLE 1

Results of test marketing Door County fisheries by-products compost

Store location	Bags delivered	Retail price per cu. ft. of DCFBC	Retail price per 40 lb. of other	Comments
Madison, Wis. #1	150	$2.95	$2.00-2.95	Could sell 600 bags: delivered, palletized and shrink-wrapped.
Madison, Wis. #2	100	$2.49	$2.49	Preferred coarser grind, forage chopper rather than hammer mill.
Lake Forest, Ill.	100	$6.00 $3.95 $1.49	$1.49-2.95	Compost initially sold well at $3.95; when inside of bag turned green, compost sold for $1.49.
Milwaukee, Wis.[a]	100	$2.99	$1.49-2.49	All sold. Chain store market can be difficult for private entrepreneurs to enter. Chains usually purchase bulk material and repackage it under their own labels.
Green Bay, Wis.	50 compost	$2.99	$1.49-2.49	Part of same chain as Milwaukee stores.
Sister Bay, Wis. #1	100 compost 20 mulch	$2.50	$2.49-3.49 $2.00	All sold. Didn't sell as fast.
Sister Bay, Wis. #2	50 compost 20 mulch	$4.00 $2.00	No others sold	Compost looked more valuable, so they sold it for twice as much.
Sister Bay, Wis. #3	50 compost	$1.99 $1.49	$2.00-3.00	When compost turned green, price was reduced.
Sturgeon Bay, Wis.	50 compost	$2.98	$1.98-2.98	Could use more.
Jacksonport, Wis.[b]	10 compost	$5.00		Broke up one bag into 1 lb. packages, sold them for $1.00 each as compost tea for watering house plants.

a. Chain garden center. Fifty bags delivered to each of two locations.
b. Organic specialty store.

to customers from a variety of neighborhoods, a feed and seed cooperative, and a major garden center chain. The cooperating stores were asked to price the compost as they saw fit, and they were permitted to keep the money from compost sales in return for providing information.

The 11 cooperating stores sold the compost at prices ranging from a low of $1.99 at the hardware store to a high of $5.00 at the organic specialty store. Among the garden centers, prices for a 1-cu.-ft. bag ranged from $2.49 to $3.95, with the most common price range between $2.95 and $2.99. The organic specialty store repackaged one bag into 1-lb. bags and sold them for $1.00 each to be used in compost tea for watering house plants.

Fisheries by-products compost sales were approximately equal to sales of composts made of other materials, such as cow and sheep manure, although the price of fisheries by-products compost was definitely higher. Cow compost sold from $1.49 to $2.95 for a 40-lb. bag compared to the price of $2.49 to $3.95 for fisheries by-products compost, which sold in 1-cu.-ft. bags that weighed approximately 25 lb.

All stores sold their allotments of fisheries by-products compost, indicating that the compost is readily saleable in garden stores. The fact that the Door County fisheries by-products compost sold for more than other composts indicates that sales were not based on price alone.

To find out whether sales were based on perceptions of the words "Door County," 100 bags of compost were bagged as "Washington Island Fish Compost." In Milwaukee, two garden stores from the same chain received 25 bags each of "Door County Fish Compost" and "Washington Island Fish Compost." Near Sister Bay, Wis., where the project was well known, the major garden store received 50 bags each of "Door County Fish Compost" and "Washington Island Fish Compost." The price and the rate of sales of "Door County Fish Compost" and "Washington Island Fish Compost" were the same in all of the stores.

Costs of Producing Fisheries By-Products Compost

The primary purpose of developing the fisheries by-products composting process was to find a less expensive alternative to direct land filling. During the Washington Island pilot study, approximately 100,000 lb. of fisheries by-products were composted each season at a cost of about $6,000/year. (The cost includes the expense of chipping brush.) The fisheries by-products yielded approximately 100,000 lb. of compost each year. Yield depended on the amount of water in the fisheries by-products, type of wood chips used and moisture content of the finished compost. During this study, the compost was weighed to get an approximation of yield, but it was bagged and sold by volume. While the relationship between fisheries by-products and finished compost is only approximate, the information has been included to help potential composters determine how much material to gather for a profitable operation.

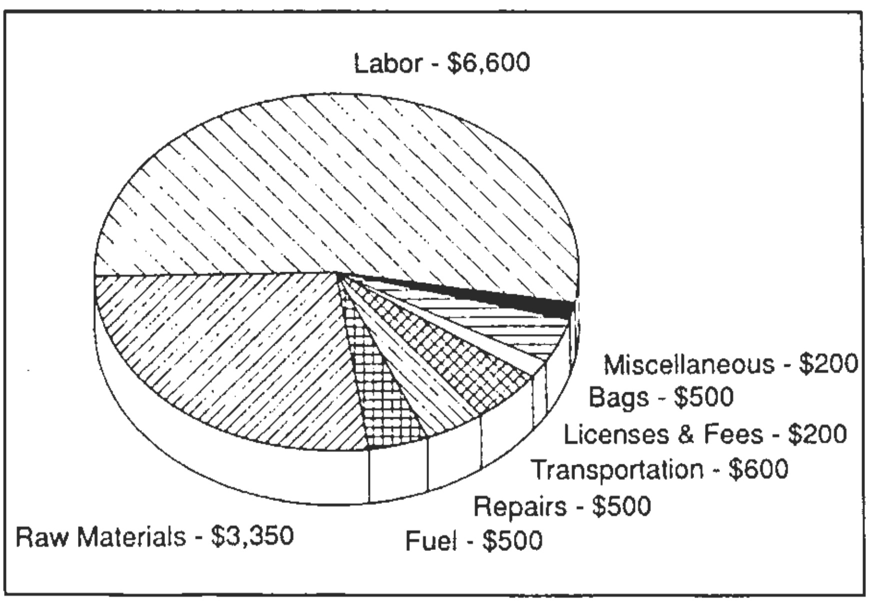
The primary purposes of the pilot project were to gather information on the costs of making fisheries by-products compost and to test the market for the fisheries by-products compost that was produced. During the pilot project, most of the expenses to the university were variable costs. The variable costs of producing 200,000 lb. of fisheries by-products compost over a two-year period during the Washington Island pilot study are shown in Figure 2.

Labor is the primary cost of producing fisheries by-products compost for an operation that handles up to about 10,000 lb. of fisheries by-products/day, or a total amount of 500,000 lb./season (Figure 2). The amount of labor needed to compost 50,000-500,000 lb. of fisheries by-products differed little among the several private sites. Beyond 500,000 lb. of compost per season, either more labor or larger machinery is needed. During the Washington Island pilot project, labor was valued at $6.25/hour, and it accounted for 53% of the variable costs associated with the project.

In the pilot project, approximately one-third of the labor was devoted to chipping brush. Brush chipping costs, including labor, were used as a basis to calculate the cost of raw materials in Figure 2 because there are numerous possibilities for acquiring bulking agents. On Washington Island, the most effective method of gathering wood

FIGURE 2

Variable costs of producing 200,000 lb. of fisheries by-products compost



chips was to buy a used brush chipper and have the composter chip brush. In other situations, it could be more cost-effective to buy wood or bark chips and/or pay to have them delivered to the site. Under the best of circumstances, a composter could accept wood chips delivered by a municipality, public utility company or tree service.

There is an obvious trade-off between equipment and labor. Since this was a pilot study, there was a minimal investment in equipment and a considerable investment in labor. In this study, the private cooperators owned the land and major equipment. Compost entrepreneurs could range from farmers, fishers or landscapers who already own land, equipment and some raw materials, to entrepreneurs who want to establish a fully capitalized operation. A basic description of the equipment necessary to produce fisheries by-products compost is included in Table 2 to guide potential composters to suitable machinery. Since an operation needs at least one year, and preferably two years, to produce finished and bagged compost, this study assumed one would purchase adequate used equipment and re-invest after profits justified additional capital expenditures (Brinton and Seekins 1988).

Economic Feasibility

Bringing the fisheries by-products compost to market cost approximately $13,000 (Figure 2, Table 3). In Wisconsin's climate, producing marketable compost takes two seasons, so costs for both years were expensed in the operating statement (Table 3), taking into account that part of the cost is in producing compost that will be sold the following year. More likely, the first year's costs would probably be amortized as startup costs. To recover $13,000 in costs, 6,500-cu.-ft. bags of compost would have to be sold at a wholesale price of $2.00/bag. These calculations assume that the individual already has access to the machinery and land needed to make compost.

If an entrepreneur plans to invest in capital equipment also, considerably more compost must be sold. To recover the costs of a $31,000 capital investment (Table 2) over a five-year period in addition to the $13,000 expense, 9,550 bags/year would have to be sold at $2.00/bag. Obviously, more compost would have to be sold to show a profit, to cover interest expenses on capital equipment or to show a reasonable rate of return on capital invested. In actuality, most potential composters probably would own much of the equipment needed to make compost and would need to purchase only a few capital items.

Practical experience with several private cooperators indicated little difference in the amount of labor required to compost 50,000-500,000 lb. of fisheries by-products. Increased costs are attributed primarily to bulking agents, bagging and transportation, with smaller increases

TABLE 2

Capital expenditures necessary for a fisheries by-products composting business of 50,000-500,000 lb./year

Major capital expenditures	**Cost**
Used industrial tractor[a]	$5,000
Used dump truck[b]	12,000
Used hammer mill and motor or forage chopper[c]	1,000
Agricultural land[d]	10,000
Cement mixing bin and pad, gravel approach, site grading and berming (corn field)[e]	2,500
Bagging equipment[f]	500
Total	**$31,000**

a. Because the fisheries by-products are heavy, an industrial tractor is needed to mix and pile them. An industrial tractor and loader, small payloader and large Bobcat® all proved satisfactory.

b. A dump truck, rigged with a barrel lifter to handle barrels of fisheries by-products, was used to haul both fisheries by-products and wood chips to the Washington Island site. At other private sites, a dump truck was not needed because wood chips were accepted from city, county, public service and private tree trimmers. Fisheries by-products were accepted at some sites, although it was more satisfactory to collect them. In place of the dump truck, a 3/4-ton pickup with a hydraulic end gate for lifting barrels of fisheries by-products was used.

c. The hammer mill was used to chop and mix the finished compost because wood chip composts are not homogenous. A forage chopper also can be used, but it produces a coarser mix. A tub grinder or "haybuster" can sometimes be rented or leased to grind and mix larger volumes of compost for marketing.

d. Sites varied, but those with 10 a. of land or more were best because they allowed sufficient room for stockpiling materials, mixing, separating windrows, berming and landscaping (Frederick et al. 1989). The Washington Island site was bermed with a cornfield — a realistic, low-cost option in agricultural areas. Approximately 1 a. was devoted to the production of 100,000 lb. of compost.

e. A cement mixing and receiving area with a gravel approach is necessary if composting must continue in rainy weather. Site grading and berming depend on the physical characteristics of the site. In some areas, a tamped gravel pad is needed to allow access to the windrows in rainy weather.

f. Bagging costs were minimal in this pilot study. The major expenditures were for the bags and labels. (A commercial operation would use 4-mil perforated bags with ultraviolet screening and imprinted labels. These can be readily ordered in lots of 10,000 or more.) The only capital expenditures were a jaw-type heat sealer and stand. Bagging was done by hand with a homemade hopper to measure volume. On a commercial scale, bagging lines with various levels of automation are available as the investment justifies it.

TABLE 3

Likely operating statement for a small private composting business

	200,000 lb.	400,000 lb.
Gross income[a]		
Compost valued at $0.08/lb.	$16,000	$32,000
Cost of materials (if wood chips are purchased)[b]	3,350	6,700
Gross profit	**$12,650**	**$26,300**
Operating expenses		
Labor and fringe benefits	$6,600	$7,000
Insurance	200	200
Fuel	500	750
Repairs	500	700
Transportation[c]	600	1,200
Licenses and fees[d]	200	250
Bags[e]	500	1,000
Miscellaneous supplies[f]	200	200
Marketing expenses[g]	1,000	1,000
Total operating expenses	**-$10,300**	**-$14,000**
Net profit (before income tax, depreciation and debt service)	**$2,350**	**$14,000**

a. Gross sales were based on a wholesale price of $2.00 for a 25-lb. bag and on volumes of 200,000 and 400,000 lb. Other scenarios are possible. One operator sold fine compost packaged in 5-lb. bags for $5.00/bag. Other operators could sell unchopped compost in bulk at the end of the first season to eliminate chopping and bagging operations.

b. These figures are based on the cost of labor, equipment, fuel and repairs needed to chip brush for 200,000 lb. of fisheries by-products on Washington Island.

c. The costs of transporting the Washington Island compost to test markets were used as an estimate. The bagged compost produced on Washington Island was ferried to the mainland and delivered to market in a cargo van. Most composts are palletized, shrink wrapped and delivered by truck in larger lots.

d. In Wisconsin, a $100 permit is required by the Wisconsin Department of Agriculture, Trade and Consumer Protection to sell compost with an approved label. Sales tonnage fees are also collected. Licensing requirements vary from state to state.

e. Costs of bags vary depending on their size and type. In large lots, the cost of labels printed on the bags is less than that of separate labels.

f. Miscellaneous expenses included tarpaulins, hoses, thermometers, shovels, etc.

g. Marketing expenses can be significant for a new product.

attributed to labor, fuel and repairs to machinery. Composting 200,000 lb. of fisheries by-products is marginally profitable if the business operator already owns the major capital items. Doubling the amount of fisheries by-products from 200,000 lb. to 400,000 lb. increases profits from $2,350 to approximately $14,000 (Table 3).

To increase profits or provide income, sales scenarios other than cubic-foot bags wholesaled at $2.00 each are possible. One organic marketer sells compost at a retail price of $5.00/five-lb. bag at major garden shows and the remainder at a wholesale price of $2.50/5-lb. bag as a top dressing for house plants and flowers. Another cooperator sold one-year-old unchopped compost for $30/ton at the composting site to make enough money to buy a hammer mill to chop the remainder of the compost for bagging. Composters with large amounts of material probably will have several types of packages, and composters with small volumes probably will try to get the highest price possible.

Summary

A small-scale composting business is financially feasible for disposing of fisheries by-products if at least 200,000 lb. of fisheries by-products are available annually. However, the feasibility is closely tied to the cost of the bulking agent. In this study, the bulking agent was free except for the cost of chipping brush. Brush-chipping costs could have been recoverable by charging for the service. Fisheries by-products were hauled for a fee or accepted at no charge. At one extreme, tipping fees can be charged for accepting fisheries by-products, brush or wood chips. However, as the amount of fisheries by-products increases, the amount of free bulking agent is rapidly exhausted, and wood chips could have to be hauled greater distances or purchased. As the cost of the bulking agent increases, the cost of composting rises dramatically, since seven to 10 volumes of bulking agent are required for each volume of fisheries by-products. The potential entrepreneur should plan carefully to ensure an adequate supply of materials at an affordable cost.

Test marketing indicated that customers were willing to pay a premium for fisheries by-products compost, and each delivered bag of fisheries by-products compost can sell for more than $2.00/cu. ft. with creative marketing and packaging techniques.

While composting seems to be financially feasible on a small scale, an entrepreneur needs to ensure an adequate supply of free or low-cost fish and bulking material before starting a fully capitalized operation on a for-profit basis. It is more likely that an individual who wants to enter the fisheries by-products compost business already is involved in a related business, such as fishing, farming or landscaping, and will already own or be able to make arrangements for land and machinery. The compost business could then be viewed as a cost-effective supplement to another business.

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Implementing Fisheries By-Products Composting Applications: The Next Step

by Scott Andree, Florida Sea Grant Extension Program

Introduction

Landfills have been and still are the primary means of disposal for fisheries by-products in Florida and in many other states (Cato 1991; Otwell 1981). In Florida, landfill space is rapidly being depleted, and landfill costs are ever increasing. Fisheries by-products, because of their high protein content, are extremely malodorous and require extra chemicals and/or soil cover to control putrification odors. This adds cost and reduces the life expectancy of the landfill. One county in the Florida Big Bend region, where 70% of the state's blue crab processors are located, spends 25% of its landfill operating budget on 17% of the waste stream: "crab garbage" (Andree 1988).

In the near future, landfills will not be available for disposal of fisheries by-products. In Florida, the 1988 Legislature passed a solid waste management act which states that "commercial food processors may not dispose of any animal parts, fats, by-products, waste products...in landfills unless approved by the department." Although most seafood processors in Florida are relatively small waste generators (less than 3 cu. m./day) (Andree 1988), landfill fees are increasing dramatically to eliminate unwanted and often expensive waste streams. Leon County, Fla., for example, implemented a $100/ton fee for blue crab fisheries by-products.

Many alternative methods have been examined and used to eliminate wasting by-products, including dehydration (Murray and DuPaul 1981; Hansen 1990), land application (Aung et al. 1981; Wyatt and McGourty 1990), ensiling (Meyers et al. 1987; Abazinge et al. 1986), composting (Cathcart et al. 1985; Brinton and Seekins 1988; Brinton 1990) and anaerobic bioconversion (Andree and Earle 1990). All of these methods, among others, have potential benefits, yet composting could be the best least-cost option for a long-term solution. Composting also has the potential to eliminate several waste streams from landfills. Not only the fisheries by-products but also other C-based materials, such as yard trimmings, brush and some construction debris, can be utilized for composting. In Florida, there is a mandated 30% recycling requirement by the end of 1994. Therefore, several objectives can be met with composting. There are several entities for which composting applications can be implemented, depending on location and amount of bulk and organic materials available. These include fish/seafood processing plants, marinas and commercial composting operations in the private sector as well as publicly owned facilities, such as landfills, sewage treatment plants and road departments.

Several factors need to be assessed when examining composting as an alternative for disposal or recovery of fisheries by-products. A few of the major attributes and limiting factors are discussed below.

Attributes

Simple Methods

No matter what method is chosen, whether open windrow or containment system, active aeration or static pile, composting is simple and cookbook in nature. Methods can be adjusted to scale and are flexible enough to fit the smallest processor as well as the largest commercial operation.

Affordable

Composting does not require expensive equipment or facilities to operate successfully. However, the larger the operation, the larger the equipment needed. Costs can be minimized by utilizing equipment already purchased for other uses. For example, a front end loader at a landfill can also be used at the compost site; a fork lift used in a fish/seafood processing plant or marina could be used for composting.

Minimal Labor

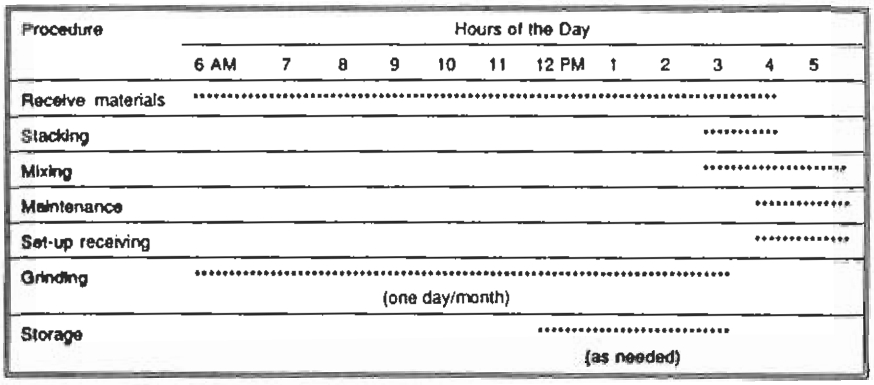
Composting does not require excessive manpower. One man working two or three hours a day can maintain a large-scale composting operation. In Taylor County, Fla., one man was able to handle daily waste inputs of up to 10 tons in a two- to three-hour period (Figure 1). This adds to the affordability of the process by reducing labor costs. Efficient composting does require that one person be responsible for coordinating the delivery of bulking materials and organics with the labor schedule to meet the needs of the compost mix. However, this management task is also a part-time job.

Marketable End Product

Obviously, the attribute that brings the most attention is the one determined by value. In general, fisheries by-products composts will command a higher price on the market if quality control is maintained. In particular, quality control applies to crustacean-based composts containing chitin, which have limited nematicide value as well as soil enhancement properties (Cato n.d.). The fact that the end product can

FIGURE 1

Composting daily procedures: Wakulla County landfill



be sold, thereby providing a means of recovering a portion, if not all, of the cost of production, indicates that composting can be a least-cost option for handling fisheries by-products.

Limiting Factors

C/N Supply

The composting process requires the right mix of ingredients for the microorganisms to function (Brinton 1990). The general rule of thumb is a 2 to 1 ratio of C to N, by volume. The availability of C and N sources can vary dramatically over the course of the year as seasons change. One must be flexible and ready to substitute other types of C or N to maintain an ongoing composting operation. Certain fisheries (e.g., calico scallop and Spanish mackerel) tend to be seasonal; therefore, composts produced from by-products of these fisheries will also be cyclical. Difficulties in marketing could arise due to an unpredictable supply throughout the year, or inconsistent quality (e.g., NPK, pH, organic content, etc.), due to changing ingredients.

Space

Space can be limiting at fish/seafood processing plants or marinas. Commercial operations and landfills generally have plenty of room. A fish/seafood processing plant or marina could have to find a remote site to have enough room to set up windrows or store finished compost. This is not a large problem to overcome; however, space limitations will affect the operational logistics and ultimately the cost for long-term composting.

Maintaining Quality

The quality of the finished compost will determine its value on the market. Even though we are taking what is currently thought of as "waste" and making compost from it, quality control is still required to produce a high quality end product. Our experience in Florida with blue crab processors has been that often the incoming "crab garbage" also contained plastics, metal cans, fish boxes, waxed cardboard boxes, bed springs, garden hoses, trash bags, etc. Needless to say, more time was spent sifting out the unwanted materials than mixing the compost. Landfills and commercial operations will need to screen incoming compost ingredients to maintain quality and reduce time and manpower "cleaning" the compost.

Regulations

The biggest obstacle in Florida's development of compost operations at processing plants, or at private facilities, is the regulations regarding siting and site design criteria. Since the composting industry is just getting started, the regulatory agencies in Florida have set up very cost-prohibitive rules without much input from the fledgling industry, or available research data. These strict rules are primarily related to protection of groundwater quality. For example, sites must have concrete or asphalt pads under the windrows and have on-site leachate collection and removal systems (Fla. Admin. Code, Rule 17-709.5). Many of these precautions could be alleviated over time as more information is gained and research is conducted on leaching, contaminants, etc. Currently, however, regulations could limit operations in certain areas. Landfills are not faced with this problem since compost permits can be added to landfill operation permits.

Technology Transfer

If composting technology is simple, manageable and affordable, and if the end products are marketable, then putting these applications into practice in the real world should be relatively easy as well. Unfortunately, although on a small scale this could be true, on a larger scale there are some questions as to where composting will ultimately fit in.

In Florida, three large-scale composting demonstrations were conducted, two involving blue crab by-products and the other, scallop by-products. The ultimate goal of each was to turn the demonstrations over to either county governments or private enterprises to be continued as ongoing operations. The two projects that were continued at county landfills (Brevard and Wakulla counties) were approved by the Florida Department of Environmental Resources under landfill operation permits and are successfully planning to proceed with composting. The Taylor County demonstration was transferred to a private farm in a neighboring county with the assistance of the Suwannee River RC&D Council. However, after two attempts to acquire the necessary permits from Florida Department of Environmental Resources, each denied for leachate concerns, this operation will be temporarily put on hold (Johnson 1991).

The difficulties in acquiring permits, specifically the costs associated with meeting the compost design criteria and the apparent unwillingness of the permitting agencies to work with the industry, could prevent the private sector from getting involved at the present time. However, the prediction is that a large percentage of the municipal solid waste stream will be composted by 1994 to meet the mandated recycling requirements. Composting fish/seafood processing by-products will complement this pattern, at least in the public sector and hopefully in the private sector in the future.

Implementation Needs

The following needs assessment is based on the Florida composting demonstrations and results reported in earlier papers. There appear to be four gaps that need filling before this technology will take hold and begin to operate on its own.

First, as mentioned above, there is an immediate need for more research-based information on compost leachates and their potential effects on ground and surface waters. This will help the permitting agencies understand what level of contaminants exist in composts and be better able to determine what site designs are necessary to protect water supplies.

Second, there is a need for manuals and guides directed to the audiences that will be producing compost: fisheries by-products generators, commercial compost operators, landfill operators, etc. These materials should include a cookbook of recipes for the novice composter as well as the experienced. These recipes should describe a variety of inputs, with some formulas for producing desired end products, and also describe the different compost technologies, listing advantages and limitations.

Third, a manual describing the uses of the various composts will be necessary for teaching consumers how to best apply the products. Since these composts are just being developed, studies are needed on how to best use them for vegetables, in horticulture, as nematacides, etc., including how to use the composts in conjunction with more traditional soil amendments.

A final need is in the marketing area. With the volume of composts expected to be produced, moving these products could create bottlenecks. Given higher quality attributes of fisheries by-products composts, marketing studies would be a great help in placing these products in the best form and packaging for the consumers to recognize them as a value. This will ensure a premium price on the market.

Conclusion

The future looks bright for the development of fisheries by-products composting, an idea whose time has come. Composting has been around a long time, but now the time is right to apply this age-old practice to the current disposal problems of fish/seafood processing by-products. The outcome is a natural and cost-effective solution that will produce long-term positive results for many businesses and communities.

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Discussion Session on Technology Transfer

by Scott Andree, Florida Sea Grant Extension Program

Participants in this discussion session concurred that composting technology has not changed, except for newer equipment to replace pitchforks and shovels. The established techniques, however, are now accommodating different input materials (e.g., fisheries by-products).

One participant said that, for composting, the effective transfer is sociological rather than technological. People must change how they view waste and, instead, think of its potential value (e.g., as compost) — both economically and environmentally. Another participant said that the current throwaway mentality must shift to a recycling mind-set.

Overall, the discussion generated several recommendations on technology transfers and social changes to promote fisheries by-products composting, including:

- Compile an information base on fisheries by-products composting in a loose-leaf notebook format. New compost recipes, equipment and procedures specifications, end uses, etc., could be added as they become available.
- Produce how-to publications/videos for small-scale fisheries by-products composters.
- Develop model legislation, or sample regulations for permitting agencies, to showcase mechanisms and data that could alleviate environmental concerns about fisheries by-products composting.
- Draft business feasibility guidelines for entrepreneurs who plan to start fisheries by-products composting operations.
- Initiate a master gardener program to familiarize gardeners with fisheries by-products composts and how to use them.

- Publish fisheries by-products composting newsletters locally (e.g., county- or statewide) to disseminate information at the grass roots level.
- Continue positive press relationships to enhance public perceptions of fisheries by-products composts and their uses.
- Inventory potential input materials at county and state levels, evaluating for both C and N sources.
- Expand broad-based marketing efforts via school programs, local businesses and civic clubs.
- Examine the success stories of other products made from recycled material (e.g., tires) to find transferable ways of maximizing income from fisheries by-products composts.
- Focus all fisheries by-products composting enterprises on generating the highest quality products and, thereby, building market value.

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AKU-W-90-001. Sue Keller (ed). **Making Profits Out of Seafood Wastes.**

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FLSGP-Z-80-016. David A. Stuiber. **Fishery Waste Management in the Great Lakes.**

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VIMS-R-81-003. Louis H. Aung and George Joseph Flick, Jr. **The Use of Fish Solubles and Crab Wastes on Agricultural Crops.**

VPI-TL-82-001. Jan C. Dean, Larry A. Nielson and George Joseph Flick, Jr. **Seafood Processing Wastes as Fish Meal Substitutes in Catfish Feeds.**

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VSGCP-T-84-001. Louis H. Aung, George Joseph Flick, Jr., G.R. Buss, et al. **Growth Responses of Crop Plants to Fish Soluble Nutrients Fertilization.**

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