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Composting and Using By-Products From Blue Crab and Calico Scallop Processing Plants in Florida

James C. Cato, editor

FLORIDA SEA GRANT COLLEGE PROGRAM

Florida Sea Grant College Program

Florida Department of Environmental Regulation

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I. RECOMMENDATIONS

Blue crab and calico scallop processing plant residues traditionally are landfilled, creating unique waste management problems. Alternative methods to landfilling were investigated including: in-plant compacting; anaerobic bioconversion potential; composting; compost marketing; use of compost on crops; and nematode control using compost. It appears feasible to compost blue crab and calico scallop processing plant scrap and there appear to be uses for the final compost products. Composting is a viable alternative to landfilling these processing by-products. However, composting should only be attempted after consideration of the complete production, use and associated problems.

General recommendations resulting from these projects are listed below. Each section should be consulted for detailed data.

Wet Extrusion

- Grinding and making pellets from blue crab scrap for use as aquaculture feed for spiny lobster, shrimp and freshwater crayfish is not recommended without additional research. Potential exists for finfish feeds.

Compacting

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

Anaerobic bioconversion

- Production of gas using crab scrap has potential, and the fluids were found to have more potential than the solids. Between 30 and 50 percent volume reduction was achieved, and the gas could be used for energy generation at the plant site if economically feasible. More research is necessary on-site with prototype systems before exact recommendations could be made.

- Most crab plants are isolated and in rural areas, which would require a biogas generation plant on-site. The capital costs may be too large for these small businesses, particularly without subsidies, as long as more convenient alternatives such as composting are available. However, biogas plants can be customized to suite the waste generating facility.

Open windrow blue crab scrap composting

- Large scale centralized composting using mechanical aeration is recommended as a scrap management option, where adequate crab scrap exists and can be transported to an acceptable central site.

- A number of materials including fresh cypress sawdust, aged cypress sawdust, pine bark and shredded yard trimmings can be used as a carbon source to compost crab scrap. The result is variable qualities of final product.

- A large scale blue crab scrap composting operation similar to the one demonstrated in Taylor County, Florida, 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 scrap composting

- For smaller blue crab scrap waste streams, this technology will work and is recommended. Sawdust, bark, and shredded yard trimmings and brush will work as carbon source materials. Additional grinding of this material after composting will be necessary to produce a desirable final product. With the exception of grinding equipment, existing "landfill type" equipment is all that is necessary for turning and managing the compost.

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

Calico scallop viscera composting

- The composting of scallop viscera will work and is recommended. However, more cooperation at plant sites with scallop processors is necessary due to the high portion of cracked shell and other material which must be removed. This is not necessary with blue crab processors, where the entire residuals stream can be composted. Several types of carbon sources also appear satisfactory for scallop viscera composting.

Compost use and marketing

- While it is recommended that blue crab and calico scallop viscera composting is a viable waste management alternative, it should not be attempted without prior analyses of the potential market and/or use of the final product. This is often a major and fatal flaw in "new-use" concepts.

- It appears crab scrap compost can be successfully marketed in the area of the demonstration project. Public acceptance appears genuine. However, promotional and educational programs will be necessary and the product and supply must be consistent, and the price competitive.

- There appears to 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 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 might result from either the crab scrap or organic matter used in the composting. Consumers will want this security.

- A complete marketing study needs to be conducted before starting any large scale compost operation. 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 they will receive from uses in the various applications they anticipate 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 scrap seems to offer some 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 and odor standpoint, is of limited value as a nutrient-supplying amendment.

- Long-term effects on soil organic matter levels, and adequacy of nutrient supply for more slow-growing crops including pine plantations, are other considerations where blue crab compost may 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 crab scrap in other studies. The depletion of nitrogenous compounds and reduction of energy sources probably reduced chitin concentrations and the nematode suppressive characteristics of the crab scrap.

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

- The ability of crab scrap to increase organic matter, and soil water retention, and to provide/retain soil nutrients, may be of more value than suppressing nematodes.

Environmental concerns

- Some areas have sandy, well-drained soils with generally low organic matter and low moisture retention capacity. In these areas, ground water may be susceptible to contamination from applied insecticides, herbicides, and fertilizer nutrients, and increased soil organic matter levels as a result of continued compost aplication may be a decided benefit. Laboratory condition tests indicate that arsenic, selenium and manganese leached from the crab compost may 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. These elements occur naturally in the crab scrap.

II. INTRODUCTION

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Residues from blue crab and calico scallop processing plants in Florida have usually been landfilled. Since these materials are highly organic and putrescible, they have created environmental problems at landfills. Various options have been examined to deal with these and other seafood processing plant by-products. These options range from dehydration for use as meal along with other handling methods (Cato, et. al., 1977 and Andree, 1988), and as a feed stuff for swine (Myers, et.al., 1987), to a complete overview of all seafood waste management problems nationwide (Otwell, 1981).

Chapter 88-130 of the Florida Statues signed into law during the 1988 legislative session mandated major changes in solid waste management in Florida. A portion of that legislation focused on handling of residues produced by 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 by-products, including shellfish parts, at public landfills. Such project shall (1) Identify alternatives of disposing of such seafood processing by-products; and (2) Determine the feasibility of disposing of such seafood processing by-products in an environmentally acceptable manner."

Section 83 (10) of Chapter 88-130 specified that:

> "There is hereby appropriated for fiscal year 1988-1989 from the Solid Waste Management Trust Fund to the Department of Environmental Regulation the sum of $500,000 for a demonstration project on alternative ways for disposing of seafood processing by-products as authorized by section 60 of this act."

After the passage of Chapter 88-130, the Florida Department of Environmental Regulation contracted with the Florida Sea Grant College Program for technical and managerial assistance to meet the objectives specified in the legislation. A number of meetings with county officials, seafood processing plant operators, state regulatory agency officials and university faculty led to the identification of the critical waste management problems and of possible projects that would demonstrate solutions to those problems (Cato, 1989).

Blue Crabs

Blue crabs yield 20 percent water when cooked, 12-14 percent meat, 35 percent shell (carapace) and 31-33 percent remaining body parts as scrap. Most of the waste management problem occurs in contiguous Dixie, Franklin, Taylor and Wakulla counties of north-west peninsular Florida. In Wakulla county, scrap from blue crab processing plants has represented about one-fifth of the total waste stream landfill volume and consumed about 25 percent of the landfill operation budget.

Prior work and current discussions leading to the demonstration projects reported in this document indicated that alternatives to landfilling the scrap from blue crab plants could be listed in three categories: (1) dehydration, (2) wet form uses, and (3) ocean disposal. Landfilling was recognized as the current method of disposal which has not been a satisfactory method due to cost of handling and environmental concerns. The advantages and disadvantages of dehydration have 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 for 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. Landfilling problems result from (1) large volumes of waste arriving at day's end, (2) large volumes of waste relative to all other wastes received, (3) large proportion of landfill costs increased due to crab scrap, (4) odors and (5) physical handling problems.

Calico Scallops

Calico scallop production is normally highly concentrated in Brevard County on the Atlantic coast. Production on a daily, weekly, monthly and annual basis is inconsistent and unpredictable. Typical annual production ranges from 2 to 15 million pounds (edible meat weight), with one recent year reaching 30 million pounds. Processing requires large amounts of water, with the by-product including by-catch from the vessels, processing effluent, shell, and raw viscera. Residues represent over 90 percent by weight of the original vessel production.

By-product management concerns have been listed in two general categories. Water quality concerns have included effluent volume, basic constituents in the effluent (BOD, 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 debate 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 some 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 cultch, drainage control, fill, etc. Viscera has been ensiled as a swine feed (Myers, et. al., 1987) and considered as a fertilizer for citrus and as feed for aquaculture species. The options have not been attractive, in that viscera supply has been inconsistent and unaffordable and the shell is desired for current local filling of low-lying areas.

Waste alternatives examined for demonstration included in-plant controls including waste restrictions and segregation, alternative screening and recycling; secondary and innovative secondary treatment facilities; composting of the viscera and by-catch; landfilling 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 after agreement by Department of Environmental Regulation staff, county officials, seafood industry leaders, private consultants and university faculty. This report presents an overview and results of these projects. Topics covered include:

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

III. IN-PLANT METHODS FOR HANDLING BLUE CRAB SCRAP

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Overview

In 1988-89, thirty-one of the forty-five Florida blue crab processors were located in six counties (Franklin, Wakulla, Leon, Taylor, Dixie and Levy) on Florida's north-west peninsular Gulf coast (Figure 3.1). Most of these plants are relatively small waste generators, producing on the average 1.5 - 2.5 cubic meters/day (Andree, 1988). However, all of them were using county landfills for disposal. These landfills will not be available for disposal of seafood processing by-products (scrap) in the near future. In 1988, the Florida Legislature enacted the Solid Waste Management Act (Chapter 88-130). Section 16 (also Section 403.8075, Florida Statutes) states that commercial food processors "may not dispose of any animal parts, fats, by-products, waste products ... in landfills unless approved by the department" (FL Dept. of Environmental Regulation). This legislation also requires landfills to reduce waste volume by thirty percent by the end of 1994. Therefore, it is likely that crab processing by-products will be prohibited from landfills in the next five years, due to their potential value as fertilizer, animal feeds and nematicides (Brinsfield, 1981; Abazinge, et al, 1986; Mankau and Minteer, 1969). However, these options, among others, have not been fully explored and utilized in Florida.

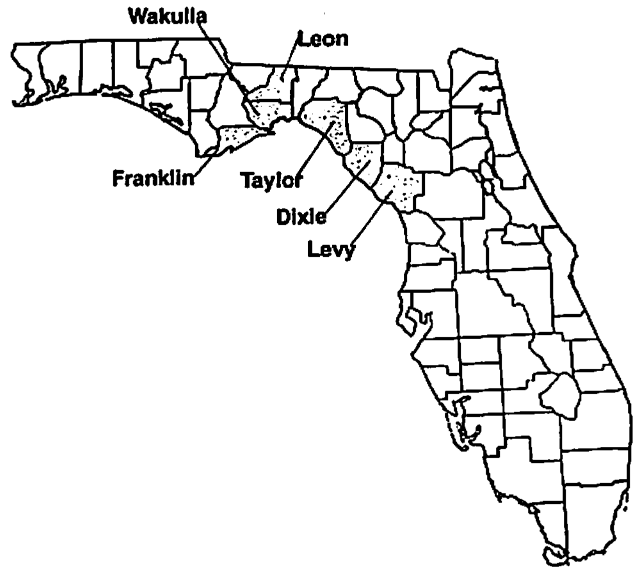

Figure 3.1 Six counties on north-west peninsular Gulf coast with 31 of Florida's 45 blue crab processing plants.

The goal of this project was to examine potential options for blue crab processing plants for better management and/or utilization of processing by-products at the plant. This would allow a plant to store scrap for further recycling or form new products from this waste stream. To accomplish this goal this project had the following objectives.

1. Determine the feasibility of handling crab processing by-products at the plant via (a) grinding and extruding (b) compacting, or (c) anaerobic bioconversion via small scale pilot demonstrations.

2. Evaluate all three methods with respect to volume reduction, storage and handling of the scrap within current plant operations.

3. Evaluate the fluids from by-product compaction for disposal into septic systems or waste water treatment facilities.

Wet Extrusion

Materials and Methods

Two hundred pounds of blue crab scrap were ground in a Hobart (2 hp) sausage grinder followed by a Fitz-Mill grinder to a final particle size of 1-2 mm. This material was frozen and shipped to the Kansas State University Extrusion Feed Lab in Manhattan, Kansas. The ground crab material was mixed in a ribbon mixer with soybean meal (48% TKN), potato starch and herring oil in two formulas (Table 3.1): one with herring oil and one without. A Wenger TX-52 wet extruder was used to produce a sinking feed pellet (7 mm dia. x 13 mm long). Feed pellets were run through a Wenger double pass burner dryer.

Table 3.1 Wet extrusion feed trials results

	Ingredient	Percentage by Weight	Pre-Extrusion Moisture	Post Dryer Moisture
FORMULA 1:	Ground crab scrap*	35.0		
	Soybean meal (48% TKN)	60.0		
	Potato starch	5.0	30.11	18.17
FORMULA 2:	Ground crab scrap	45.0		
	Soybean meal	41.0		
	Potato starch	10.0		
	Herring oil	4.0	36.04	20.29

*Ground Particle Size - 2mm

Approximately 15 pounds of the feed pellets, with herring oil, was sent to scientists experimenting with culture of crustacean species. These were spiny lobster, Panulirus argus, (Harbor Branch Oceanographic Institution), shrimp, Penaeus vannamei, (Florida International University), and freshwater crayfish, Procambarus peninsulanus, (University of Florida). These samples were sent to examine the acceptability of the pellets containing crab by the above cultured animals.

Results

Of the two formulations, the one which contained herring oil flowed the best off the extruder. Without herring oil, the pellets did not form properly and not enough pellets were produced for feeding trials. All formulations were extremely high in moisture (mean = 19.2%), even after two passes through a forced air dryer. The pellets began to mold within fourteen days and approximately 50 percent floated. One set of feeding trials was attempted with spiny lobsters at Harbor Branch Oceanographic Institution (Bill Lellis, personal communication). The lobsters readily accepted the pellets, however, the pellets tended to break apart before they could be totally consumed. This led to tank fouling and water quality problems. The remaining pellets had become too moldy for feeding trials with shrimp and crayfish.

Compacting

Materials and Methods

A simple box compactor, used by shrimp packers in Biloxi, Mississippi, was custom built for the blue crab demonstration and installed at the Gulfstream Crab Company plant in Chiefland, Florida (Figure 3.2). The compactor unit consisted of a rectangular box (2'x2'x3') with a movable end pushed by an 18-stroke ram (2500 psi operating pressure). The end opposite the ram was a hinged door to allow the compacted material to be removed. Holes were made in the bottom of the box to allow the compressed fluids to flow downward into a catch basin, and the top had a 1'x2' opening for loading. A heavy metal screen with 1 mm mesh matting was built to insert into the compactor for moisture removal trials.

Compacting trials were run to examine moisture and volume reduction and cohesion of compressed crab scrap in the following comparisons.

a. With screen versus without the screen

Photo by Scott Andree

Figure 3.2 Simple box compactor used in crab waste compacting trials.

b. Ground versus unground
c. Variable compression times (1 to 8 minutes)

Crab scrap for this demontration were ground using a claw machine hammermill.

Between 0.06 and 0.08 cubic meters (15 to 20 gallons) of crab by-product was weighed and poured into the compactor box. Compacting pressure of 600 psi was maintained for the trial times of one to eight minutes. Following the subsidence of pressure, the volume of fluid produced was measured and the compacted crab scrap were pushed out of the box via the ram into a basket. This material was poured back into a 20 gallon barrel for weighing and volume estimate. Weights were measured using a digital scale which was located at the crab plant for weighing incoming fresh blue crabs.

Samples of compacted scrap were taken at the middle of the compacted mass for moisture analysis and a subjective evaluation of cohesiveness. Moisture analyses were run at the Bio-Process Lab at University of Florida in Gainesville, Florida.

Results

Volume reduction of crab scrap was highest via grinding, achieving 42.5% reduction. Compacting without the screen achieved the best volume reductions for both ground and unground crab scrap (25.0% and 28.6%, respectively). However, volume reductions via compacting were approximate estimates only, whereas the weight reductions, and moisture analyses were measured.

Weight reduction, representing the fluid removed, was highest for ground scrap without the screen (20.8%) (Table 3.2). However, there was only one observation in this category because it was found that using the screen provided a more even compaction of the material and was determined to be the preferred method for future trials. Of the remaining trials with the screen, the greatest weight reduction was at one minute with ground material (12.3%). There appeared to be a general trend of increasing percentage of weight lost (or fluid removed) with increasing time of compression in the remaining trials for the ground crab scrap. This is more apparent when examining the percent moisture reduction (Table 3.3).

The inconsistencies seen in this pilot study data may be partially attributed to the high variability of moisture content in the raw crab scrap, ranging from 65 to 75%. This was especially apparent in the unground scrap, which appeared to have no correlation of weight lost (or fluid removed) with time of compression.

Additional contributing factors leading to these results was that the compactor box was not completely filled to the top during the runs and a top plate did not exist to keep pressure downward during compression. Therefore, moisture was pushed up to the top of the mass and, after pressure subsided, reentered the material increasing the variability of the moisture reduction data. These factors could be easily solved through slight modifications to the compactor design in future studies. This compactor was selected because it was inexpensive and was currently being used in the seafood processing industry for dewatering shrimp hulls.

Anaerobic Bioconversion

Materials and Methods

Raw crab scrap and compressed fluids from the compactor trials were collected and evaluated in the following stepwise series of studies:

Table 3.2 Compacting trials: mean percent reduction by weight (lbs.)

	Unground		Ground	
Time (mins.)	W/O Screen	W/Screen	W/O Screen	W/Screen
1:00	4.9 (1)	--	--	12.3 (1)
2:00	6.2 (3)	6.7 (1)	--	8.1 (2)
3:00	10.1 (1)	--	--	--
4:00	8.3 (2)	8.8 (1)	--	9.4 (3)
5:00	10.0 (1)	--	--	--
6:00	7.8 (2)	8.7 (1)	20.8 (1)	10.6 (3)
8:00	--	11.3 (1)	--	10.5 (2)

( ) Number of trials

Table 3.3 Compacting trials: mean percent water content reduction

Compression Time (min.)	Ground (w/screen)	Unground (w/o screen)
1:00	1.9 (1)	+ 0.2 (2)
2:00	1.4 (2)	1.3 (2)
3:00	--	4.7 (2)
4:00	2.0 (3)	+ 1.5 (2)
5:00	--	2.4 (1)
6:00	3.3 (3)	2.0 (1)
8:00	4.5 (2)	--

( ) Number of trials
\+ Moisture gain

a. physical and chemical analyses of the wastes;

b. assessment of the ultimate conversion and rate of conversion via the biochemical methane potential (BMP) assay;

c. process development and optimization using bench-scale digesters.

Through this approach, results generated could be used as a basis for systems calculations and decision-making for incorporation into future design, and operation of demonstration and full-scale bioconversion facilities.

Where appropriate, analytical procedures outlined in Standard Methods (APHA, 1989) were used to determine total and volatile solids, total nitrogen (TKN), phosphorus (P) and chemical oxygen demand (COD) of the raw waste. Ammonia-nitrogen concentration was determined by steam distillation followed by titration with standard sulfuric acid, using boric acid as an indicator.

The ultimate anaerobic biodegradability of the waste was determined by BMP assay, conducted in accordance with a modified procedure of Owens et al. (Owens, et al, 1979). In this assay, approximately 180-220 mg of the substrate (waste) volatile solids were placed in 250-ml Wheaton serum bottles and incubated at 35 C, following addition of an active seed inoculum and defined nutrient medium. Measurement of gas production and gas composition were made at regular intervals until gas production ceased, using a measuring syringe.

The bench-scale reactor used in this study was a non-mixed, 20-liter capacity vertical flow system equipped for leachate recirculation. The body of the reactor comprised an epoxy-coated 8-in dia. carbon steel barrel, 30-in long, fitted with carbon-steel base, top flange and head plate. The barrel was slotted to accommodate a 1-in wide sight glass for the full height of the reactor. Inside the reactor were perforated substrate support and leachate distribution plates at the bottom and top respectively. The substrate was placed on the lower plate, and the upper plate placed on top of the substrate.

The head plate of the reactor was fitted with 3/8-in dia. ports controlled by needle valves, for gas collection, head space gas sampling, and head space purging. Feed and leachate recirculation ports complete the openings in the head plate. The bottom plate was also equipped for leachate recirculation. The reactor was operated at a controlled temperature of 35 $\pm$ 1 C, heating being accomplished by two external heater strips. A storage reservoir and leachate recirculation pump, temperature controller, and manometric Berlometer (TM) gas meter complete the bench-scale equipment used.

Gas composition analysis was performed on a Fisher Model 1200 Gas Partitioner chromatograph. For this determination, a 30-ml aliquot of gas was injected manually into a sampling loop from which 0.25 L was passed through two stainless steel columns, one a 6-1/2 ft. x 1/8-in. OD column packed with 80/100 mesh Poropak Q used for the separation and detection of CO_2, and the others an 11 ft. x 3/16 in. OD molecular seive column for the separation of O_2, N_2 and CH_4. Helium was the carrier gas, maintained at 30 mls/min. Determination of the separated gases was accomplished by comparison with standard gases using thermal conductivity detectors. This instrument was used with a Perkin-Elmer LC-100 Laboratory Computing Integrator.

Volatile fatty acids were analyzed using a Shimadzu 9-AM gas chromatograph equipped with a flame ionization detector. Samples and standards were acidified with 20% (V/V) H_3PO_4 to a final concentration of 2% (V/V), centrifuged, and the supernatant transferred to 2ml vials and preserved for analysis. Chromatographic separation and analysis were accomplished using a glass column packed with 10% SP-1000 on 100/120 Chromosorb. Analyses were conducted under the following conditions: N_2 carrier gas 30 ml/min., H_2 30 ml/min., air 25 ml/min., injector temperature 160 C, detector temperature 200 C, and oven temperature 140 C. Baseline separation of acetic, propionic, isobutyric, butyric, isovaleric, and valeric acids was accomplished by this procedure within 12 minutes. Acid concentrations were computed by a Perkin-Elmer LC-100 Laboratory Computing Integrator connected to the gas chromatograph.

Results

For this study, the total waste stream (TWS) and the liquid fraction (LF) were analyzed separately. Evaluation of these results are indicated in Table 3.4. Physical analyses of the samples indicated an average total solids (TS) concentration of 31.5% for the TWS, and a volatile solids (VS) concentration of 56% (dry weight) of the TS. This indicates a very high ash content (average 44%) for this waste stream. In the case of the LF the comparable results were 71% and 29% for VS and Ash (Fixed Solids), respectively.

Chemical analyses indicated COD value of 256 gm/L for the liquid fraction and 348 gm/L for the TWS, highlighting the pollutional potential of this waste stream. For the TWS, the TKN value was 2.01%, NH_3 -N was 1.96%, and total Phosphorus 0.09%. In the case of the LF, the TKN was 1.5%, the NH_3 -N was 0.3% and the total Phosphorus was 0.03%.

After 95 days, results from the BMP assay indicated a methane yield of 0.44 cubic meters of biogas per kilogram of volatile solids added for the liquid fraction. The yields from the TWS were 0.22 cubic meters of biogas, or about one half the output of the liquid fraction. In 65 days, the completed digester studies indicated that TWS was being completely digested in the process since the output was equal to the output in the BMP assay for the TWS at 0.22 cubic meters/kg of VS added.

The biogas being produced was a high grade gas containing at 65% methane. This compared favorably to solid waste garbage biogas production, which runs at 50-55% methane.

Table 3.4 Crab scrap analyses: anaerobic bioconversion trials

Characteristic	Total Waste Stream	Liquid Fraction
Physical Analyses		
Moisture Content (%)	68.6	
Total Solids (% wet wt.)	31.5	
Volatile Solids (% dry wt.)	56.0	
Fixed Solids-Ash (% dry wt.)	44.0	
Total Solids (mg/L)		107,270
Volatile Solids (% dry wt.)		70.6
Fixed Solids (% dry wt.)		29.4
Chemical Analyses		
COD (gm/L)	348	256
TKN (%)	2.01	1.5
NH_3-N (%)	1.96	0.3
Total P	0.09	0.03
Biogas Analyses		
BMP (m^3/kg of VS added)	0.22	0.44
Digester (m^3/kg)	0.22	
Methane gas (%)	65.0	

As for total volume reduction from this method, it was estimated that between 30 and 50 percent reduction was acheived.

Recommendations

The best method examined for volume reduction at the plant level was grinding. Of the type grinders used the hammermill would be the easiest to use. These are already being used in those plants that have claw machines. The sausage type grinder and Fitz-Mill would take more manpower and time to operate, although they can produce a finer particle size, hence a slightly greater volume reduction. If these crab by-products were to be used in an extrusion process for making feeds, the finer particle size would also be preferred. Other types of grinders should be examined, such as cork screw types, as alternatives.

Accurate volume reductions were difficult to determine following compacting due to the type of compactor used. However, despite the low pressure applied during compacting (600 psi), it was noted that the ground crab by-products held their compacted form much better than the raw crab scrap. Design changes would be necessary to improve the compacting capability and maintenance of the compacted block of crab scrap, yet, the potential is there to reduce the volume up to twenty-five percent via compacting leaving the fluids for anaerobic bioconversion.

Of the methods examined, compacting and grinding are the methods that could be implemented immediately using existing manpower at the plant and would not take a large amount of training to put into practice. However, these methods do not eliminate the by-products, only change their form and make them easier to store.

Wet extrusion and anaerobic bioconversion both need additional product development research before they can be implemented at the plant level. These methods do utilize the by-products, however, and can produce economically viable end-products that need to be examined further. The wet extrusion process can produce a feed pellet made of crab scrap which have potential for finfish culture of species such as red drum and tilapia hybrids which need the crustacean proteins in their diet for the red color. Unfortunately, the pellets broke apart too quickly in seawater for crustaceans to eat, also creating water quality problems in closed culture systems. Therefore, these feeds may not be suited for crustacean culture. Nutritional studies and diet analyses would be necessary to determine the appropriate ingredient ratio for final product development.

The biogas area has great potential since this process could address the energy requirements of the crab processing plant, as well as the by-product disposal. It does not require additional ingredients, as does extrusion. It is highly recommended that additional work be funded to examine this method to its fullest potential, such as with anaerobic wastewater treatment systems (Eilers, 1990). Several modifications to improve compaction would also enhance the development of biogas generators, since the fluids were found to be more useful in this process than the solids. The compacted solids could be utilized in making feeds a compost.

IV. COMPOSTING OF FLORIDA BLUE CRAB SCRAP

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Overview

The composting of blue crab scrap was demonstrated using two different methods. A large scale centralized conversion of blue crab scrap was undertaken in 1989 in Taylor County, Florida, utilizing open-windrow mechanical aeration (Wildcat™) methods. This method was designed to demonstrate the feasibility of a mechanized composting procedure where large volumes of blue crab scrap could be assembled in one location. A second demonstration project was conducted during 1990 in Wakulla County, Florida, to demonstrate a much less capital intensive method referred to as a low-technology static pile system. This process was examined for use where smaller amounts of crab scrap (200-500 pounds per day) were available from small, local processors and where central composting drawing on processors from a wide area was not possible. This low-technology static pile system has been used previously by Sea Grant at the University of Wisconsin for dockside fish scraps (Frederick, 1989).

The first several months of the composting projects in both regions were devoted to site selection and satisfying Florida Department of Environmental Resources permitting codes. A considerable effort was undertaken to develop the concept involving local participation of crab processors, universities, agency and consulting scientists and compost users. The Wakulla County static pile project grew naturally out of the previous demonstration in Taylor County and utilized many of the same resources, including processors and cypress sawdust. Woods End Research Laboratory, Inc., was the composting project leader, having been formerly involved in developing fish scrap composting in New England (Brinton and Seekins, 1988), where similar concerns about economic and environmental disposal of fish by-products are dominating industry discussions.

Open Windrow Mechanical Aeration Composting

By-Products Inventory

To begin the blue-crab composting demonstration project, a rough inventory was conducted of by-products currently available in the Taylor County region of Florida. Sufficient quantities of carbonaceous by-products were necessary in the region in order to conduct the crab scrap compost project.

Availability of materials is dictated by season, distance to use-point, and existence of commercial markets (Table 4.1). A large landscaping market exists for cypress mulch, so there are several regional processors who also handle other carbonaceous materials, such as cypress sawdust, of which some should be available for composting.

Table 4.1 Compostable by-products inventory for Taylor, Lafayette, and Wakulla Counties of Florida, 1989.

By-product material	Estimated annual volume in cubic yards	Source
Blue crabs	3,000	processors
Dairy manure	300,000+	area farmers
P&G knots/shives	15,000	P&G Plant
Cypress mulch	15,000	commercial
Cypress sawdust	10-30,000	region mills, commercial
Pine bark	>5,000	commercial
Yellow pine sawdust	>5,000	region mills
Chicken litter-manure	>5,000	area farmers
Poultry processing	2-3,000	region processors
Seaweed	>1,000	area beaches
Shredded brush	n.t.	limbs and yard trimmings
Wood chips	n.t.	recycling
Hardwood sawdusts	n.t.	region mill

n.t. not tabulated

Materials Used in Composting

A range of these materials was gathered for use in testing alternative compost mixes. The principal objective was to acquire cypress sawdust, which was present in the greatest quantities. Proctor and Gamble's knots and shives, a by-product of wood processing, and pine-bark, a coarse screen reject from processing bark for the commercial landscaping industry were second and third choices, respectively (Table 4.2).

Table 4.2 Summary of materials composted in the Taylor County, Florida blue crab windrow project, 1989

By-product material	As is tons
Blue crab scrap	380
Cypress sawdust	431
P&G knots/shives	148
Pine bark	42
Wood chips	22
Poultry processing	19
Chicken litter-manure	9
Shredded brush	6
Super-phosphate	6
Dairy manure	4
TOTAL TONS COMPOSTED	1067
Percentage crab-scrap	36%
Estimated cubic yards	2200

Photo by Jay Humphreys

Figure 4.1 Windrow of cypress sawdust before preparation for mixing with crab scrap.

The Composting Process

To begin the actual project, the site was prepared by laying a crushed limerock pad and organizing on-site enough carbonaceous materials to begin the first windrow (Figures 4.1 and 4.2). The blue crab scrap was collected from the four county area in three ways. A major waste management firm contracted to daily pick up the crab scrap from all of the plants located in Wakulla and Franklin counties. This was delivered to the compost site at the end of each day for a two month period. The one firm in Leon county transported its crab scrap daily to the site. Local Taylor county firms delivered their own scrap to the landfill site. The scrap was accumulated at a collection site and then worked into each windrow with a front end loader (Figure 4.3). All crab scrap and carbon materials were weighed at the on-site Taylor county landfill scales. Final composted materials were also weighed. Windrows were turned daily or as needed using the Wildcat^{TM} machine leased from the project powered by a tractor provided by Taylor county (Figure 4.4 and 4.5). The final product was stored on-site and at a local farm where it was screened and prepared for sale in both bagged and bulk form.

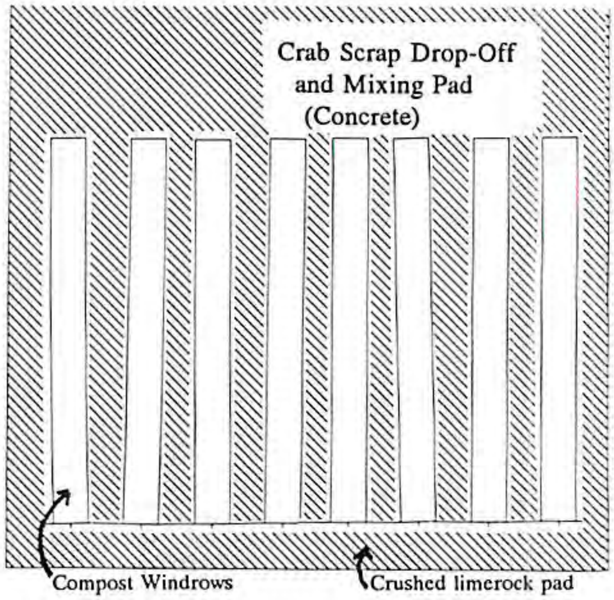

Figure 4.2 Taylor County blue crab scrap windrow composting site layout.

Photo by William T. Mahan, Jr.

Figure 4.3 Method used to place crab scrap and scallop viscera into opened windrows.

Photo by Jim Rich

Figure 4.4 WILDCAT™ machine turning crab scrap compost (front view).

Photo by Scott Andree

Figure 4.5 WILDCAT™ machine turning crab scrap compost windrow (rear view).

Recipes for Composting

The materials inventoried for use in composting varied greatly in quality. Carbon:nitrogen ratios ranged from a low of 3.6 in the crab scrap to over 200 in the sawdust (Table 4.3). An appropriate mix ratio was calculated based on the C:N, moisture and density. The calculation is performed by solving a simultaneous equation for two unknowns. This analysis suggested that a 1 part by weight crab to 2 of cypress sawdust (30% inclusion rate of crab), was the optimum mix rate.

All the materials tested with the exception of Proctor and Gamble "dregs" appeared to have qualities which in the context of a proper mix would be useful or desirable for composting. The dregs unfortunately contained sodium carbonate residue, with a resultant pH of over 13, and very little organic carbon. Eight windrow "piles" were composted (Table 4.4).

Tests of Beginning Compost Piles

After the first week, the compost piles were analyzed periodically to determine the changes occurring during the composting process. The first tests were for piles 1-7 when their age was between 7 and 10 days (Table 4.5).

Average initial mix moisture content was 45%, pH was 8.4 and organic matter 52%. The reason the organic matter appeared on the low side is due to the crustacean shell content, which was about 20% on a weight basis. Also, some initial breakdown and mixing with sand lowered the organic content.

Carbon:nitrogen ratios ranged from 15 to 56 in the mixes, with an average of 26, which is acceptable. A target C:N of 30 was desired for the initial piles. Using large scale mixing equipment meant that approximations of weight/volume had to be made during mixing.

Ammonium content averaged 0.5% in the fresh piles, which is 37% of the total nitrogen. At these levels of ammonium, which push the pH upwards, loss by ammonia release is expected ($NH_4OH \rightarrow NH_3\uparrow$

Table 4.3 Quality measures of materials used in blue crab scrap composting in Taylor county, 1989.

Lab Control Number	H20	pH	OM	TKN	C:N	NH3-N	P	K	Ca	Salt	C02
					Blue-crab scrap						
1670.0	65.0	7.65	55.47	8.84	3.6	n/t	2.25	0.35	14.2	6.2	n/t
					Seaweed						
1686.1	71.3	6.88	55.84	2.16	15.0	n/t	0.01	0.07	0.9	5.6	n/t
					Sawdusts						
1659.0	60.5	5.41	99.54	0.29	201.6	n/t	0.01	0.04	2.5	0.1	n/t
1665.1	48.0	4.15	98.92	0.34	171.01	-----n/t-----					
1665.2	53.6	3.88	99.44	0.31	187.1	-----n/t-----					
1665.3	50.0	5.10	96.51	0.64	87.0	-----n/t-----					
					Proctor & Gamble, knots-shives						
1665.5	63.7	9.08	94.45	0.75	72.8	-----n/t-----					
					Proctor & Gamble, dregs						
1665.6	47.3	13.8	33.18	n/t	n/t	n/t	0.03	0.11	10.7	61.7	n/t
					Pine bark						
1686.0	58.6	6.90	80.88	0.50	94.4	n/t	0.13	0.13	1.7	0.1	n/t

n/t not taken

Table 4.4 Description of windrow materials used in Taylor County blue crab scrap composting.

Pile Identification	Description
Pile #1	Fresh cypress + crab
Pile #2-3	Fresh cypress + crab, no phosphate
Pile #4 & 5	Aged cypress + crab
Pile #6	Pine bark + crab
Pile #7	P&G knots/shives + crab
Pile #8	Yard-trimmings, chips + crab & manure

Table 4.5 Values of variables measured from compost piles 1-7 after 7-10 days of composting.

Age	Lab#	H20	pH	OM%	TKN%	CN	NH3	P	K	Ca	Sal	Co2
7	1684.1	47.7	8.33	72.46	1.65	25.4	n/a	1.27	0.12	5.9	2.6	n/a
10	1689.0	48.6	8.73	56.12	1.39	23.5	0.577	0.06	0.16	7.8	6.0	n/a
10	1689.1	46.1	8.37	63.95	1.60	23.2	0.448	0.11	0.19	9.8	7.9	n/a
10	1689.2	45.9	8.03	54.53	0.56	56.2	0.254	0.08	0.07	3.9	2.2	n/a
10	1690.3	40.9	8.48	47.07	1.07	25.5	0.371	0.11	0.13	6.1	4.3	n/a
10	1693.4	37.1	8.46	35.45	0.96	21.4	n/a	0.16	0.07	4.8	5.9	n/a
10	1704.5	38.4	8.55	36.27	1.38	15.2	0.457	0.01	0.11	4.0	5.5	1.21
10	1704.6	54.1	8.60	51.20	1.77	16.8	0.811	0.25	0.12	4.0	4.2	0.07
MEAN :		44.8	8.44	52.13	1.29	25.9	0.486	0.25	0.12	6.1	4.8	0.64
SD :		5.7	0.21	12.71	0.40	12.8	0.191	0.41	0.04	1.9	1.8	0.80
MIN :		37.1	8.03	35.45	0.56	15.2	0.254	0.01	0.07	3.9	2.2	0.07
MAX :		54.1	8.73	72.46	1.77	56.2	0.811	1.27	0.19	9.8	7.9	1.21

n/a not available

+H_2O). The pH of the piles was strongly dependent on ammonium levels (Figure 4.6). Some measures were taken to correct the pH with addition of super-phosphate fertilizer which buffers pH. Consequently, less than half the piles had levels of ammonia that could be detected olfactorily (Figure 4.6).

Salt levels as measured by conductivity showed a range of 2-8mmhos/cm with a mean of 5, considered normal for a fresh compost. Considering that a relatively large quantity (40%) of seafood scrap was used in the composts, salinity is obviously not a problem.

Temperature Performance of Compost Piles

Composting temperatures are the single most valuable data for assessing the progress of decomposition. Temperature was monitored in all piles by taking readings every other day throughout the composting term (Figure 4.7). The difference between core versus outer layer temperatures is often used as an indice for aeration quality: the smaller the difference, the more evenly distributed is the oxygenation. Core versus surface temperatures were tracked by taking readings at 2.5 and 1 foot depths, respectively, in each pile.

Temperature monitoring results are presented graphically for three types of carbon source. These are windrows using fresh versus aged cypress as the sole carbon source (Figure 4.8), windrows amended with pine bark (Figure 4.9) and for windrows depending on either knots and shives or shredded yard trimmings as a carbon source (Figure 4.10).

Pile 1 (and similarly piles 2-3 which are not shown) which had fresh cypress sawdust sustained the longest period of active heating, but did not differ appreciably from aged cypress in early stages of composting; in fact, aged cypress showed higher earlier averages of heating. However, the aged cypress lost its heating potential after 75 days, whereas the fresh cypress re-heated after a cold spell that followed a period of rainfall (Figure 4.8). Both piles had completed active composting by about the 60th day, when the temperatures began to drop noticeably.

When pine bark was used as a sole carbon source, the heating was much more short-lived and

Data from all compost piles.

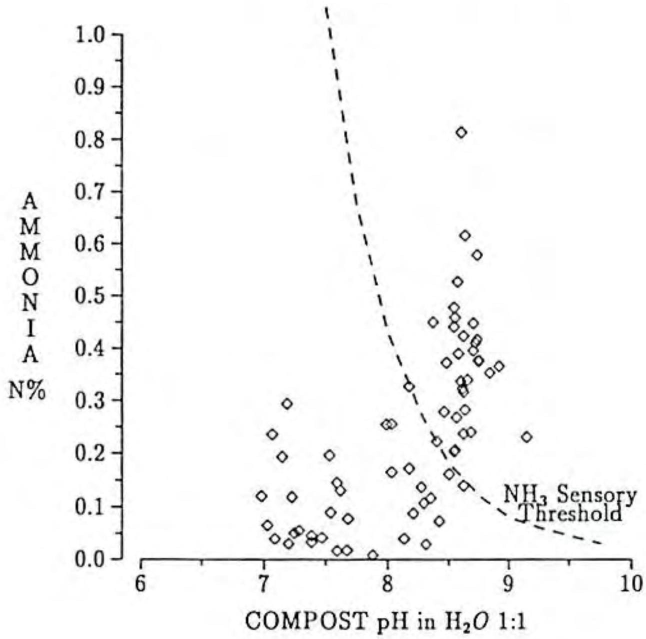

Figure 4.6 Ammonium level versus pH of pile for blue crab scrap windrow composting trials.

Photo by Jay Humphreys

Figure 4.7 Method used to measure interior windrow temperature using temperature probe.

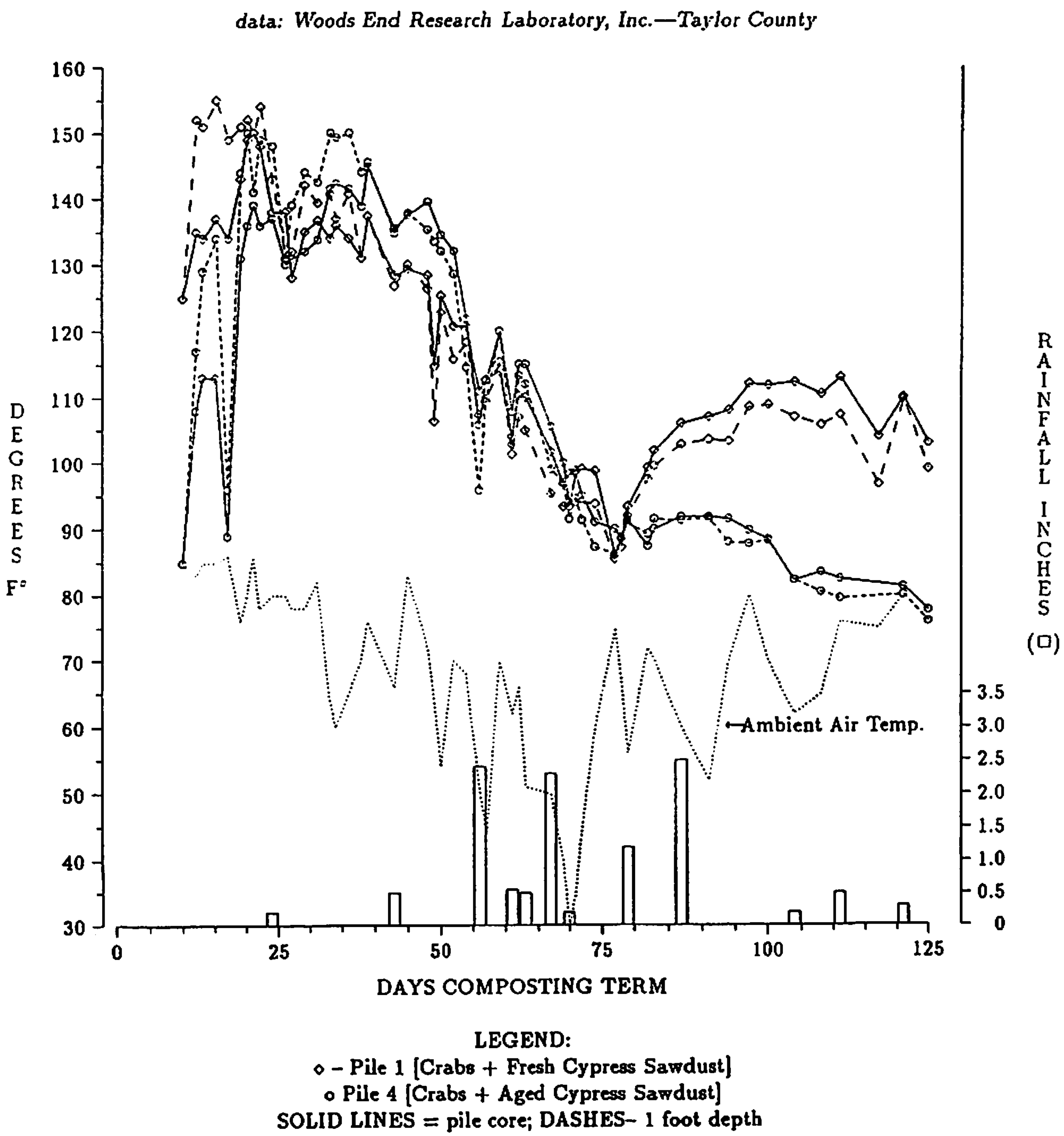

Figure 4.8 Temperature performance of blue crab scrap windrow composting trials using fresh versus aged cypress as carbon source.

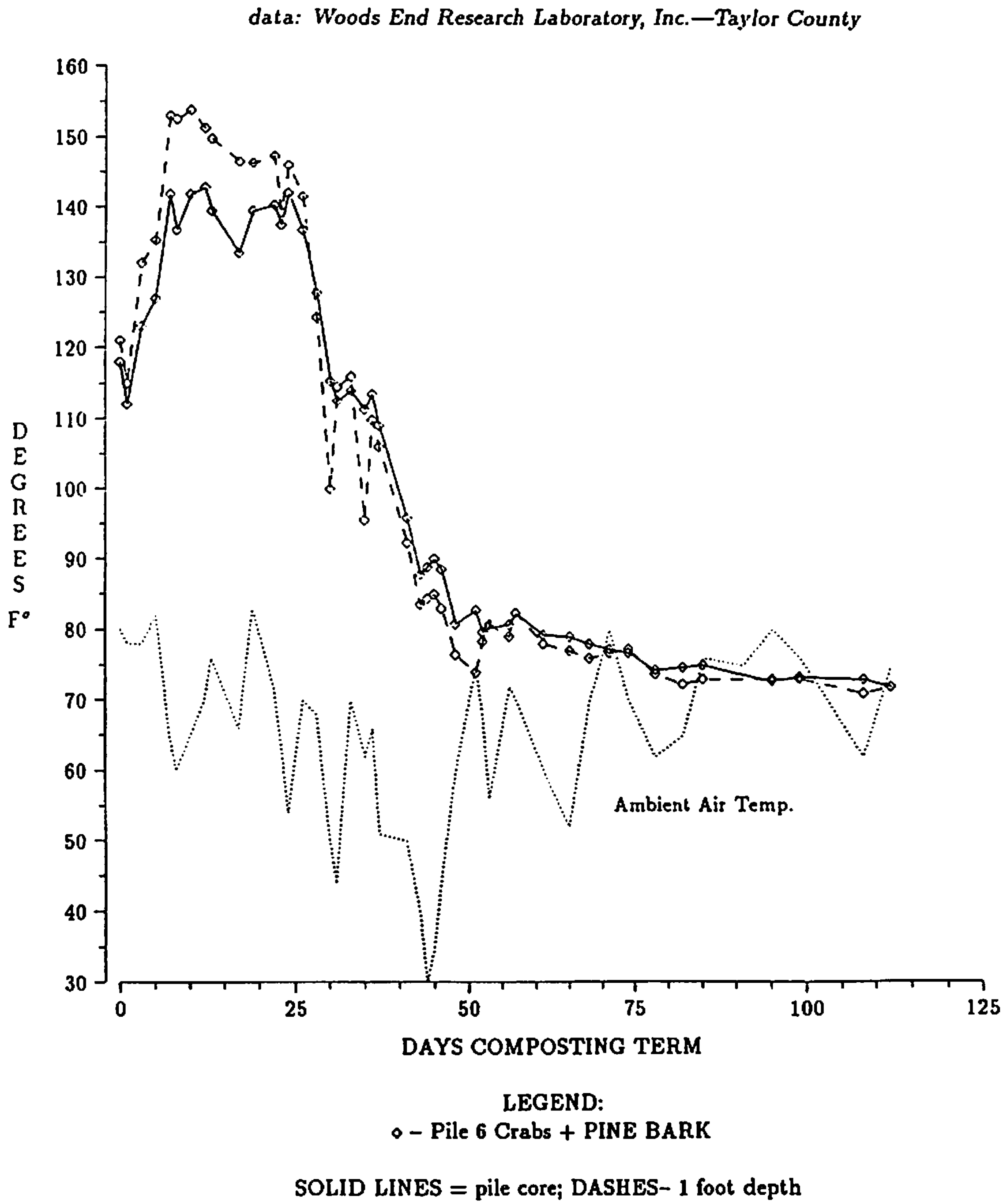

Figure 4.9 Temperature performance of blue crab scrap windrow composting trials using pine bark as carbon source.

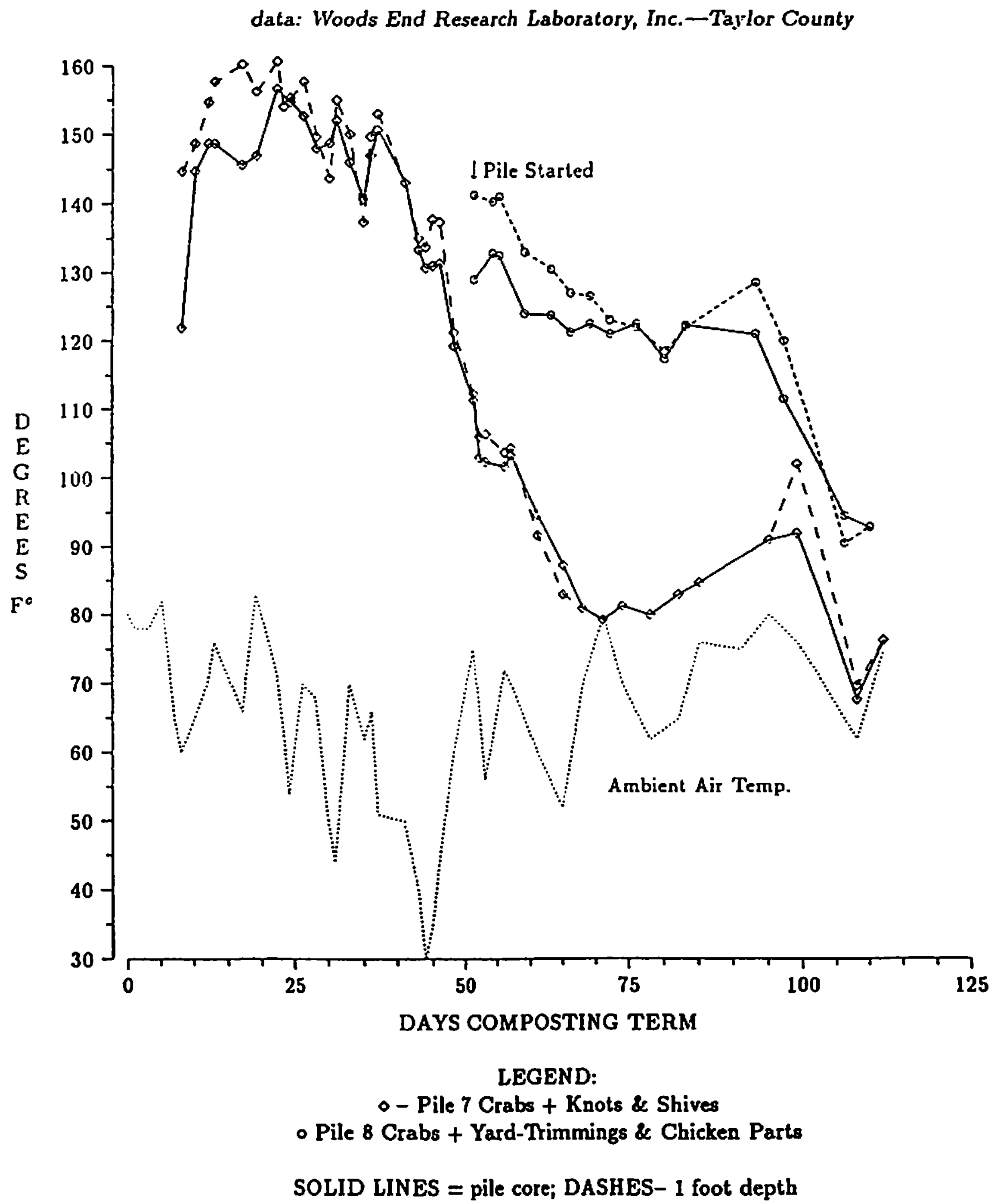

Figure 4.10 Temperature performance of blue crab scrap windrow composting trials using knots & shives and yard trimmings as carbon source.

the pile lost all heating ability before the 50th day (Figure 4.9). Knots and shives from the Proctor and Gamble Buckeye Paper plant, performed similarly to the pine bark, and lost most of the heat by the 50th day, while maintaining somewhat higher than ambient temperature through 100 days (Figure 4.10). In fact, this pile had some of the highest recorded temperatures. When shredded yard-trimmings and wood chips were used, temperatures were similarly elevated for about 50 days, then fell dramatically. The distinct difference about the shredded yard-trimmings and wood chips pile is that the temperatures never exceeded an average of 125F (mean of core and surface), which is much lower than all the piles. The piles with lower heating also emitted more odor. There may be some relationship to weather, however; the shredded yard-trimmings and wood chips pile was started just after the lowest winter temperatures occurred (Figure 4.10).

Rainfall may have played a role in Pile 1 re-heating after the 75th day, since these piles were beginning to get somewhat dry (35-40% moisture). There was no significant rainfall in the first two months of composting, then about 8" of rain fell within the next 30-day period (Figure 4.8). This also accompanied a rise in ambient temperature; the lowest compost pile temperatures coincided within 5 days of the coldest day of 26F, when it also snowed slightly. Compost temperatures usually track meteorologic events but lag behind by several days. Certainly, the winter temperatures encountered in Florida do not appear to present a significant limitation for active compost piles.

Temperature averages per day are given as is the number of days the pile core exceeded 55C or 130F, a temperature that is frequently used as a yardstick for performance (Table 4.6). Normally, composts which achieve this heat for 15 or more days are considered to be very successful, and in the trials all piles except the shredded yard-trimmings and wood chips compost attained this mark.

Test Results for Aged Compost Piles

These same groups of piles were sampled at the end of composting to ascertain the material condition (Table 4.7). These ripened composts averaged 74 days old. They differed distinctly from the initial compost in color, odor and texture; they were darker, humus-like and fine-crumbly. The tests showed moisture ranging from 31 to 53% with an average of 44%, similar to the initial compost. Rainfall occurred during the composting, so that with the loss of solids, even if the moisture percent stayed the same, the composts lost water. This is generally a desired result, since dryness favors a marketable product. However, if the compost gets too dry, then decomposition slows down.

The pH of the final product was much lower than the initial composts with an average of 7.6; the range of values was from 7.2 to 8.7, the high values being the same as the initial range. Some piles were not adjusted for pH. However, there was little ammonium present; the average being one-tenth what it was at the outset. Some of the difference is loss by ammonia, and some of the change represents immobilization into humus. Most of the change is ammonia loss, as the amount of fertilizer added was not enough to bring the pH low enough to make a substantial difference. Also, less nitrogen was in the product at the end (1%) versus at the outset (1.3%), although there is considerable variation between the piles. Later, the results of a mass balance calculation to ascertain nitrogen recovery, will be shown.

Normally, the C:N ratio will decline substantially during composting. Here, the final average

Table 4.6 Summary temperature data for crab compost piles in Taylor County project.

Variable	Pile-1 Fresh cypress	Pile-2 Fresh cypress	Pile-3 Fresh cypress	Pile-4 Aged cypress	Pile-6 Pine bark	Pile-7 Knots Shives	Pile-8 Yard Trim.
Mean F°/day core	118.4	124.8	121.7	111.4	103.5	119.6	n/a
Σ Days ≥ 55°C	30	31	33	30	21	36	3

n/a - not enough data points (15) to compute comparative mean

Table 4.7 Analyses of final composts in Taylor County blue crab project.

Days Comp.	Lab #	H20	pH	OM%	TKN%	CN	NH3	P	K	Ca	Sal	C02
76	1726.0	45.5	7.20	40.35	0.73	31.8	0.029	0.12	0.13	3.3	2.8	0.40
70	1724.1	52.6	7.54	45.61	1.58	16.7	0.089	n.t	0.06	2.0	3.3	0.40
70	1724.2	53.5	7.47	45.64	2.28	11.6	0.040	n.t	0.07	2.0	2.2	0.29
70	1726.1	44.0	7.39	34.02	0.62	32.0	0.044	0.11	0.16	4.1	2.3	0.60
63	1726.2	42.1	7.25	24.77	0.76	18.9	0.049	0.18	0.14	3.9	4.3	0.73
71	1748.0	35.4	8.00	28.34	0.47	35.1	n/a	0.10	0.13	5.0	2.4	n/a
99	1748.1	31.2	8.69	17.16	0.41	24.2	n/a	0.09	0.13	4.1	5.2	n/a
MEAN:		43.5	7.64	33.69	0.97	24.3	0.052	0.12	0.11	3.5	3.2	0.345
SD:		8.2	0.52	10.88	0.69	8.9	0.023	0.04	0.03	1.1	1.1	0.277
MIN:		31.2	7.20	17.16	0.41	11.6	0.029	0.09	0.06	5.0	2.2	0.200
MAX:		53.5	8.69	45.64	2.28	35.1	0.089	0.18	0.16	2.0	5.2	0.730

n/a not available
n/t not taken

was 24, not much different from the initial average of 26. The range is, however, lower; 11 to 35 in the final compost versus 15 to 56 in the fresh piles. An interesting outcome of nitrogen loss is that the C:N did not appear to decline as rapidly as expected, even though the stabilization and decomposition process proceeded at a high rate.

In comparing percent organic matter in the fresh versus final composts, the values are 52% vs 34%, a difference of 18%. However, the ash percentage increased from 48% to 66%, a relative change of 38%. This change represents the actual concentration factor that would be applied to interpret nutrient changes. Of course, if a pile could be weighed in and out, the same information would be gained, but this is rarely practical. In any event, the interest in assessing the losses of nitrogen and organic matter from the composting is high since this could affect the recommendation of methods for further composting and it would possibly influence product end-uses.

Analysis on the average composition of the blue-crab composts indicates several important facts (Table 4.8):

- 53.4% of the organic matter was decomposed, or 27.8% of the total solids;
- 45.7% of the total nitrogen was unaccounted for (lost);
- 48.7% of the volume was reduced, based on initial vs. final volume measurements.

Table 4.8 Recovery factors for blue crab scrap compost.

Parameter	Recovery %
Organic matter[a]	46.6
Total nitrogen	54.3
Solids[b]	72.2
Volume[c]	51.3

The changes in organic content (measured as volatile solids) show considerable spread (Figure 4.11), but the data clearly indicate a decrease of about 0.24% OM per day. Since full stability is generally reached when 40% of the volatile solids are broken down, the requisite composting period would be 85 days. Judging from the temperature graphs, the composts certainly appear to be stable after approximately 75 days, which compares favorably with the calculation.

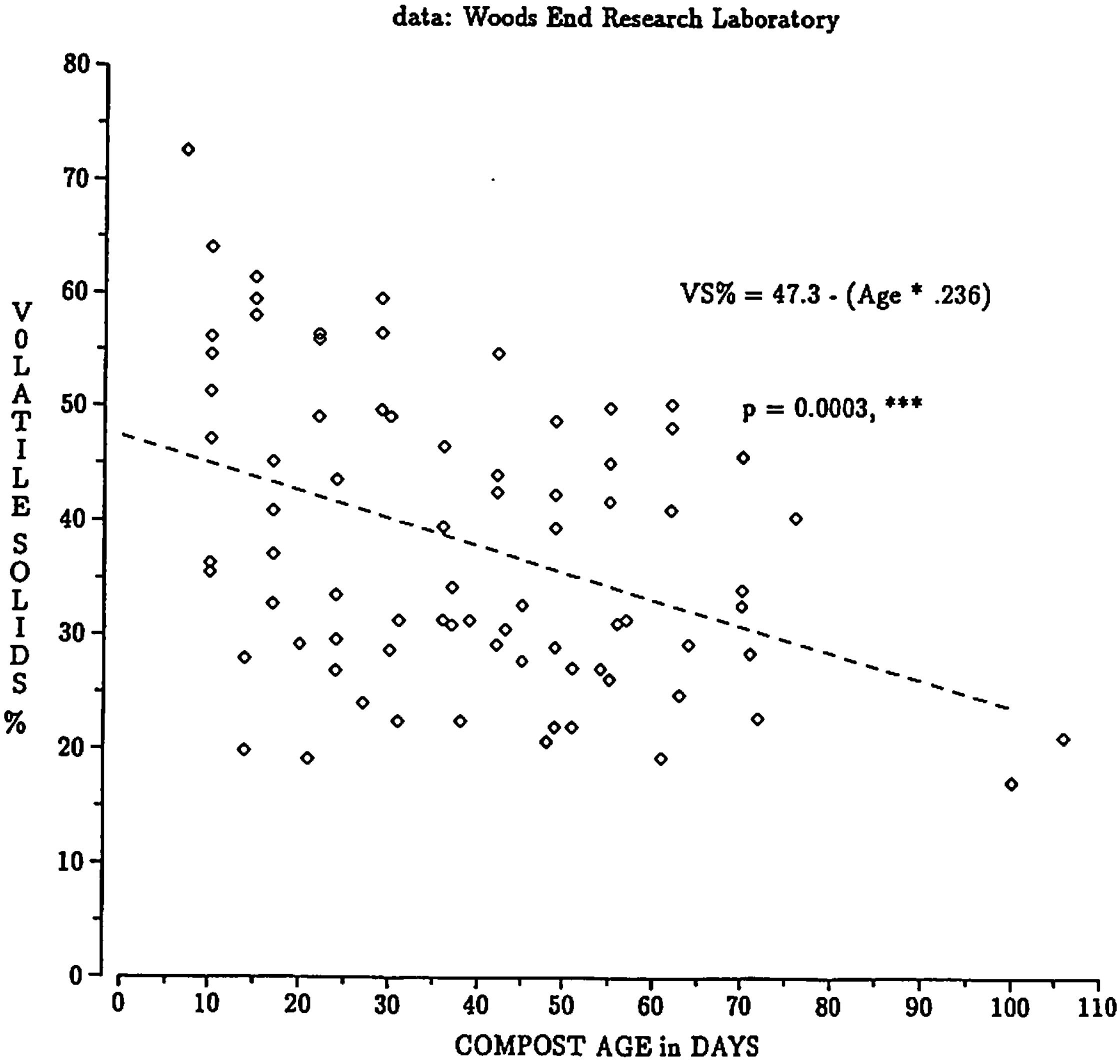

Figure 4.11 Change in volatile solids (OM) versus age of piles in blue crab scrap composting trials.

Economic Feasibility Analysis

The composting methods demonstrated in this report carry with them certain costs. This portion of the report is intended to present the costs associated with a moderate scale compost operation using the type of systems employed in the Taylor County blue crab scrap compost project.

With the rise of environmental concerns in general, and problems associated with seafood processing residuals in particular, traditional disposal costs have risen so significantly in the industry as to provide a new framework within which to assess feasibility of composting operations. In fact, compared to traditional disposal practices which formerly cost very little, a composting operation that exists on a break-even basis may be justified. The concept of composting as "value-added" and the potential of a commercial soil-amendment option for these by-products is something entirely new.

The Taylor County blue crab scrap composting operation principally addressed technical feasibility issue. Economic assessment of this particular option is constrained by the short-term nature of the project, and the research and development framework that was imposed on it. In developing a realistic economic model for the composting system used in Taylor County, some cost factors were excluded while others were expanded. Since a great many factors can have a significant impact on the cost of a compost operation and on the return per ton of product, many possible scenarios exist which could be proposed and for which these various factors would be adjusted. The analysis here is limited to a simple scenario believed to be realistic in the particular setting of this project. Important factors included in this assessment are site preparation costs, required equipment, operating costs, sources of raw materials, transportation costs, tipping fees, proposed markets, and land requirements. Where possible, cost factors used are based on the Taylor County project, but certain assumptions with regard to financing terms were made.

Assumptions -- This cost and returns budget (Table 4.9) assumes the composting operation is part of another enterprise -- either a farm or landfill with land-costs already paid. It is assumed that the equipment needs to be acquired separately, but that the tractor is purchased used from a farm-dealer.

It is assumed that the composter has an arrangement with crab processors to accept 3,500 tons of by-products annually, the maximum amount of crab scrap expected in the Taylor-Wakulla-Franklin region. It is also assumed that the composter will receive a tipping fee of $5 per ton ($0.35/barrel) from the processor. It is also assumed that 90% of the product will be sold locally in bulk at a price of $7.5 per ton, or only $4.50/yd. Ten percent of the product will be bagged and sold in garden centers, nurseries, etc., in the five-county area. The wholesale price is expected to be $1.00 per 40 lb. bag, a moderately low price due to the newness of the product in the market. In order to develop a high quality product for bagging as well as for spreading on farmland, all compost product will be screened.

For composting, it is necessary to have 5,250 tons of bulking agent. In addition to locally available cypress sawdust, an option exists to acquire a "knots and shives" product from a local mill at only the cost of trucking, as well as shredded yard-trimmings at no cost from county recycling operations. For purposes of this analysis, it is assumed that 2250 tons will be cypress sawdust at the cost of $10/ton ($4/yd) and the balance split between knots and shives at $1/yd ($4/ton) and shredded yard trimmings at no cost.

The operation will require a total of about 3.0 acres, of which two acres must be graded and layered with a 6 inch layer of marl rock. An unpaved open pole storage building with an area of 40 x 100 ft. will be constructed. The costs of the building and pad are amortized over 7 years. Equipment purchases include a compost turning machine powered by a tractor, a hopper and conveyor setup, a compost screening device and small bagging equipment. Testing equipment, such as thermometers, will also be needed.

For operations, 1 1/2 man-units are needed, or in other words, one full-time and one part-time. In addition, quality control is contracted to a composting consultant and includes required testing and environmental permitting compliance costs. As part of operations, some odor control additives in the form of gypsum, or equivalent, are utilized during the composting.

Findings -- This operation should produce approximately 5,000 tons of final product, based on assumptions of a solids loss of 30-40%. It is

Table 4.9 Budget for blue crab scrap composting operation.

Equipment	Cost Basis	Cost/ Year	— Cost per ton — Crab Scrap	Finished Compost	Rate/ Term
Compost turner	$23,000	$ 6,140	$ 1.75	$ 1.23	12%-5 yrs
Tractor	9,200	3,696	1.06	0.74	14%-3 yrs
Monitoring Equipment	450	450	0.13	0.09	—
Payloader	100/hr	3,600	1.03	0.72	Rental
SITE DESIGN					
2 acres/marl	12,907	2,928	0.84	0.59	12%-7 yrs
Storage building	35,000	7,414	2.12	1.48	12%-7 yrs
PROCESSING					
Screener	15,000	6,152	1.76	1.23	14%-3 yrs
Bagger	7,000	2,871	0.82	0.57	14%-3 yrs
OPERATING COSTS					
Labor 1.5	8/hr 1.5 men	15,360	4.39	3.07	
Quality Control		4,500	1.29	0.90	
Supplements		5,250	1.50	1.05	
Bulking agents	10.00	30,500	8.71	6.10	
SUBTOTAL– GROSS COSTS		88,861	25.39	17.77	
REVENUES					
Tip fee/ton crab	5.00	17,500	5.00	3.50	
Bulk Sales/cu.yd	7.00	47,727	13.64	9.55	F.O.B.
Bagged Sales/bag	1.00	25,000	7.14	5.00	Wholesale
TOTAL REVENUES		$90,227	$25.78	$18.05	
NET INCOME		$ 1,366	$ 0.39	$ 0.27	

assumed that all the product will be sold, allowing for screening recycling of coarse material back into the compost.

Total annual costs for this operation would be about $90,000. This would result in a net profit of about $1,400, or essentially a break-even operation.

Major cost items for this operation would be the cost of the bulking materials (about 34%) and the cost of labor (17%). An interesting point is that the compost turner, amortized over 5 years, represents only 7% of the annual costs, similar to the screener.

Significant changes in production costs could be made by identifying lower cost sources of carbonaceous materials. However, costs of these materials are already relatively low in this project compared to others. This is because the cypress sawdust was readily available in Taylor County, shredded yard trimmings are free, and knots and shives are delivered at cost. The use of more yard trimmings would require more screening since the coarse materials must be recycled, and the screening would increase labor demands.

A tipping fee has been charged to the fish processor to accept the crab scraps. At $5/ton, the fee is nominal and much less than landfill costs which can be $100/ton or more. It is also affordable for the small producer.

This analysis is based on the assumption that the composting operation will be able to sell the product. If it can not sell any, in the worst case, then the costs to run the operation are $25/ton. This is comparable to the lowest tipping fee currently assessed at the local landfills in Wakulla, Franklin or Leon counties, but is more than fees at the Taylor landfill, which are zero.

In summary, the study demonstrates that composting blue crab scrap is technically viable and is economically competitive in view of current disposal costs. This economic study has used conservative estimates of product value. If marketing can be developed, then there is a potential for earning profits.

Low Technology Static Pile Composting

In order to accommodate the variable and at times small waste stream of crab scrap, a small composting site was implemented at the Crawfordville, Florida, landfill in Wakulla County. This was the site where most of the crab scrap from the area was routinely landfilled. During the permitting process, the county began stockpiling brush for grinding into compostable bulking material. The compost source materials inventory available from the Taylor County project was utilized (Table 4.1). A variety of compost source materials including samples of available sawdust, bark and yard trimmings brush, and knots and shives were evaluated at the laboratory to ascertain compost mix ratios. A variety of compost source materials became available for the composting project including stockpiled pinebark residues from the Newport, Florida, chip mill and the abandoned Woodville sawmill.

Static Pile Compost Design

A modified "static pile" type of compost design was used for the Wakulla County project, similar to a design used in Wisconsin by the Sea Grant composting program (Frederick, 1989). A static pile of this nature is not aerated except by infrequent bucket loader turning and thus the success rests on timely initial blending and use of sufficient bulking/carbonaceous matter to effect natural air penetration and stabilization.

A simple layering technique was adopted whereby a pre-determined amount of crab scrap was placed onto previously deposited wood products, and piled to heights of 6-8 ft. For each of the pile types using either yard-trimmings or pine bark, a single-mix operation was implemented. This means that crab scrap was dumped daily or as produced directly into the woody products, mixed by bucket loader, and left to compost. The idea was to simplify composting while keeping within the bounds of acceptable odor and performance standards (Figure 4.12).

General Site Activities

The composting project in Wakulla county, was launched in the middle of October, 1990. Both receiving and composting pads were built utilizing crushed limerock. The receiving pad was layered in bark mulch or shredded yard-trimmings each day for the incoming loads of crab scrap. The crab was pre-blended with a payloader either when it came in or the following morning. Site workers would sometimes pile up the pre-mix at which point it started composting in the piles, but Woods End staff

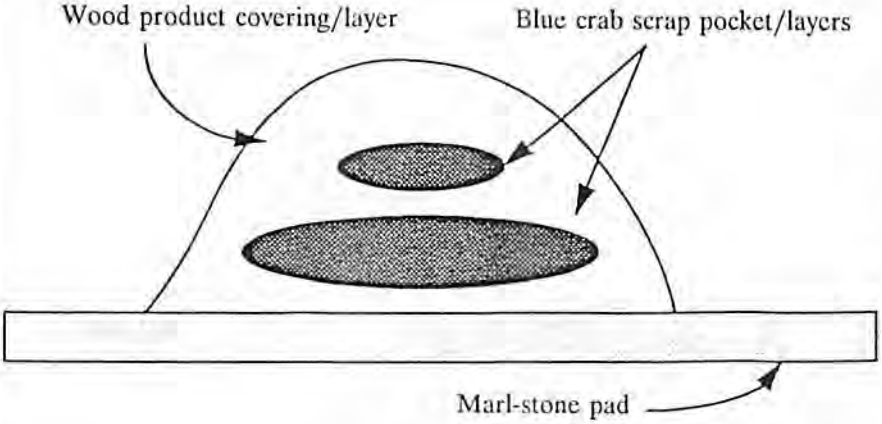

Figure 4.12 Static pile composting of blue crab scrap

worked with them to get an efficient routine established for pre-blending and windrow formation on a daily basis.

The Wakulla County solid waste crew observed positive changes in management and reduced odor production for the overall landfill site after starting the composting project. They reported that as early as two weeks after composting start-up the seagull population at the landfill had dropped dramatically to approximately one-quarter its usual level. Following this, the landfill crew reported that odors at the landfill significantly lessened. Finally, the landfill equipment operators observed that the other municipal solid wastes were handling and packing much better, and they attributed this to the fact that crab scraps were no longer going into the landfill (J. Henderson, Wakulla County Solid Waste Department, personal communication, 1991). Thus, there were important indirect benefits associated with the diversion of crab scrap to the composting operation.

Woods End scientists also assessed the potential recovery of monofill space with the County Solid Waste director. A large area estimated at 4000 cubic yards had been excluded from landfill operations resulting from crab scrap burial practices over the past four years. A sample was excavated from the monofill layer at the 4-5 foot depth under the 2 ft. gravel overlay. The anaerobic crab sludge was analyzed in the laboratory (see later discussion).

Materials: Crab Scrap, Monofill Crab, Wood Residues and Composts

A laboratory analysis for the raw incoming crab scrap, the monofill crab scrap (previously buried) and the recycled yard-debris (RYD) and bark compost mixtures was made (Table 4.10). No analytical data were collected for the raw incoming yard trimmings which varied considerably each day. The data clearly showed that the crab scrap had an extremely low C:N and moderately high moisture content, and only about 55% organic content, the remainder being calcium carbonate in the shells.

Tests on the monofill (recycled crab scrap) indicated that virtually all volatile solids have been removed as well as most of the original nitrogen. Phosphorus and potassium were slightly over their original levels. The concentrations of heavy metals were also tested and found to be very low and of no concern. The monofill crab scrap could not be considered an energy source in composting. However, this crab scrap could be recycled into existing composts with enough additional yard trimmings to compensate for the density and moisture.

A feature of this form of static, low-tech composting will always be variability. The different mixtures of crab with bark and yard-trimmings, as well as the final tub-ground mixture, differed quite noticeably. Nitrogen content ranged from one to two percent on a dry basis and moisture from 28 to 54 percent where the most crab scrap was placed in the piles. Indicative of crab percentages in the mix is the C:N ratio which ranged from 31 down to 13 among the various piles.

The final compost was piled up and passed through a tub-grinder to produce an even-textured, homogenous compost (Figure 4.13). The analysis of this material revealed an above-neutral pH and a moderately high C:N of 28 with nitrogen at 1 percent. Grinding compost materials is known to expose new carbon and thus the C:N will generally increase. The product tested out as relatively sta-

Table 4.10 Laboratory analyses of fresh crab, landfilled crab, and final crab composts.

Sample Type	Water %	Org. Matt.	pH 1:1	Total N	C:N Ratio	P %	K %	Ca %	Salts mmhos/cm	CO_2 Rate %
Fresh crab	65.0	55.5	7.7	8.8	3.6	2.3	0.35	9.8	6.2	---
MonoFill crab	22.0	5.4	8.9	0.49	6.4	0.41	0.56	3.4	6.8	---
ACTIVE COMPOSTS										
Crab+bark	28.0	49.2	7.9	0.92	31	0.43	0.19	9.1	7.7	0.27
Crab+RYD	49.0	44.2	8.0	1.78	13	0.77	0.15	3.4	3.7	0.13
Crab combined	53.7	47.0	8.1	2.00	13	-	-	-	6.4	0.50
FINAL Homogenized Compost:										
Crab final	48.1	7.6	50.0	0.95	28	-	-	-	2.6	0.20

Photo by Scott W. Andree

Figure 4.13 Grinding composted materials to produce an even textured, homogeneous compost mix.

ble, showing a respiration rate of only 0.2 percent carbon/day. This blend did reheat after piling, but did not exceed a temperature of about 100F.

Composting Operations

The "static pile" type of design for the Wakulla county project, was similar to designs used in other fish composting trials and elsewhere in the municipal biosolids sector. The modifications proposed included simple turning with a payloader, since this is the most common equipment available at solid-waste sites. However, no forced aeration was employed (Figure 4.14).

It is important to compensate for potential odors resulting from the decreased or diminished aeration. One way to do this is to adjust the ratio of wood material to crab scrap upwards as far as is practical. It was observed during the project that if the crab premix of any ration stands more than a week in an overly large stockpile (8 feet high), then significant odors will start to emerge and be very evident when the pile is disturbed.

Based on this, it is considered that the ratios that are appropriate for this form of modified static-pile composting in order that it be effective and environmentally safe are likely to be higher than those generally recommended for compost sites. This also applies to small compost bin designs utilizing wooden slats or hardwood pallets on a scale which would satisfy a small crab picking operation.

Some initial logistical problems were encountered because the Solid Waste crew did not feel they had time to thoroughly pre-blend the crab scrap at the end of the day (scrap tended to arrive at or after closing hours). It was important for the compost management staff to work out a simple, efficient way to deal with this problem on a daily basis.

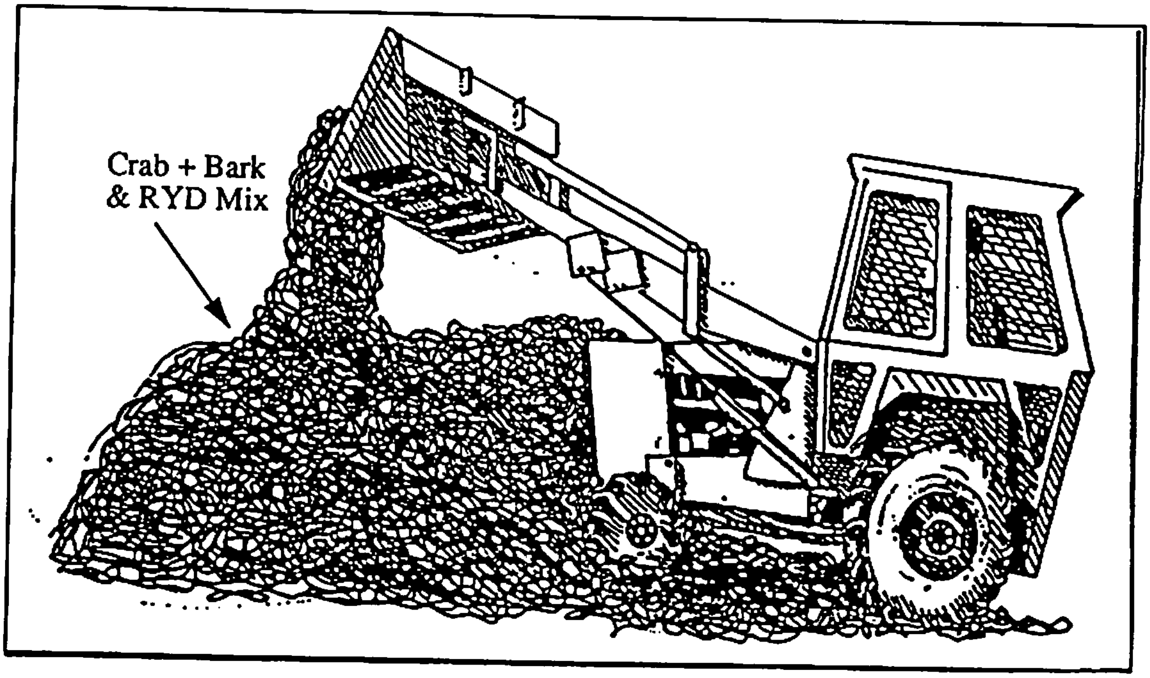

Figure 4.14 Bucket loader turning crab compost mixture.

It was finally recommended that crab scrap be dumped off the trucks directly onto the end of an active compost windrow, and blended immediately into it. This avoided the time-consuming double handling (pre-mixing off the edge of the site, then moving into windrows) that had been the practice.

As another option, the crab could be pre-blended with an agricultural mixing machine and deposited right onto the side of a windrow. A Knight blender was demonstrated for this purpose. Pre-mixing in this way proved, however, to be slow and cumbersome.

Fresh scrap deposited into active composts were deodorized and decomposed more quickly than if the piles were started fresh each day. Apparently, the activity and heat (120F) of the existing compost piles into which the scrap were mixed mitigated the process substantially. There were no complaints or bottle-necks after composting activity was pre-established and kept going in this way.

The proper ratios of coarse bark and chips to crab scrap was 2.5 volumes (wood) : 1 of crab. However, in order to use a Knight or other mixer, no large pieces of wood can be present. If no mixing machine or compost turner is used, the crab scrap can actually be composted in a very coarse pile of material. The coarser the material, the higher the ratio should be to allow for enough carbon to be made available to microorganisms consuming the crab components.

To test an optional strategy of dealing with the very course yard-trimming fragments, the Wakulla Solid Waste crew brought in a demonstration tub-grinder and processed the crab-wood mix after it had composted for several weeks. Grinding the coarse feedstock made pre-mixing with the Knight Mixer very simple, but it was not necessary to effect successful composting. However, the grinding of the compost blend made a great improvement in appearance of the compost product. Subsequent to tub-grinding, the piles of compost re-heated, an indication that residual carbon was being freshly exposed for biological activity and further stabilization.

The Wakulla county solid waste crew seem to be excited about the outcome of the project. They feel composting has been demonstrated to be practical and safe. They anticipate acquiring a tub-grinder which not only will serve the composting but also the yard-debris and pallet processing for the landfill.

V. CALICO SCALLOP VISCERA COMPOSTING

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Overview

The majority of scallops harvested on the Atlantic seaboard of Florida are landed at Port Canaveral. After processing, some of the residue is barged back to sea by certain processors, while shells, mixed viscera and by-catch are landfilled nearby at the Brevard county landfill.

While the scallop harvest is processed by fewer than five firms, the quantities of residue material contributed by calico scallop processing can be enormous. The waste stream includes clean shells which are presently used as roadbed preparation material at the local landfill in lieu of charging tipping fees for viscera residue. The viscera and by-catch portions are buried as soon as delivery is made at the landfill; the material is so wet and odorous that the trucks are not even allowed to stop for weighing before proceeding to the selected dump site.

Scallop harvests vary tremendously year to year. The variability has most likely acted as a significant impediment to designing and capitalizing suitable alternatives to landfilling. Monthly production of viscera over the past four years has been the lowest during the summer months (Figure 5.1). The data clearly indicate that composting must be scaled for the peak seasons which occur in the middle of winter, and that the chances of having material in the summer are low (only one year saw year-round scallop production).

During the 1991 season on which this project focused, scallop production began in November, 1990 and was concluded by February, 1991. All viscera produced during January and February was composted in these trials. This amounted to about 100 tons or approximately 10% of the total season production. Most of the available scallop viscera was composted in this time period.

Site Selection and Design

Site selection for the intended composting project entailed identifying the area requirements for the amount of expected viscera and carbonaceous ingredients. It was necessary to devise the compost recipes in advance in order to ascertain the area

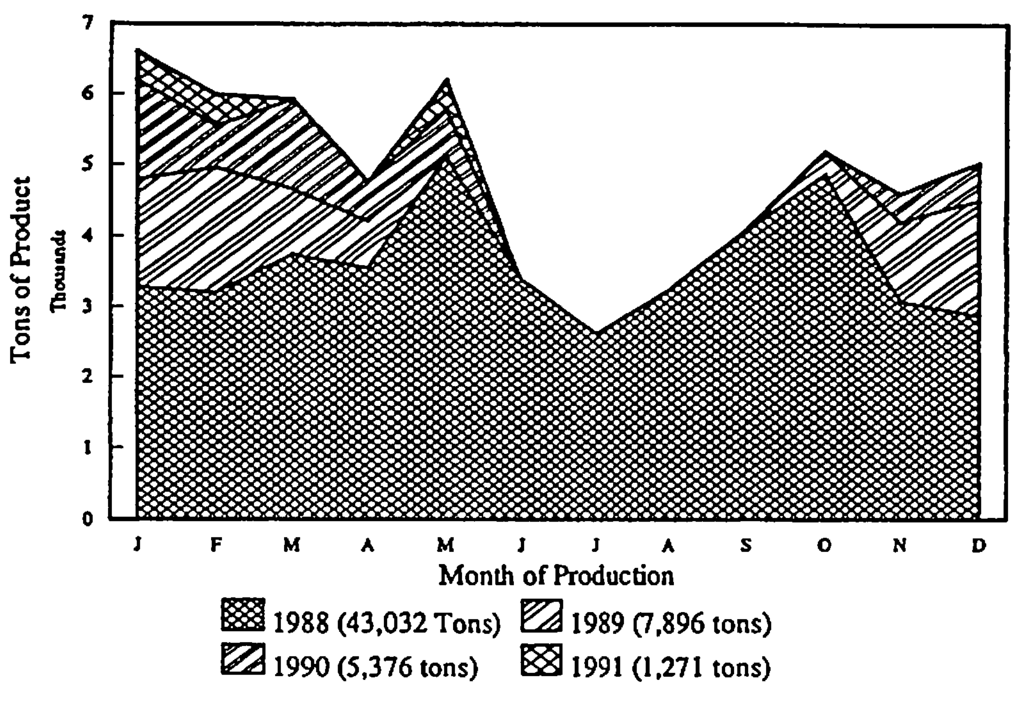


Figure 5.1 Calico scallop viscera production at Port Canaveral, Florida, by month, 1987-1991.

requirements. In addition, it was necessary to apply for a Florida Department of Environmental Regulations Research, Development, and Demonstration (RD&D) Compost Permit and wait for approval before starting operations.

An extensive limerock storage site was selected as the basis for the composting project. The area was level and was re-shaped with a slight slope (<1%) and drainage swales around the perimeter to allow runoff to flow into a storage pond. A 25-year rainfall event was used to compute the required pond size. The compost pad area of one acre was determined to be sufficient to hold three windrows side by side for a total of 2100 lineal feet of 1.5 yd/foot or 3100 cubic yards of compost mix. This would be adequate for 450 tons of scallop viscera if not more than 30% of the fresh mix consisted of scallop viscera for a three month composting period, or about 1400 tons/year over ten months, an amount roughly comparable to the 1991 season total residue. The computations of compost mix were based on analyzing the scallop viscera and various carbonaceous residues and applying a simultaneous equation solving algorithm to reach the desired mix portions (Figure 5.2).

Composting Equipment

The equipment needed to conduct a project of this nature is one payloader and a turning machine. In one of the blue crab composting projects a Wildcat™ compost turner was used to provide mixing and aerating action for blue crab scrap compost. For the scallop project, a SCAT™ composting machine was tested. The SCAT™ differs from a Wildcat™ in that the former lifts and drops the materials (Figure 5.3) while the latter churns the material like a rototiller.

The SCAT™ composter was tested on windrows of pure cypress sawdust and chips. At this time the necessary operational adjustments were made. The equipment was capable of turning a pile up to 14-feet wide if two passes were made. In addition to this, Brevard County Solid Waste demonstrated the use of a tub-grinder in anticipation that

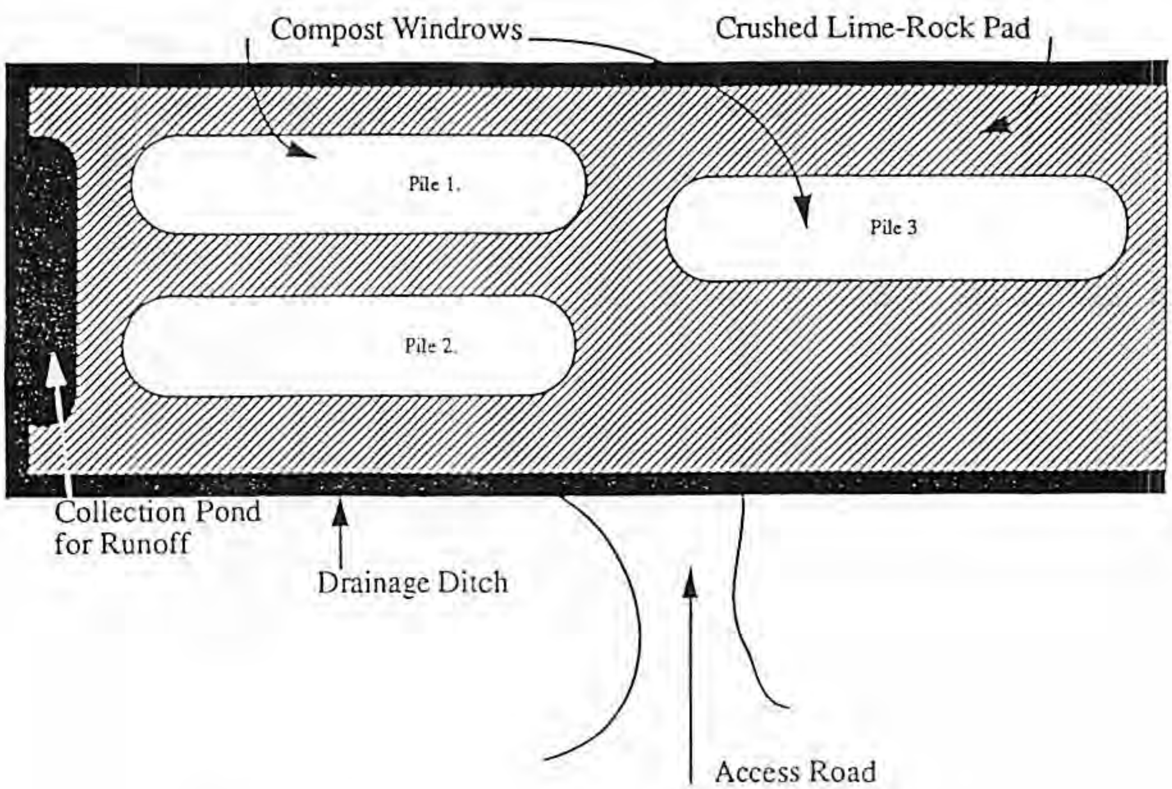


Figure 5.2 Scallop compost site layout at Cocoa, Florida.

Photos by William T. Mahan, Jr.

Figure 5.3 SCAT™ turning machine employed for scallop composting.

it would prove useful for preparing compost feedstock from recycled yard debris. Presently, yard debris is landfilled in Brevard county. In this demonstration 30 yards of chips were processed for the compost project.

Materials: Viscera, Wood Products and Alternative Bulking Agents

In addition to composting viscera and related by-catch, other local complementary materials were necessarily added to the compost. These included pine-bark and log-splinters, sawdust, shredded tree trimmings, seaweed, rejected citrus pulp, water hyacinth weed and horse manure mixed with bedding.

Analyses of all source materials including viscera and mixed by-catch (Table 5.1), and sawdust and bark and alternate bulking agents including orange culls, water hyacinths and red-algae (Table 5.2) were conducted. These tests are necessary not only to ascertain the quality of the materials but to determine the mix ratios for composting.

The scallop plants co-mingle dead and cracked shell as well as by-catch with the pure viscera output. This results in a waste stream that contains a considerable portion of non-scallop residue. This is not necessarily a problem for composting since it can tolerate certain variations and extraneous materials. However, it could substantially impact the required mix-ratio if by-catch portions are non-protein products such as shells.

The raw (pure) viscera and viscera mix (including cracked and dead shells) data clearly show that in the viscera mix the non-organic component is significant. This results in a dilution of protein and a lowering of volatile solids (organic matter). The nitrogen content of the viscera is very high at 14.2 percent. In contrast, the mixed viscera waste, including cracked and dead shells, is one-fourth the nitrogen level of raw viscera with almost no organic content. This results from coating of shells during processing with proteinaceous compounds and gives a misleading impression of the C:N ratio. However, caution is required in order to compost properly since essentially no organic solids are contributed by the mixed viscera and all the composting biology must be conferred by the carbonaceous portion of the compost blend.

Table 5.1 Analyses of scallop viscera and viscera by-catch mix used in composting study.

Sample Type	Moisture Content%	Organic Content%	Total N	C:N Ratio	Phos %	Potash %	Salts mmhos/cm
Raw scallop viscera	80.0	81.65	14.20	3.3	0.76	0.33	1.5
Viscera/ Shell Mix	26.0	2.20	3.30	0.4	0.07	0.06	2.1

Table 5.2 Analyses of carbonaceous products used in scallop composting study.

Sample Type	Moisture Content -- % --	pH 1:1	Organic Content -- % --	Total N -- % --	C:N Ratio Units	Salts mmhos/cm
Model log bark*	43.8	5.41	99.5	0.08	697	0.1
Model log chips*	60.4	4.37	97.9	0.25	230	0.1
Cypress sawdust	36.4	5.25	98.2	0.14	403	0.1
MEAN of wood	46.9	5.01	98.6	0.16	440	0.1
Water hyacinth	92.5	6.51	87.6	0.93	50.9	2.0
Red algae	90.7	5.74	34.7	1.97	9.5	51.8

* Trademark for model log homes, Mims, Florida (Lathe turnings from pine logs, includes bark and splinters).

Raw viscera is rich in iron and has slightly elevated cadmium (9.0 ppm) but appears to be low in all other metals. The lime equivalent of the mixed material was about seven percent. The mean analyses of the principal carbonaceous ingredients used in the scallop composting project (Table 5.2), shows that these materials are obviously very rich in organic matter, and moderately low in pH, a desirable aspect for composting high nitrogen materials. The average C:N ratio is 440:1.

Mix Ratio Determination for Composting

A mix-ratio algorithm was used to determine the appropriate mixture of ingredients to produce the desired compost blend. The computed ideal mix ratios for pure viscera compost and viscera-mix compost were based on the assumption of using an average blend of the carbonaceous ingredients as shown.

Results of the analysis, using simultaneous equation solving for C:N with a target 30:1 final ratio, show surprising conformity of mixture regardless of using pure viscera or the scallop-mix. The analysis indicates that a 25 percent addition by weight of viscera to the carbonaceous blend will produce a mix of C:N = 30, moisture of 55.3 percent and density of 715 lbs/yd. If mixed scallop-viscera/by-catch is used then an addition of 27 percent by weight also produces a C:N of 30:1, but with a moisture of 41 percent and density of 729 lb/yd, close to the original measures.

The reason it does not matter which scallop waste stream is used is explained by the different moisture contents which compensate for the widely divergent analyses. Thus, compost mix-ratios are fairly independent of purity of viscera scrap and this is an advantage for composters. No evaluations were made to determine if all variations would produce the same effect. Clearly, if computed on a dry weight basis, the viscera-mix with by-catch could be added at a five-fold dosage as compared to raw viscera.

Composition of the various piles is shown in (Table 5.3). Because of the unexpectedly short scallop season, only half the amount of scallop was added as expected. This is reflected in a higher C:N ratio, drier composition and lower temperatures (Figure 5.4).

Table 5.3 Composition of scallop compost piles.

	Piles	Amount
Scallop viscera and by-catch	1, 2, 3	96 tons
Pine bark and splinters	1, 2, 3	1016 cu. yards
Shredded tree trimmings	1, 3	43 tons
Red algae	1, 2	40 tons
Orange pulp	2, 3	24 tons
Cypress sawdust	1	21 tons
Aged horse manure and bedding	2	14 tons
Shredded water hyacinth	2	9 tons
TOTAL MATERIALS COMPOSTED		697 tons = 1300 cu. yards

Percentage scallop viscera in compost = 14%

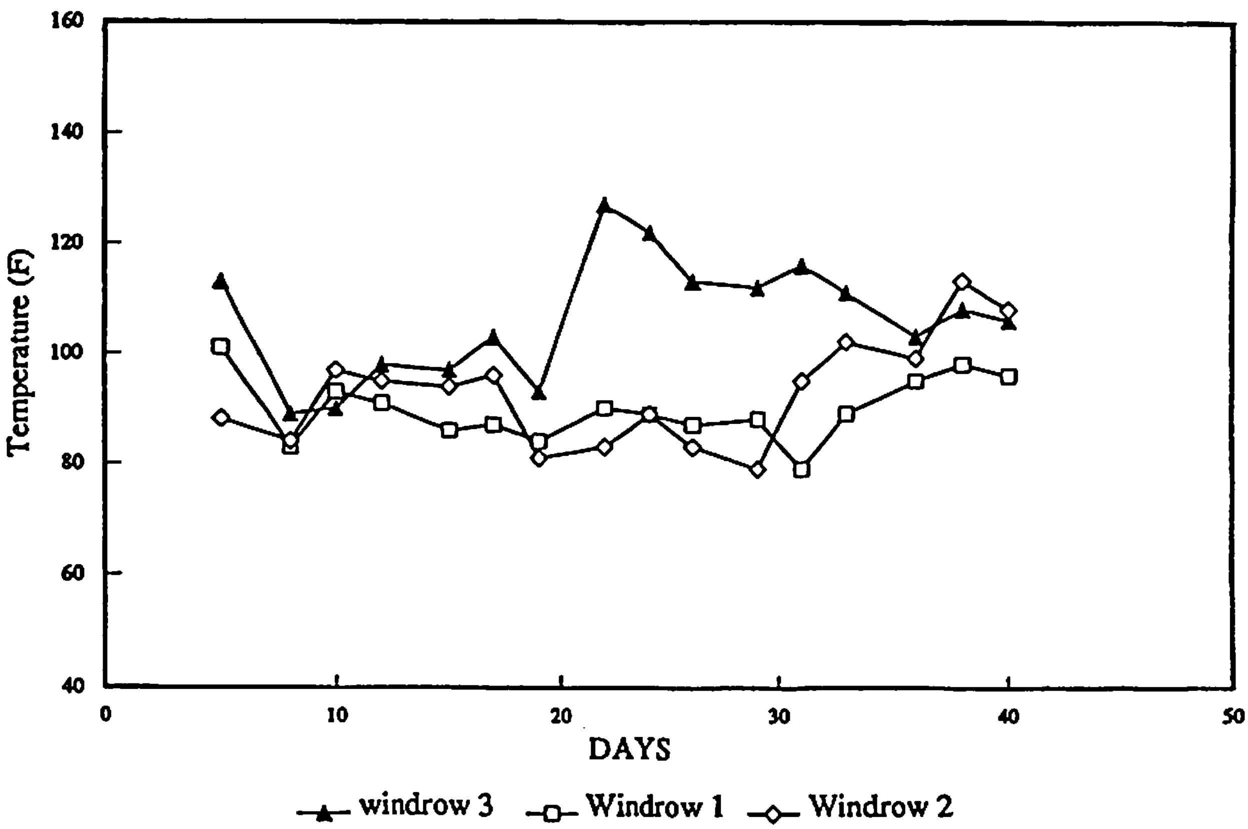
Compost Turning

The mechanical-lift SCAT™ compost turner was used successfully to turn the windrows, but it did not chop the materials so that whole fish (by-catch) remained whole for at least a part of the composting cycle. In fact, the machine's lifting and dropping action was such that whole shells, crabs and fish were deposited on or near the surface and at the pile aprons. As far as could be seen, this did not pose a problem, however. It was thought earlier that this was likely to attract gulls from the nearby landfill, and but it did not. There was also minimal fly attraction at the pile surface, and certainly little odor associated with the piles. Had larger percentages of fish been used, it is likely that the lack of grinding and surface deposition would have been a problem. The turning process rolled conch shells out of the windrows into the aisles between windrows. Later, the compost turning maching sustained several flat tires from the conch shells. Subsequently, conch shells were removed from the aisles between turnings.

Temperature Performance of Composts

Monitoring of temperature and oxygen levels during the composting process indicated mesophylic temperatures throughout the process as opposed to thermophilic (130F) with the possible exception of some peaks close to 130F in the third windrow (Figure 5.4). Although this was partly a result of water becoming a limiting factor, the primary reason is that the C:N ratios were high throughout, as less viscera was added to the pre-set carbonaceous piles than expected.

Oxygen levels fell to low levels in the first three days particularly where the fine cypress sawdust was used and then rose to 15 percent for the duration of the composting project. Apparently, the SCAT™ turner oxygenates the piles extremely well, but the higher than usual C:N ratio helped keep the oxygen demand within reasonable limits, thus preventing odor build-up. The lifting and dropping action of the turner is responsible for exposing large quantities to the air. By enabling



WERL/1991

Figure 5.4 Average windrow temperatures of scallop viscera compost.

ties to the air. By enabling rapid infusion of oxygen, odors resulting from anaerobic conditions are not likely to be produced. On the other hand, the intensive lifting and air-exposure of the compost means a lowering of the temperature. For this project, turning resulted in measured drops of up to 30F.

Compost Consistency: Screening Trials

The final compost appeared to be somewhat coarse because of the wood fragments. A screening trial was performed to determine the textural breakdown (Table 5.4).

Particle sizes of the initial compost were not recorded, but the results suggest that the coarse yard-trimmings piles broke-down very well, resulting in more than 70 percent fines. The fine portion is generally preferred for use as a soil amendment and for potting mixes. The coarse fragment would be preferred for mulch-type landscaping operations.

Nutrient composition of compost is changed as a result of screening. The analysis indicates a slight shift in most values after the screening; the density increases, nitrogen content increases and C:N decreases. Thus, the product is more stable and contains more nitrogen after screening.

Final Compost Analyses

Final composts were analyzed for major and minor nutrients, presence of metals and respiration rate (stability) as summarized (Tables 5.4 and 5.5). The data indicate stable but moderately high C:N materials. Since the original C:N was over 250 for the source ingredients, the resulting ratio of 60–70:1 represents a large drop, but normally composting should proceed until the C:N is below 25. The explanation for the high C:N has already been discussed.

The addition of other ingredients (orange pulp, water hyacinth and red algae seaweed) could be noticed to some degree in the tests, and above all in observing the piles. The orange pulp reduced all apparent ammonia odors. The red-algae raised the salt levels dramatically, but this actually stimulated respiration, and the CO_2 rate increased. High levels of conductivity resulting from algae additions to compost must be guarded against if the product is intended for nursery uses.

Calcium content resulting from the large amount of by-catch shells is a major factor in controlling the pH, which was 7.0 in all cases. Thus, the sawdust which has an acid reaction is neutralized by the use of shellfish products. The screening trials show a relatively large percentage

Table 5.4 Scallop finished compost particle size properties.

Windrow Identity	% Material in size category: Fine (≤ 1/4 inch)	Coarse (> 1/4 inch)
Pile 1 - North end	59	41
Pile 1 - South end	65	35
Pile 2 - North & south	53	47
Pile 3 - Shredded yard trimmings	72	28

Table 5.5 Laboratory analyses of final scallop viscera composts.

Sample Type	Water %	Org. Matt.%	Total N	C:N Ratio	P %	K %	Ca %	Salts mmhos/cm	CO_2 Rate%
Viscera pile 1A	36.2	45.4	0.31	78.4	0.13	0.13	7.10	2.4	0.04
Viscera pile 1B▓	50.7	66.8	0.52	69.8	0.10	0.90	5.56	8.9	0.47
Viscera pile 2*	40.5	58.5	0.36	87.1	0.07	0.49	8.10	5.0	0.25
Viscera pile 3A	37.8	54.1	0.47	61.8	0.09	0.08	9.90	0.4	0.03
Viscera pile 3B	48.2	77.3	0.69	60.7	0.16	0.15	5.33	0.2	0.14

▓ has added red algae; * with orange peels

of fine material in the compost. Even the yard trimmings trial gave a very high recovery of fines.

Conclusions

Mechanized windrow composting of fish scraps was first established on a large scale in trials conducted as early as 1987 in Maine (Brinton and Seekins, 1988). At the same time, several other projects were underway to test static composting with peat (Brooks, 1986), and later with mixtures of wood products (Bonaker, 1991). In addition, composting of aquaculture mortalities was undertaken in containerized systems (Bailey and Brinton, 1991). With the growing need for disposal alternatives, composting methodologies must be tested under more and varied circumstances.

This project arose out of a state-wide desire in Florida to develop disposal alternatives for seafood by-products. The calico scallop industry of the Atlantic coast is faced with dramatically variable and diminishing fishing reserves. In all cases, disposal alternatives must be capitalized fairly easily and not be dependent on a uniform supply and quality of products.

Scallop viscera can be composted with suitable aeration and mechanization. Due to potentially large swings in production, however, only a portion of the viscera is most likely to be consistently composted. If mix ratios are kept reasonable (low amount of viscera) for the overall compost, there are not likely to be any odor problems. Composting options for Florida are highly desirable since the sandy soils and high water tables preclude high usage rates of inorganic fertilizers. A soil amendment product which is relatively rich in organic matter from supplemental wood products and nutrients from fish protein sources may find an easy acceptance among consumers.

VI. COMPOST MARKETING AND USE DEMONSTRATIONS[1]

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Overview

Three levels of marketing activities were conducted to determine the consumer acceptance of compost produced using blue crab scrap by the windrow and static pile methods and for calico scallop viscera compost. The results of these activities are reported in this section.

Blue Crab

Open Windrow Compost

The principal purpose of the marketing study conducted by the Suwannee River Resource Conservation and Development Council, Inc. (RC&D) for open windrow blue crab compost was to determine if markets for the compost produced at the site in Taylor County existed in Suwannee, Columbia, Hamilton, LaFayete, Madison, and Wakulla Counties, Florida.

A market survey was conducted to:

- provide information on related products such as topsoil, manures, other composts and soil amendments that would compete for market value.
- study potential consumer requirements, likes, dislikes, and concerns that would ultimately determine whether crab scrap compost would be acceptable and successfully marketed.
- identify potential buyers.
- establish bag and bulk use patterns.
- outline marketing options for the compost.

A market field survey was conducted by volunteers of the RC&D. The survey was not based on a scientific design, but rather attempted to survey as many user groups and potential respondents as possible in this low population, rural, agriculturally based area. Fifty respondents representing distributors, garden/farm centers, other retailers, nursery/greenhouses, landscapers, farmers, organic farmers, golf courses, sod farmers and contractors were interviewed. Garden/farm centers and nursery/greenhouses represented 27 of the respondents. A formal questionnaire was used, with additional qualitative information gathered based on comments of the respondents.

Survey Results -- One of the principal objectives of the survey was to determine public acceptance of crab (and fish) scrap compost. The extent that end users are positive or negative toward any new product on the market determines the amount of promotional/educational funds and time that will be required to successfully market the product. An example is that the general public associates fish products with objectionable odors, whereas, if properly processed and cured, fish scrap compost is free of objectionable odors.

The fact that 100% of those surveyed already use or handle topsoil, manures, composts or other soil amendments is evidence that these products are in demand. Seventy-two percent of the respondents were not familiar with fish compost. However, 76% indicated they would use it if it were available, indicating a very high level of acceptance by all groups (Table 6.1).

Timing appears favorable for composting. Much of the general population (potential compost users) are environmentally aware, and realize that:

- Landfills are reaching capacity.
- Converting waste products into useful, valuable resources makes economic sense.
- Organically-grown foods are in greater demand each year.
- Recycling - composting is nature's way of recycling - is "in."

[1]Greenfield and Harrison prepared the blue crab open windrow compost section. Andree provided the blue crab static pile compost section. Mahan provided the scallop section.

Table 6.1 Fish scrap compost - familiarity and usage.

	Yes %	No %	Don't know or no reply %
Familiar with	24	72	4
Use at present	4	92	4
Ever used	8	88	4
Would use if it were available	76	14	10

- Polluting and contaminating is "out."

More specialized groups, those who are concerned about soil erosion, water contamination by overuse of commercial fertilizers, etc., are aware of the value of soil amendments in improving water retention, enhancing soil texture, and in the case of crab scrap compost, the nutrients and micronutrients available for plant growth. Those products determined to be most competitive for crab scrap compost were topsoil, potting soil, peat moss, cow manure, chicken manure, composted sludge, and other specialized soil amendments such as mushroom compost.

Seasonality -- Although spring - March, April, and May -- are the peak sales months for retailers (bagged product customers), other survey respondents (primarily larger volume bulk product handlers) use or would use compost over a longer period:

- A nursery and sod farm, March through September.
- A nursery, year round.
- An organic farmer, monthly.
- A contractor, mostly spring, but some year round.
- A distributor of mushroom compost, "in business all year."

Bulk users would alleviate some of the problems of peak spring demand, since they would spread the demand more nearly year round. Also, retailers of bagged products order their anticipated spring requirements during November and December.

Method of handling -- Seventy-four percent of the respondents prefer handling compost in bags. The remaining 24% who prefer bulk products are the larger volume users. The fact that a large number of users are geared toward bagged products, but the largest volume users prefer bulk products, indicates that it would be desirable to provide both bagged and bulk products.

Volume of related products -- Total present and potential volume information was insufficient to project accurate market potential for crab compost. Previous studies indicate that of the two million tons of commercial fertilizer sold in Florida annually, only about two percent is organic natural fertilizer. However, these figures do not include manures, composts, and related products that do not have a guaranteed constituent analysis. Survey respondents were hesitant to estimate sales and volume usage of a new product, with some single estimates ranging from 300 pounds for personal use to possibly 30,000 tons if the price were competitive.

Larger annual use estimates as stated by individual respondents are as follows:

- Golf Course - 1 Ton
- Farmer - 2 to 3 Tons
- Farmer - 35 Tons
- Farm/Garden Center - 24 Tons
- Garden Center at local store of a national chain - 21 Tons

- Sod Farmer - Tons!!
- Contractor/Distributor - possibly 5,000 Tons
- Distributor - possibly 30,000 Tons if the price is competitive with spent mushroom compost
- Distributor - "All of your production" (When local goal of 1,000 acres of organic crops is reached.)

Compost and manure product preferences are as follows:

- 65% - Cow manure (most familiar product)
- 11% - Chicken manure
- 8% - Crab compost
- 8% - Mushroom compost
- 4% - Horse manure
- 4% - Seaweed compost

100%

Seventy-two percent of survey respondents are not familiar with crab compost. "Black Cow" composted cow manure is well known. It is processed by Black Gold Compost Co., Oxford, Florida, and is available in 5, 25, and 50 pound bags. Estimates of annual volume were too indefinite to be considered valid.

Related Product Prices and Preferences – Prices vary considerably among products that are thought to be related or competitive with crab scrap compost (Table 6.2). These products also have certain characteristics associated with them (Table 6.3).

Preferences for Crab Scrap Compost -- Information was gathered qualitatively from personal comments and open-ended questions, and quantitatively from questionnaire responses. The information was analyzed to arrive at strengths, weaknesses, opportunities, and threats.

Strengths -- A major strength of crab compost is the positive attitude toward it. This attitude was expressed by 76% of the survey respondents, who said they would use it if it were available.

Most of those interviewed could relate fish compost to other similar products they are familiar with, particularly composted or dehydrated cow manure, which they look upon favorably.

The local, national, and worldwide concern for the environment and the widespread trend toward organic or natural products favors composts. Most consumers are aware that a waste product has been converted into a useful, valuable resource and view this favorably.

Crab scrap compost has both actual and perceived strengths, particularly pertaining to nutrients and micronutrients. Several comments were made regarding the richness of crab compost.

Weaknesses -- Lack of familiarity is the primary weakness of crab compost. Users tend to be loyal to the product they are familiar with, which is cow manure (composted or dehydrated). Only 24% of those asked said they were familiar with crab compost.

Perceived odors is a problem. Forty-three percent of those who would not use crab compost gave odor as the reason.

Opportunities -- A major opportunity for crab compost is in the growth of organic farming, natural products, and worldwide environmental awareness. Recycling - converting wastes into useful products - is now an everyday household word and in many cases, involves daily participation.

Threats -- Increased composting of other materials, particularly biosolids and yard trimmings, could be a threat to successfully marketing crab compost due to price competition. Leaf and yard trimmings compost frequently is given away by local governments. It is difficult to sell a product if a related, even if less desirable, product is available.

Should volume of bagged crab compost become large enough to expand sales from the local area, additional transportation costs could be a threat. Lack of commitment on the part of those promoting the product and education of potential users could cause delay in developing demand or, where markets have been developed, result in rapid deterioration of markets.

Sales Results -- After the market survey was completed a pilot marketing program was established in six of the seven north Florida counties

Table 6.2 Local prices for products determined to be competitive with crab scrap compost, 1989.

Product	Wholesale	Retail
<u>Bulk</u>		
Topsoil		$6 - 10 cu yd
Spent mushroom compost	$110-145 load $2.60-3.45 cu yd	$8 cu yd
Sludge compost		$170-275/ton
Poultry manure	Farmers use own	
<u>Bagged</u>		
Topsoil	$.98-2.00 40#	$1.69-3.10 40#
Potting soil	$1.00 20# $2.60 50#	$2.79 3.5# $1.59 8# $1.50 20#
Peat	$7.15 4 cu ft $10.75 6 cu ft	$10-12 4 cu ft $16.70 6 cu ft $2.27 40# $3.29 10 qt
Dehydrated cow manure	$2.25-4.00 50#	$3.50-5.00 50#
Composted cow manure (Black Cow NPK .5-.5.-5)	$1.90-2.20 50#	$2.27-3.00 50#
Sludge compost or dehydrated Milorganite)	$4.58-7.00 40#	$2.75 5# $7.10-9.95 40#
Spent mushroom compost	$2.60-3.45 cu yd	$2.00-4.00 40#

pound

Table 6.3 Important ratings associated with characteristics of products determined to be competitive with crab scrap compost.

Product	VERY Important %	SOMEWHAT Important %	NOT Important %
Nutrient analysis*	50	40	10
Availability in bags	49	27	2
Bag size Prefer 40# - 47% 50 - 27% 25 - 6% 20 - 20%	53	33	14
Form Prefer Ground - 62% Granules - 35% Pellets - 3%	50	40	10
Percent moisture	27	38	35
Price Ranges $1.00-5.00 40# $17.50 200 ton	67	28	5
Odor	41	37	22
Consistent supply	74	22	4
Free of biological or chemical risks Concerns Health (pathogens, nitrates in water, etc.) 66% Weed seed 29% Plant damage 5%	81	15	4

* Nutrient analysis (NPK)
Guaranteed nutrient analysis on the label is not as important as having the results of lab analysis available for users' information.

included in the survey. Sales of the compost occurred both in bulk form and bagged for retail outlets. A total of 14 retail outlets and several public service organizations were involved in the test sales project. By the end of 1990 compost sales totaled $8,558 (wholesale value). A total of 311 bags (40 pounds each) had been sold, primarily through farm and feed supplies at a wholesale price of $3.00 per bag. Retail price was $6.00 per bag. Bulk sales were 305 cubic yards at $25 per yard. An estimated 200 cubic yards and 100 bags remain to be sold, but the supply has been controlled to maintain a constant supply to the market. Adequate demand appears to exist in the six-county north Florida area to annually sell the entire compost production possible from the blue crab scrap of Taylor, Wakulla and Leon counties.

Static Pile Compost

A very different type of marketing and use demonstration was conducted with the blue crab compost produced by the static pile method in Wakulla County, Florida. In an effort to show good faith to the citizens who supported the project, as well as test the consumer interest in the end-product, the Wakulla County Solid Waste Department held a crab compost giveaway day on April 13, 1991. Conditions of the giveaway restricted the amount to only one pickup load per family on a first come, first served basis, and the compost had to be loaded by hand. Nevertheless, by the time the landfill opened at 8:00 a.m., trucks had lined up waiting to get the material. By 12 noon, 63 vehicles had taken 85,060 pounds of crab compost. John Henderson, Wakulla County Waste Director, has been pleased with the results of the composting project removing two waste steams from the landfill; e.g. crab scrap and wood waste, and turning them into a useable product. The side benefits of this have been: 1) saving the county valuable landfill space and 2) reducing wear and tear on machinery used to bury this waste, which translates into saving dollars.

The county planned another giveaway day later in 1991 and the Wakulla County Road and Bridge Department plans to use the compost for growing grass in erosion prone areas. The long term commitment by the county is to purchase a tub grinder for further refinement of the compost and eventually sell the material to recover the cost of production.

Scallops

The scallop viscera compost project was the last to be completed, finishing during the spring, 1991. This report was prepared before adequate time had passed to allow for the full completion and evaluation of the grow-out demonstrations. However, some initial non-scientific short term grow-out trials have been completed.

Preliminary grow-out trials on vegetables, trees and cantaloupe have been conducted by the Titusville Men's Garden Club. Their standard procedure has been to supplement the scallop compost with Osmokote fertilizer and by treating with Ronstar pre-emergence weed killer. The compost is typically used in a 50-50 mix with potting soil for planting. However, various compost/potting soil mixtures up to 100% scallop compost have been used.

To date, the compost has performed well, even when used at full strength. The group reported that cantaloupes grown in the compost were much superior to those grown in their normal garden soil. In addition, they have produced the best squash they have seen using a 50-50 mix and have found the material to work well as a potting medium for their trees.

In fact, the only negative they have reported is that bib lettuce grown in 100% compost grows well, however, it needs more nitrogen fertilizer than when grown in garden soil. However, this finding is not surprising considering that the compost recipe contains only one third as much scallop viscera as originally planned.

In addition to home gardens, local agriculture extension agents have identified seven potential uses for the scallop compost in Brevard County. They are:

Pasture land
Turf/sod farms
Lawn dressings
Roadside median strip wildflower displays
Vegetable farms
Ornamental/potting soil
Citrus

Two industries, cattle and turf/sod, were identified as the best long-term potential users of the scallop compost. This was because both industries are located near the landfill and cattlemen are always looking for ways to improve pastures while turf/sod farmers need to replace topsoil that is lost when their product is harvested.

In addition, two industries, ornamental plants and citrus, were identified as potentially having the most problems with the scallop compost. Agriculture Extension agents felt that the ornamental plant industry would be concerned about weed seeds and plant pathogens not being killed during the compost process. These fears would necessitate the sterilization of the compost before use, adding to the cost and time to prepare the compost for use.

Since these initial meetings, inspections of the compost site have revealed that a few citrus seedlings are now growing out of the scallop compost windrows. These seedlings are most likely the result of seed germination from the assorted citrus fruits that were added as part of the compost recipe. The reason these seedlings have survived the composting process is unclear. However, very few weeds have been seen growing on the windrows.

Possible concerns of the citrus industry were also identified. The first concern dealt with the level of copper in the compost. Over the years, citrus trees have been exposed to high levels of copper from the fungicides used by the industry. Over time, the concentration of copper can build up in the soil and reach a toxic level for the tree. Therefore, growers try to avoid using anything that can add copper to the soil.

The second concern was increasing the water holding capacity of the soil to a level that root rot could become a problem. This appears to be a much greater potential problem than the copper level in the soil. In fact, because of the compost's high water holding capacity, its use as a container medium may be limited.

Recommendations

These marketing projects provided a number of recommendations which are summarized below into some general statements.

- It appears crab (and fish) scrap compost can be successfully marketed. Public acceptance appears genuine. However, promotional and educational programs will be necessary and the product and supply must be consistent, and the price competitive.
- There appears to 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 analyses on the label should be considered, and the compost 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 might result from either the crab scrap or 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 they will receive from uses in the various applications they anticipate for the compost. Specific information on plant and soil response to the compost will be critical to the success of the marketing program.

VII. RAW AND COMPOSTED BLUE-CRAB SCRAP AS SOIL AMENDMENTS SUPPORTING THE GROWTH OF SORGHUM/SUDANGRASS

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Introduction

Composting to produce an odor-free, non-nuisance product with possible nutritive, mulch, and soil conditioner properties has been proposed as a viable alternative for handling of raw crab scrap. In addition, the material has interesting chemical/biochemical properties, including a high chitin content which may prove effective in immobilizing not only the trace metals (including Fe, Al and Cu) of the scraps, but also associated trace metals from other compost constituents including sewage sludge. The 1-year studies described here were designed to characterize response of a test crop to varying applications of raw and composted blue-crab scrap, in comparison to fertilized and non-fertilized control treatments.

Materials and Methods

Raw crab scrap was obtained in early January of 1990 from the Gulf Stream Crab Company in Steinhatchee, FL. The material was transported in a 30-gallon plastic trash can to the Gainesville campus of the University of Florida, for subsequent use in a greenhouse study. After incorporation of required amounts into the soil to be used for the greenhouse pots, the remainder was frozen at -20 C for future access. Due to subsequent bankruptcy of the above-mentioned crab-processing facility, raw crab scrap for the field demonstration plots was obtained from Porter's Crab House in Perry, FL in mid-March of 1990. All crab was of the Florida blue crab variety.

Compost was initially collected, also in 30-gallon plastic trash cans, from Windrow No. 1 at the composting site located at the Taylor County landfill near Perry, FL. Parent material for the compost consisted of 48% crab scrap and 52% fresh cypress. The material corresponds roughly to sample No. 1726.0 (Table 4.7), and was also collected in early January, 1990. A second compost subsample, of unclear origin, was collected from a large pile at the field site in late March of 1990. Soil to which the two compost materials had been applied varied only slightly in its total phosphorus (0.020% vs 0.023%) and nitrogen (0.057% vs 0.050%) contents. The second material, with apparently somewhat higher phosphorus (P) content relative to its nitrogen (N) content, may have been amended with a small quantity of superphosphate fertilizer prior to sampling. Promotional literature for the composted material implies that this is to be a regular feature of the material.

Field studies were conducted, and soil samples were collected for the greenhouse studies, at the Rudy Parker farm, 5 miles east of Perry, FL, near the village of Boyd, FL (on Highway 98 East). Topsoil for the greenhouse studies was collected in 30-gallon plastic trash cans from this location, transported to the Gainesville campus of the University of Florida, air-dried, and screened through a 1/4-inch sieve prior to use. Though a modern soil survey for this portion of Taylor County has not yet been completed nor published, soils of this area are identified on the General Soil Map (1:500,000) of Florida (Caldwell and Johnson, 1982) as belonging to the "Chipley-Kureb-Lakeland Association of nearly level poorly drained sandy soils, (including) some with a dark subsoil and some with a loamy subsoil and with minor contents as well of Osier, Mascotte, Pamlico and Rutledge soils".

Greenhouse studies were conducted in one-gallon plastic pots under ambient light conditions during the period 6/15/90 to 8/10/90, after initial failure of a preceding squash crop which was to be grown in the pots. Test crop was an SX-17 variety sorghum/sudangrass hybrid from Dekalb Pfizer Genetics of Dekalb, IL. Seeding rates were 125 lbs/acre for the 3/4-acre field-plot study, and 13 seeds per pot (subsequently thinned to 5 stems per pot) for the greenhouse studies. The field-plot portion was an unreplicated demonstration effort, comparing the growth, relative yields, and plant composition of traditionally-fertilized, raw crab-scrap amended, and compost-amended plot areas at a single application rate for each. The greenhouse study was a replicated (3 replicates per treatment) variable-rate study in which soil and plant composition, and plant yields, were compared for various rates of raw crab scrap, crab compost, traditionally-fertilized and unamended/unfertilized pots.

For the field studies, raw crab scrap was applied at a rate of 10 tons/acre of material containing 7.65% N (a total of 1530 lbs N/acre). Fertilization was at a rate of 1000 lbs/acre of 10-10-10 (N-P_2O_5-K_2O) material (a total of 100 lbs N/acre), while crab compost was applied at a rate of 20 tons/acre of material containing 0.48% N (a total of 192 lbs N/acre). These rates, although each realistic from an amendment/disposal standpoint, thus varied somewhat in their N amounts and hence in their anticipated (and actual) growth responses. The compost material was of significantly less N content than the material from Windrow No. 1 in late December, 1990 (Table 4.4), which had been sampled in early January for the greenhouse studies. Reasons for this variation are unclear.

Plant yields following the 121-day growing season were determined for 1.0 m^2 areas in each treatment block. Samples were clipped at ground height, bagged, transported to the Gainesville campus of the University of Florida, weighed, and then dried for approx 3 days at 65 F. Subsamples from each container were then ground in a Wiley mill for subsequent analysis. Soil samples to the 6-inch depth were also taken from each plot at time of harvest, transported to Gainesville, dried for approximately 3 days at ambient temperatures, and passed through a 2-mm sieve prior to storage and analysis.

For the greenhouse studies, raw crab scrap was applied at rates of 1, 1.5, 2.5 and 5% by weight (approx 10, 15, 25 and 50 tons per acre on a field-equivalent basis). Compost was applied at rates of 5, 10, 15 and 20% by weight (approx 50, 100, 150 and 200 tons per acre on a field-equivalent basis) because of the uncommonly low N content of this material. Whole-plant samples were clipped at ground height in each pot following the 55-day growing period (growth being terminated in the greenhouse when plants began to evidence late-season senescence and lower-leaf dieback), dried and ground in a small Wiley mill as described for the field samples. Soil samples from each pot were also taken at the time of harvest and treated as for the field-soil samples. Greenhouse pots had been watered 2-3 times weekly during the first few weeks of growth, and daily or alternate-daily (depending upon daily evaporative stress) for the final weeks of the study. No additional nutrients were applied to any of the greenhouse pots, so the frequent watering intervals, shallow rooting depth and inevitable frequent leaching of nutrients from the pots would correspond to periods of relatively-frequent leaching rains in a field setting.

A nitrogen incubation study was also conducted, over the period 5/8/90 to 7/3/90, with an incubation temperature of 39 C. Two rates each of crab-scrap-amended soil (1% and 2.5%) and of compost-amended soil (5% and 15%) along with an unamended check (control) were incubated on filter funnels above a multi-layer cheese cloth separator. Leaching with 0.1 N KCl for removal of NO_3 and NH_4 was conducted sequentially at 0 and 3 days, and at 1, 2, 4 and 8 weeks after amendment. Leachates from each collection were analyzed for ammonium, nitrate and pH.

Kjeldahl N was determined for the plants and soils as described by Bremner and Mulvaney (1982). Total P was determined by the Murphy Riley colorimetric method, following dry ashing and HCl digestion for the plant materials and Mehlich-1(double-acid) extraction for the soils, as described by Olsen and Sommers (1982). Metals (calcium, magnesium and potassium; Ca, Mg and K) were determined by EPA method 3050 (Environmental Protection Agency, 1982) following HNO_3/H_2O_2 digestion of plant materials and HNO_3/HCl extraction of soils, and boron (B) was determined by the azomethine-H colorimetric method following dry ashing and HCl digestion of plant materials (Sippola and Ervio, 1978) or hot-water extraction of soils (Bingham, 1982).

Statistical tests on the greenhouse data were performed using an analysis of variance for a completely randomized experimental design as described by Snedecor and Cochran (1967). All treatment means were compared using Least Significant Difference (LSD) analysis at the 0.05 probability level.

Results

Greenhouse Studies

Statistical analysis indicated significant differences among treatments for all soil and plant variables. Coefficients of variation ranged from 3 to 32% for the plant data and from 9 to 55% for the soil data.

The highest rates of raw crab scrap (R5) and compost (C20) each increased soil N, P, K, Ca, Mg, and B compared to the check (Table 7.1). The lower rates of raw crab scrap and compost generally resulted in soil values intermediate between the check values and those of R5 and C20. Particularly noteworthy were the marked soil-P increase associated with high rates of raw scrap addition, and the potential liming value (reflected by the enhanced soil-Ca levels) for high rates of either the crab compost or the raw crab scrap.

The R5 and C20 treatments both increased plant N and K compared to the check (Table 7.2). The C20 treatment also increased plant P and Ca compared to the checks, though the R5 treatment did not. This may be in part an anomaly, however, associated with the extremely low yields which resulted from compost application. The R5 treatment significantly increased plant Mg, while the C20 treatment significantly reduced plant Mg, compared to the checks. Although treatments significantly affected plant B, the results appeared to follow no pattern and were difficult to interpret.

Plant yields varied in the order: raw scrap > fertilized > control(check) & compost. Within the raw scrap subset, yields also increased regularly for all but the highest scrap rate. Yields for the compost-amended pots, in addition to being extremely low, were essentially invariant with amendment rate.

Incubation Studies

Typical graphs from the nitrogen incubation studies are presented in Figures 7.1 and 7.2. Of note are:

a) the high rates of NH_4 and NO_3 evident after 1 week of incubation for the raw-scrap amended soils (totalling approx 400 and 200 ug/g for the 2.5% and 1.0% rates, respectively). Because of the sequential nature of the N-mineralization (NH_4-production) and nitrification (NO_3-production) processes, it was somewhat surprising that high

Table 7.1 Results of soil analyses, greenhouse studies.

Amendment	Rate	N	P	K	Ca	Mg	B
		-------------%-------------		--------------------------ug/g--------------------------			
Compost	20%	0.080b	0.016cd	79a	5398a	867a	0.47a
	15%	0.057defg	0.012ef	63b	2777b	538bc	0.33ad
	10%	0.050efg	0.008fg	48c	443c	430bd	0.41ac
	5%	0.053efg	0.008fg	43c	417c	346df	0.31bcd
Raw crab scrap	5%	0.103a	0.056a	71ab	2369b	576bd	0.44abc
	2.5%	0.063cde	0.032b	38c	815c	384cde	0.27d
	1.5%	0.067c	0.018c	40c	527c	267dh	0.29cd
	1%	0.053efg	0.014deg	37c	233c	296dg	0.26d
Check (control)		0.050efg	0.004h	35c	<1c	197fgh	0.25d
Commercial fertilizer		0.047efg	0.004h				

Table 7.2 **Results of plant analyses, greenhouse studies.**

Amendment	Rate	N	P	K	Ca	Mg	B	Yield
		---------------%	---------------		---------------	ug/g	---------------	g/pot
Compost	20%	1.00b	0.51a	3.03a	2758b	4746d	11.7ce	1.50
	15%	0.95bc	0.44ab	2.84ab	3275a	4647d	22.2a	1.56
	10%	0.90bc	0.38bc	2.57ad	2603bc	4619d	11.5cf	1.73
	5%	0.77d	0.37bd	2.74ac	2234c	4842d	12.9bcd	1.43
Raw crab scrap	5%	1.98a	0.30cde	2.25ae	1186d	5967b	10.6cg	59.5
	2.5%	0.87bd	0.23e	1.91af	1381d	6117b	9.7ch	84.3
	1.5%	0.75bd	0.28cde	0.80g	1575d	6644a	14.0bc	56.9
	1%	0.60cd	0.29cde	0.85g	1547d	6193b	19.3ab	31.7
Check (control)		0.49d	0.25e	1.74cdefg	1379d	5461c	6.0defgh	2.3
Commercial fertilizer		0.50d	0.16f					10.5

nitrate-N values didn't persist somewhat longer. A resultant buildup in microbial biomass may have been responsible for keeping nitrate-N levels low, however, along with the successive removal of ammonium-N during the incubation studies as structured.

b) the much lower rates of NH_4 and NO_3 evident for the crab-compost treatments (totalling only 18 and 21 ug/g for the 5% and 15% rates, respectively) and for the control (check) treatment (totalling 9 ug/g after 1 week, and declining further thereafter).

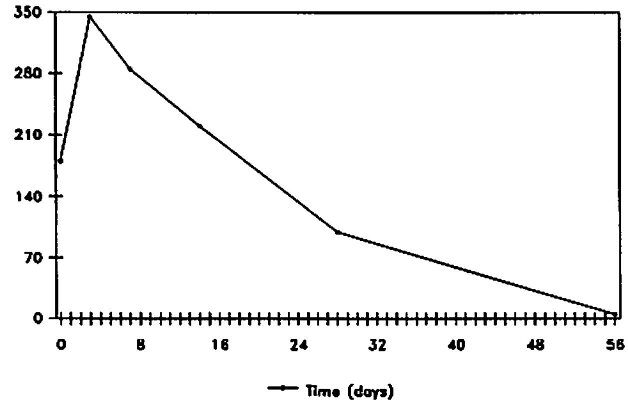
Though the compost contains an appreciable N content according to the work reported in Section IV of this document, most of this N is apparently held in only slowly-available form and hence is not likely to contribute significantly to the N-nutrition of normal agronomic crops during a given growing season.

Field Studies

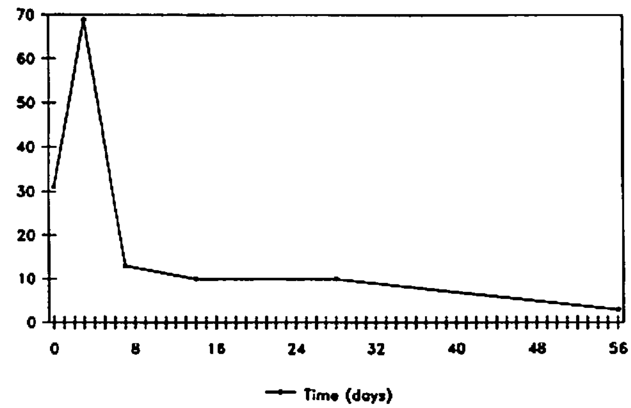
For the soil samples collected from the field studies, % P increased in the order: compost > raw crab scrap > fertilized > control(check). This was consistent with the relative P contents and application rates of the respective materials. Soil % N was higher for all amendment and fertilized rates, though essentially invariant between rates for a given amendment.

With respect to plant analyses from the field plots, % P was in the order: crab scrap & compost > fertilized, whereas % N was in the order: crab scrap > fertilized > compost. This once more reflects the extremely slow availability of residual N from the composted material, following the composting process. Plant yields were in the order: crab scrap > fertilized > compost, with relative values of 46.1, 27.9 and 7.2 tons/acre(wet weight) production from the respective treatments. Lack of

Cumulative NH_4-N (ug/g) in 2.5% raw crab treatment



Cumulative NO_3-N (ug/g) in 2.5% raw crab treatment



Cumulative NH_4-N (ug/g) in blank soil

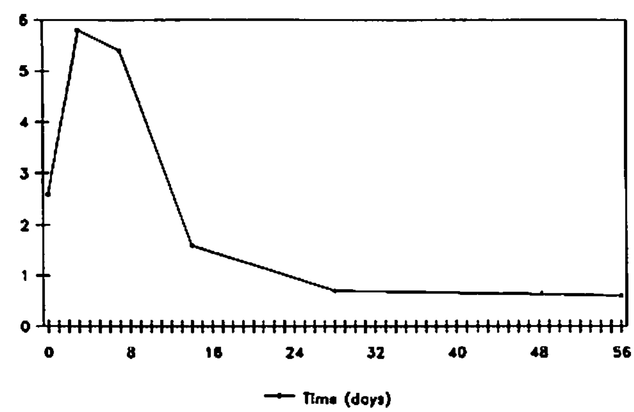
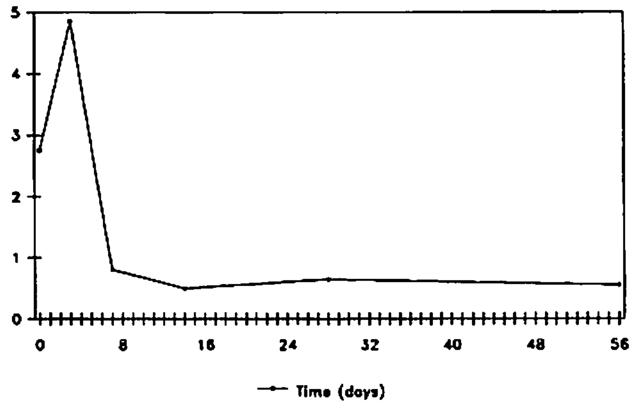
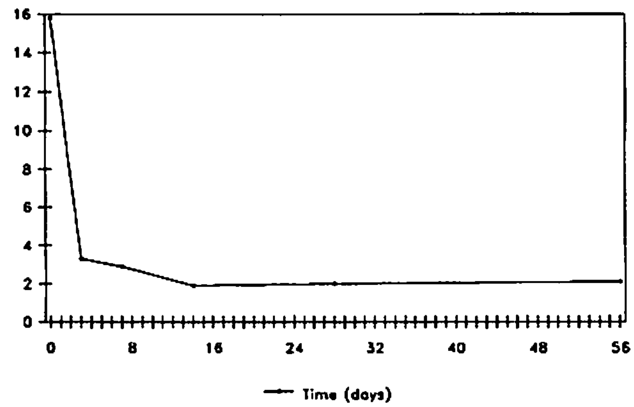


Figure 7.1 Cumulative NH_4 and NO_3 for the incubation studies, raw crab scrap.

Cumulative NH_4-N (ug/g) in 15% compost treatment



Cumulative NO_3-N (ug/g) in 15% compost treatment



Cumulative NH_3-N (ug/g) in blank soil

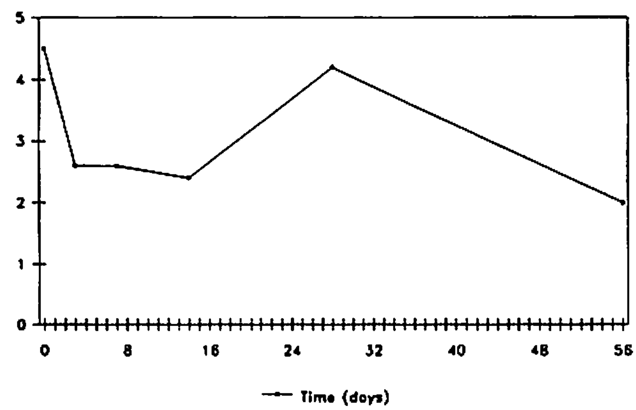


Figure 7.2 Cumulative NH_4 and NO_3 for the incubation studies, crab scrap compost.

sufficient available N is the most plausible explanation for the extremely low yields from the compost treatment.

Conclusions

Raw blue crab scrap seems 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. It would seem to be acceptable, for example, for relatively remote sites (removed from the vicinity of human residences) where crops of a low-input, low-maintenance nature are being grown. This would include pine-plantation replanting areas, which could be of considerable value along northwest Florida's Gulf Coast. The compost product, though considerably more desirable from an aesthetics standpoint, is of limited value as a nutrient-supplying amendment. Long-term effects on soil organic matter levels, and adequacy of nutrient supply for more slow-growing crops including pine plantations, are other considerations where the compost may be of considerable value but which could not be evaluated via the current studies.

VIII. SUPPRESSION OF THE JAVANESE ROOT-KNOT NEMATODE USING BLUE CRAB COMPOST

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Overview

Composted and noncomposted organic materials have been added to soil for centuries to improve soil fertility and 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 have been limited due to the availability of effective nematicides (Rodriguez-Kabana, 1986; Rodriguez-Kabana et al., 1984). Over the past 10 years, three of the most widely used nematicides have been canceled or have been placed under severe use restrictions due to ground water contamination and/or carcinogenic characteristics. Of the few remaining registered nematicides, most are under critical review due to environmental and health concerns. These factors have lead to a great interest, and indeed, a need to further pursue natural organic materials for nematode suppression.

Use of organic materials could greatly reduce or eliminate nematicide application and at the same time, transform waste products such as crab scrap into valuable resources. Products containing chitin, such as crab scrap, 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). Chitin materials are presently available in the marketplace but require rates of approximately 2,000 lbs./A to provide moderate levels of nematode control. Such high rates have made costs of application of these materials impractical except under conditions such as small garden plots and organic farms. Commercial packagers of chitinous soil amendments are, therefore, currently targeting these two market segments.

The utilization of composted crab scrap, however, for nematode suppression and plant growth enhancement has not been studied. The studies reported herein, thus, were conducted to determine the effects of compost made from blue crab (Callinectes sapidus) scrap and cypress (Taxodium distichum) wood chips on nematode populations and crop growth response.

Materials and Methods

Two greenhouse pot experiments were conducted using "Homestead" tomato (Lycopersicon esculentum L.) inoculated with the Javanese root-knot nematode, Meloidogyne javanica. Both tests were arranged in a factorial design and Test 1 was replicated 6 times while Test 2 was replicated 8 times. In Test 1, one factor was blue crab scrap compost at 0, 10, 20, and 100% (w/w) mixed with a fine sand soil (93% sand, 4% silt, 3% clay, % O.M.). The other factor was M. javanica applied at 0 or 10,000 eggs/pot. In Test 2, one factor was crab scrap compost at 0, 5, 10, 20, 40, 80 and 100% (w/w) and the other factor was Meloidogyne javanica at 0 or 15,000 eggs/pot,.

Prior to experiment initiation, soil was fumigated with methyl bromide at 0.6 a.i./kg. cubic meter. The crab scrap compost and soil were air-dried and sieved by passing through a screen containing 0.3 mm dia. openings. The compost-soil mixtures were placed in 10 cm dia. plastic pots in Test 1 and 12.7 cm dia. pots in Test 2. Water was then added to bring the mixture to field capacity, and in Test 1, pots were allowed 4 days before inoculation with nematode eggs while in Test 2, 6 days were allowed to elapse. Eggs of M. javanica were extracted from "Homestead" tomato roots (Lycopersicon esculentum L.) using the sodium hypochlorite method (Hussey and Barker, 1979). After inoculation, tomatoes were transplanted immediately in Test 1 while in Test 2, transplanting occurred 8 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 allowed to grow 56 and 60 days, respectively, in Tests 1 and 2. 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=0%, 1=1-25%, 2=26-50%, 3=51-75%, and 4=76% of the root system galled. Plant roots were stained in phloxine B and the number of egg masses counted (Taylor and Sasser, 1978). Additionally, M. javanica eggs were extracted with sodium hypochlorite (Hussey and Barker, 1979) and counted from 2 g of root tissue from each replicate in Test 1.

A third greenhouse test was conducted to determine the comparative influence of dried ground raw crab scrap and crab scrap compost on population development of M. javanica. It was conducted utilizing air-dried fine sand soil and treatments included soil alone, 0.5% w/w raw crab scrap, and 20% w/w crab scrap compost. The 12.7 cm dia. pots were inoculated with 15,000 M. javanica and one tomato plant was immediately placed into each pot. Treatments were placed in a randomized complete block design containing 6 replicates. Tomatoes were allowed to grow 60 days before harvest. Data collection was conducted as above.

Fiberglass microplots, 76 cm dia. x 51 cm deep, were located in a field containing a fine sand soil (93% sand, 4% silt, 3% clay, O.M.<1%). Soil was treated with 760 kg/ha methyl bromide and 476 l/ha 1,3-dichloropropene prior to experiment establishment to reduce nematode, disease and weed contamination. The test was a factorial design with 6 levels of crab scrap compost at 0, 2.25, 4.50, 9.00, 18.00, and 36 mt/ha as one factor. The second factor was the addition of 125 M. javanica eggs/100 cm^3 soil mixed to a 23 cm depth or the addition of 0 M. javanica eggs. Each treatment was replicated 8 times. After compost addition, two "Homestead" tomato plants were transplanted into each microplot. Plots were irrigated as needed throughout the season and maintained according to standard cultural practices. Tomato fruit was harvested three times over the season and fresh weights were recorded. At final harvest, fresh top weights were collected. Root gall indices were rated on a scale of 0-4. Four soil cores were collected to 30 cm deep from each microplot, composted and 250 cm^3 processed with the modified centrifugation-sugar flotation technique (Jenkins, 1964). Plant roots collected from the samples were treated with sodium hypochlorite and number of eggs counted.

Results

In Test 1, all levels of crab scrap compost significantly ($P \geq 0.05$) increased both foliar and root weights of tomato and reduced root gall indices compared to the control treatment (Table 8.1). Numbers of eggs/plant, and egg masses/plant similarly were reduced significantly by addition of 10, 20 and 100% crab scrap compost (Table 8.2). Little additional suppression of root galling and nematode reproduction was observed beyond the 20% compost level (Figures 8.1, 8.2, 8.3).

In Test 2, significant increases in foliar weight was observed at the 20, 80 and 100% crab scrap compost levels as compared to the control treatment (Table 8.3). Fresh root weights were increased significantly at the 80 and 100% crab scrap compost level. Root galling was reduced significantly at 20% and higher levels of compost while egg masses/g root was reduced significantly by all compost treatments (Table 8.4). Egg mass numbers per plant, however, were reduced only at the 20% and higher compost levels. Little additional suppression of root galling and nematode reproduction was observed at levels higher than 20% compost (Figures 8.4, 8.5, 8.6).

In Test 3, root weight was reduced significantly by both the raw crab and crab compost treatments while foliar weights were not affected (Table 8.5). Root gall indices and number of egg masses were significantly reduced by both the raw crab scrap and crab compost treatment compared to the control. The raw crab scrap treatment showed significantly less root galling and number of egg masses than the crab compost treatment.

In the field microplot study, no significant differences between compost levels and the control treatment were observed in tomato yield or plant top weights (Table 8.6). A trend toward greater yield, however, was observed in the compost treatments. Similarly, no difference between compost levels and the control treatment was found in root galling or M. javanica recovered from roots and soil. The control treatment, however, showed the greatest number of nematodes.

Recommendations

An effect of crab scrap compost on M. javanica reproduction was found at levels as low as 5% in greenhouse Test 2. In both Tests 1 and 2, however, the 20% compost application rate was the lowest level of compost that produced large reductions in root galling and M. javanica reproduction. These results and those found in Test 3 indicate a much lower level of nematode suppression with crab scrap compost than with the raw crab scrap (Godoy et al., 1983; Mian et al., 1982).

Table 8.1 Effect of crab scrap compost on tomato growth and root gall index in greenhouse test 1.

% Crab Compost	Top Wt.	Root Wt.	Root Gall Index
0	4.32	5.81	4.00
10	22.17*	12.54*	3.00*
20	26.86*	10.65*	1.00*
100	26.60*	11.64*	0.40*

* Differs significantly when contrasted to 0% level.
** No significant interaction (nema. x crab) was observed, therefore, top wt. and root wt. data include pots with and without M. javanica.

Table 8.2 Effect of crab compost on M. javanica population in greenhouse test 1.

% Crab Compost	Eggs/ Plant	Eggs/g Root	Egg Mass/ Plant
0	479,120	93,927	606
10	210,000*	16,937	328*
20	25,720*	2,233*	35*
100	23,280*	2,644*	1*

* Mean differ significantly when contrasted with 0% crab compost.

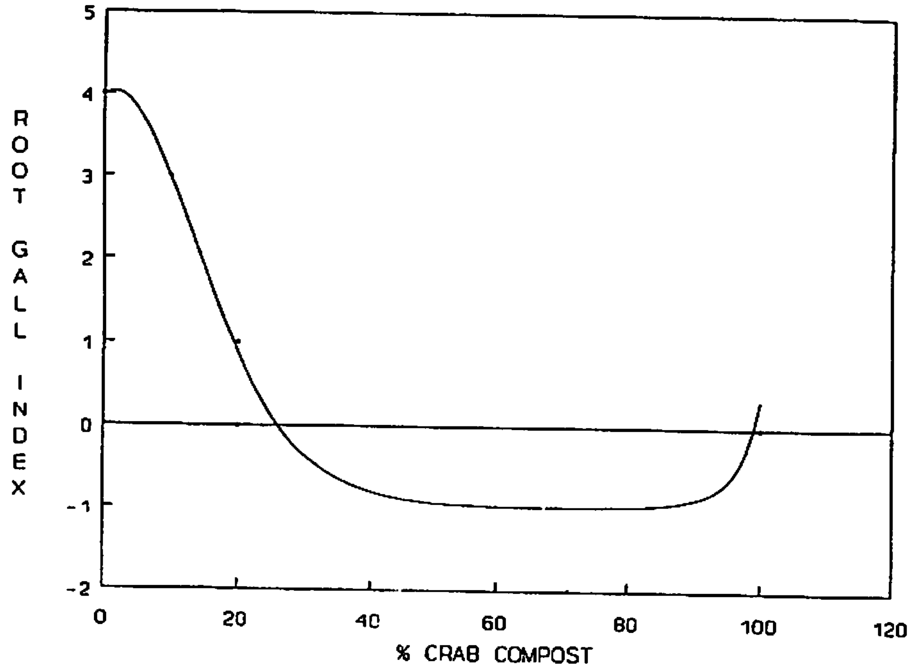

Figure 8.1 Effect of % crab compost in soil on the root galling (0-4 scale) of tomato roots induced by Meloidogyne javanica in greenhouse test 1.

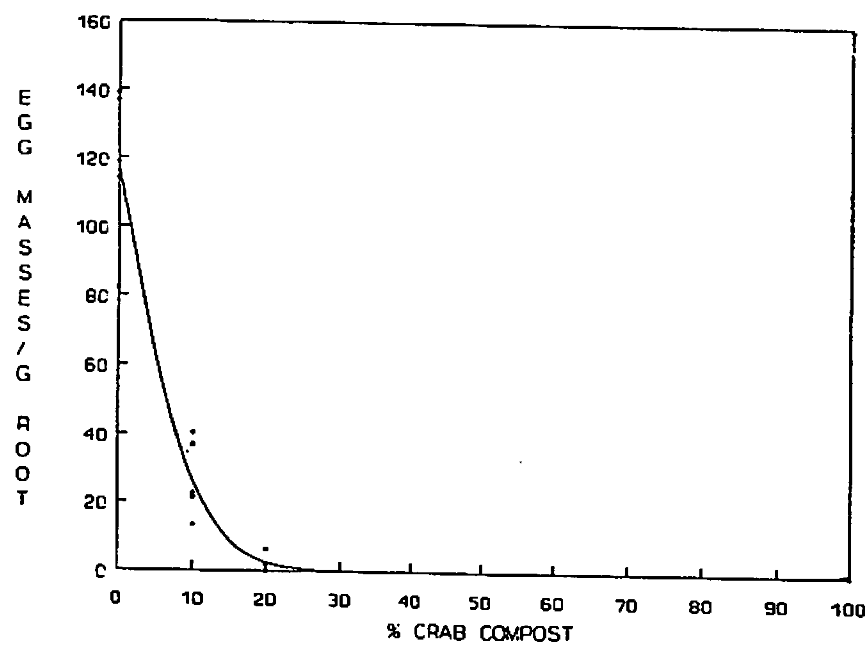

Figure 8.2 Effect of % crab compost in soil on the number of M. javanica egg masses per gram of tomato root in greenhouse test 1.

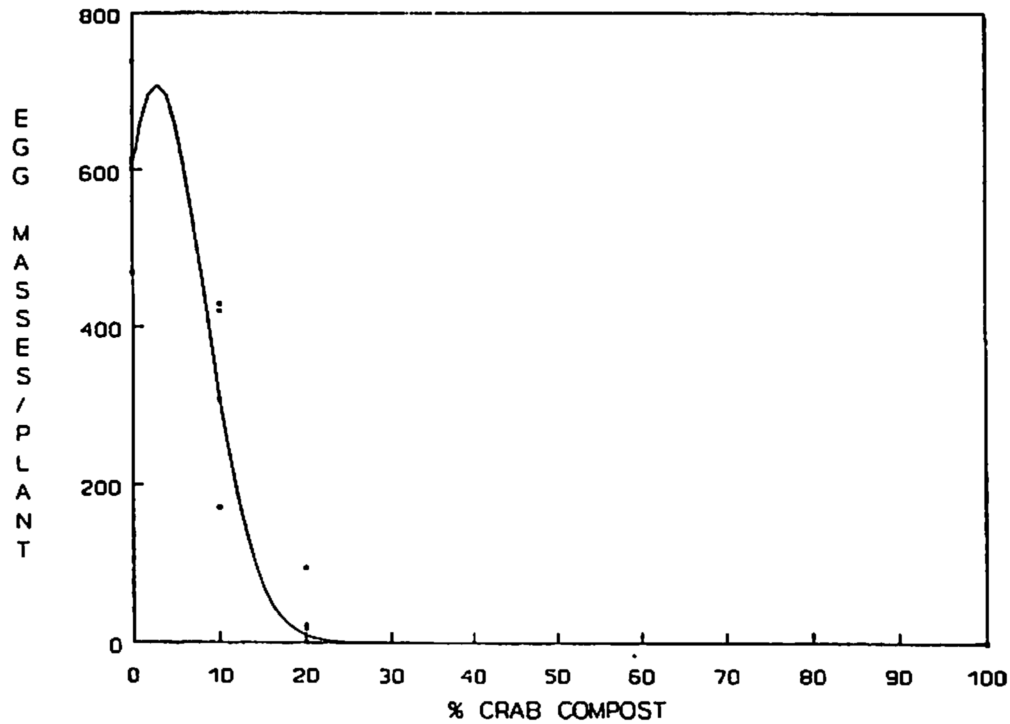

Figure 8.3 Effect of % crab compost in soil on the number of M. javanica egg masses per tomato plant in greenhouse test 1.

Table 8.3 Effect of crab compost level on tomato plant growth in test 2[a].

% Crab compost	Fresh top weight	Fresh root weight
0	31.7	11.7
5	32.1	14.5
10	34.0	13.8
20	56.8[b]	15.9
40	41.0	13.0
80	60.4[b]	18.1[b]
100	58.6[b]	19.6[b]

[a] These data include both those pots that were and were not inoculated with M. javanica.

[b] These levels differ from 0% level ($P \leq 0.05$).

Table 8.4 The influence of crab scrap compost levels on Meloidogyne javanica[a].

% Crab compost	Root gall index	Egg mass g/root	Egg mass per plant
0	4.0	163	1610
5	4.0	114[b]	1680
10	4.0	91[b]	1340
20	3.0[b]	37[b]	761[b]
40	1.8[b]	7[b]	171[b]
80	2.0[b]	25[b]	451[b]
100	2.2[b]	21[b]	441[b]

[a] These data were from pots that were inoculated with M. javanica only.

[b] These levels differ from 0% ($P \leq 0.05$).

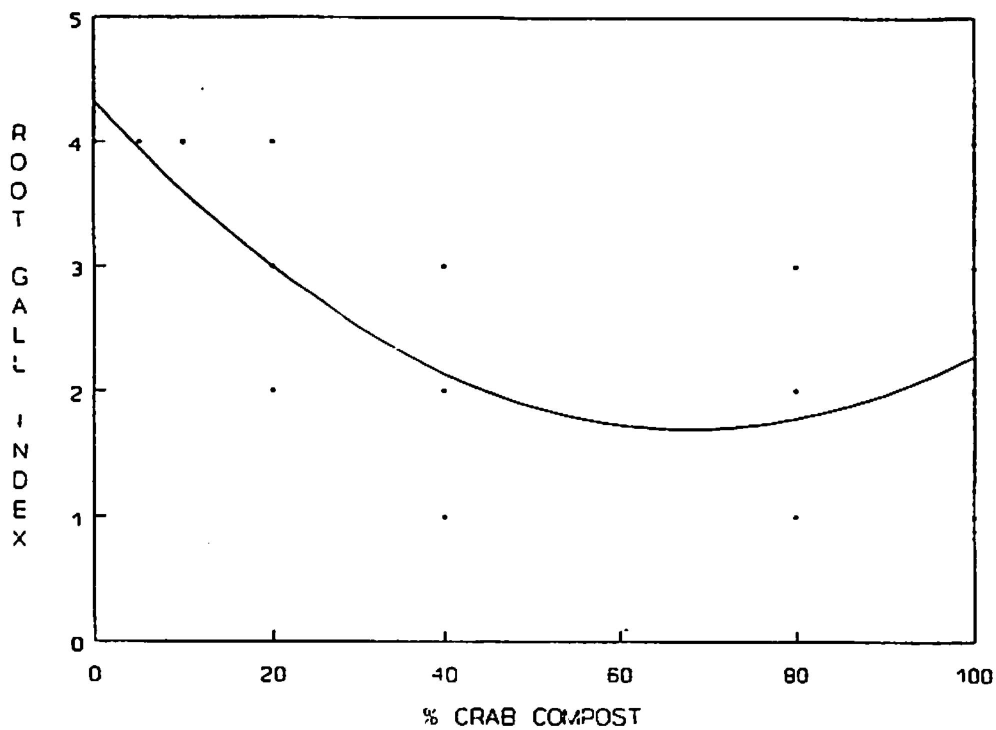

Figure 8.4 Effect of % crab compost in soil on root galling of tomato roots induced by M. javanica in greehouse test 2.

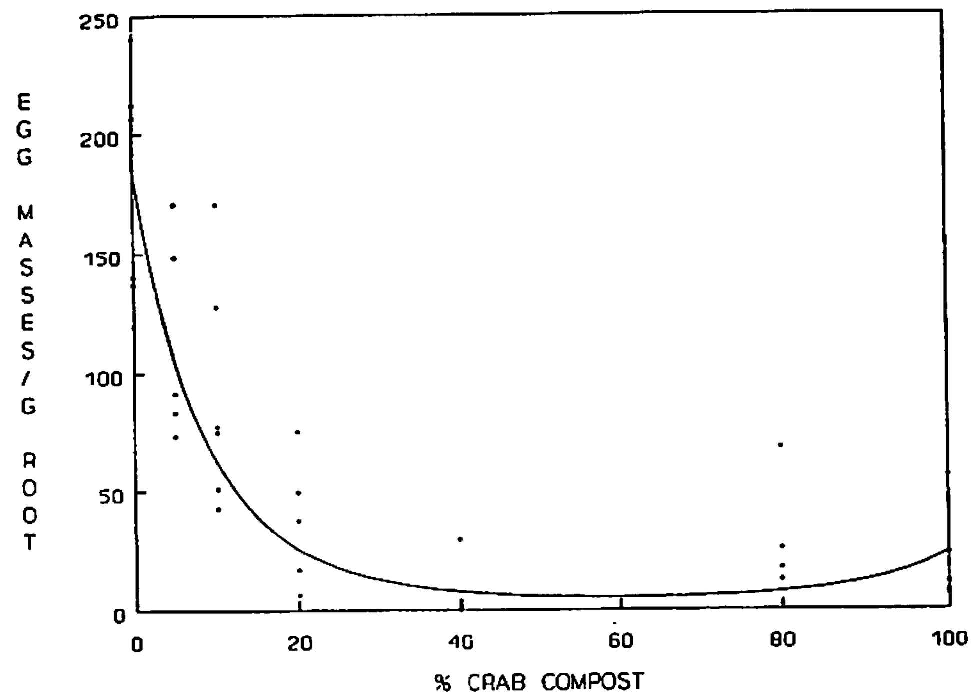

Figure 8.5 Effect of % crab compost in soil on the number of M. javanica egg masses per gram of tomato root in greenhouse test 2.

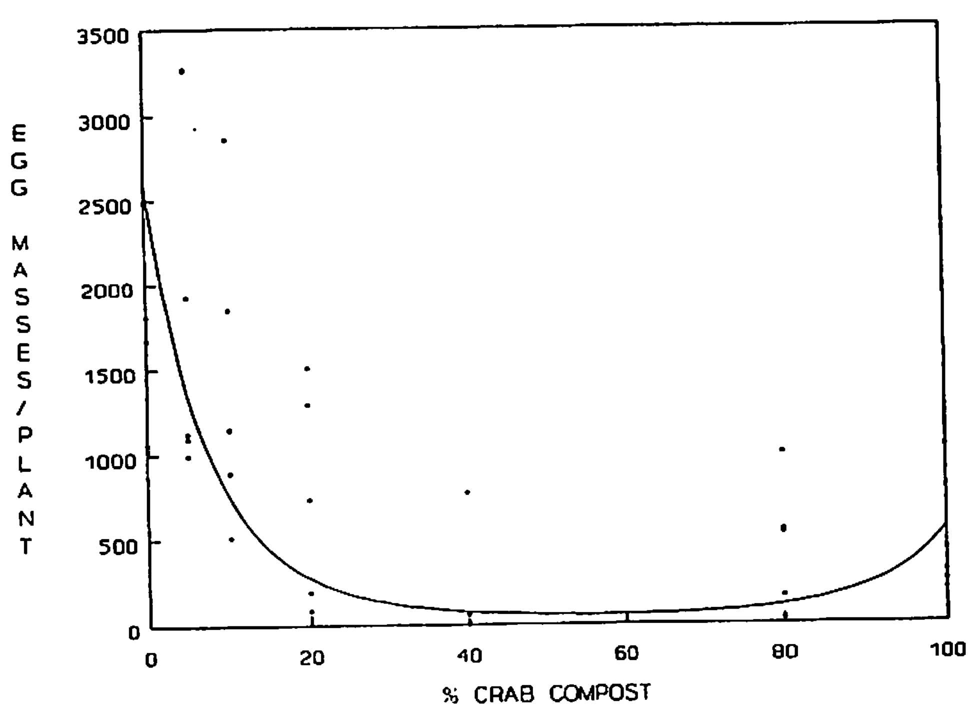

Figure 8.6 Effect of % crab compost in soil on the number of M. javaniva egg masses per tomato plant in greenhouse test 2.

Table 8.5 Comparative influence of raw crab scrap and crab compost on tomato growth and *Meloidogyne javanica* reproduction.

Treatment*	Foliar wt.	Root wt.	Root gall index	Egg masses/plant
Control	14.4 a	11.5 a	4.0 a	218 a
Crab compost (20%)	20.1 a	5.6 b	2.2 b	134 b
Crab scrap (0.5%)	15.2 a	7.6 b	1.3 c	21 c

* Treatments added on a percentage dry weight basis on air-dried fine sand soil.

Means within the same column followed by the same letter are not significantly different according to Waller Duncan K-Ratio T-Test ($P \leq 0.05$).

Table 8.6 Effect of crab compost on plant growth and *Meloidogyne javanica* population in a microplot study.

Crab compost mt/ha	Yield g/plant	Plant weight	Root gall index	Eggs and larvae/250 cc soil
0	775	208	4.0	5113
2.25	1317	200	3.9	2432
4.50	1173	293	3.9	3756
9.00	683	140	3.4	1677
18.00	1363	218	3.9	2363
36.00	1342	213	3.4	2576

No significant differences were observed.

The mode of action of chitin on nematodes has been hypothesized to be the production of toxic levels of NH_3 and enhanced microbial antagonism activity (Rodriguez-Kabana, 1986). The depletion of nitrogenous compounds and reduction of energy sources through composting (Brinton and Seekins, 1988), probably reduced chitin concentrations, and thus, the nematode suppressive characteristics of the crab scrap compost.

The 20% level of crab scrap compost represents an application rate of over 200 mt/ha which would not be economical for nematode control in large scale agriculture. In the field microplots, little nematode suppression was observed with rates of 36 mt/ha. Data from these tests indicate that crab scrap compost has the same limitations for nematode control as many other materials containing low C:N ratios (Rodriguez-Kabana, 1986). Additions of large quantities of these materials have been found necessary to inhibit nematode reproduction. Thus, these products may not be generally economically feasible for use in large scale agricultural systems as a nematode management agent. Thus, the greatest potential for use of crab scrap compost for nematode suppression would be in container grown plants and organic home gardens. In these situations, high loading rates are normal practices in production systems.

The ability of crab scrap compost to increase organic matter, soil water retention (Figure 8.7) and provide/retain soil nutrients may be more important than the ability of the compost to suppress nematodes. Further greenhouse and microplot tests need to be conducted to verify and extend results of these experiments.

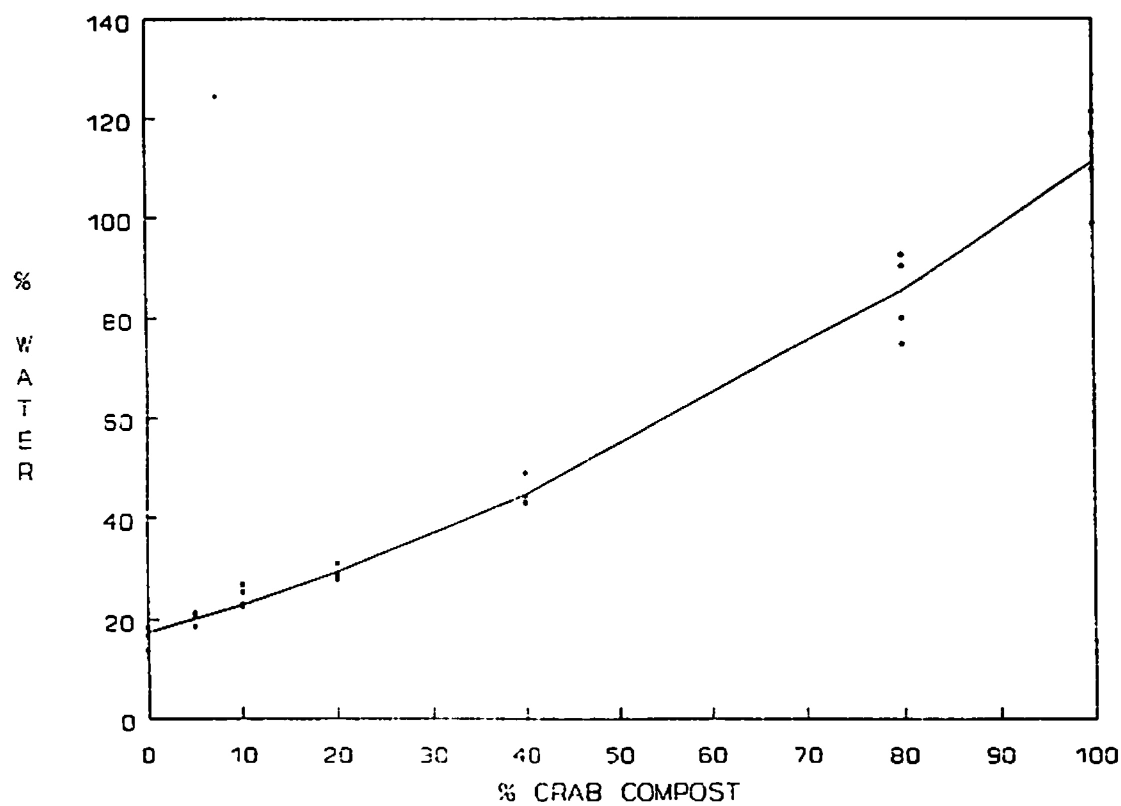

Figure 8.7 **Effect of % crab compost in soil on the relative water holding capacity of the soil compost mixture.**

IX. LEACHING OF SELECTED CHEMICAL CONSTITUENTS FROM SOIL AMENDED WITH CRAB SCRAP COMPOST[1]

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Introduction

Crab scrap composting appears to offer several advantages to traditional disposal methods. However, as with any new method for disposing of crab scraps, or any by-product, the potential harmful environmental hazards and/or benefits, must also be measured.

Agricultural areas in Florida are commonly underlain by sandy, well-drained soils that generally have low organic matter and low moisture retention capacity. As a result, ground water is highly susceptible to contamination from leaching of applied insecticides, herbicides, and fertilizer nutrients. Compost made from crab scrap may impact the quality of the ground water in two ways: 1) decomposition of crab scrap compost may add organic compounds, chemical residues, or trace elements to ground water, and alternatively, 2) crab scrap compost may provide a means of enhancing the retention and/or degradation of pesticides and nutrients in the upper portion of the soil profile. Some preliminary work was done to evaluate whether the application of crab scrap compost as a soil amendment will lead to beneficial or adverse impacts on water quality.

Objectives

Shellfish residues have been shown to contain relatively high amounts of certain trace elements such as iron, manganese, zinc, copper, and boron (Mathur and others, 1986). Leachate from crab scrap or composted materials may also contain elevated concentrations of these trace elements that could be leached into the ground water. Tests were done to evaluate the potential leaching of selected organic compounds and metal ions released during decomposition of field-applied compost made from crab scrap.

Compost represents an organic amendment which can influence both the soil microbial populations and the potential levels of soil organic matter. Changes in the populations can affect the degradation of added pesticides. Increases in soil organic matter can lead to retention of pesticides and nutrients through the process of absorption (Houzim and others, 1986). Increased degradation and/or retention could result in decreased leaching potential to the ground water. Work was also done to determine if crab scrap compost can retard the movement of a field-applied pesticide into the water table.

Accomplishments

A greenhouse lysimeter study with a factorial experimental design was initiated. Time of leaching was one factor (14 or 28 days), and three levels of crab compost (0, 15, and 30%) was the other factor. Lysimeters were 55 cm dia. and 45 cm deep, constructed from 0.7 cm thick plastic drums. They were fitted with a PVC outlet having a metal screen placed at the joint to prevent soil loss. Gravel was placed in the bottom to a depth of 6.35 cm to facilitate drainage. A Lakeland fine sand soil was fumigated with methyl bromide for use in this experiment. The lysimeters were filled with soil or the appropriate crab compost soil mixture.

Soil and soil compost mixtures in the lysimeters were lightly compacted, and saturated by adding enough water from the top to wet completely without generating drainage. They were allowed to settle for one week.

On September 21, 1990, all lysimeters were inoculated with 150 _Meloidogyne javanica_ eggs/100cc of soil. Lysimeters were fertilized with 20.5 g of 13-3-14 fertilizer on October 1`, 1991. Ethoprop was applied on October 2, 1991, as a 10% granular material at 10.9 g/lysimeter (20 kg a.i./ha) and incorporated. Two "Homestead" tomato seedlings were transplanted into each lysimeter.

[1] Hilda Hatzell, U.S. Geological Survey, Tallahassee, Florida also participated in work complementary to this project. U.S.G.S. reports were made directly to the Florida Department of Environmental Regulation. The U.S.G.S. was not a recipient of funds under contract SW28, the work reported on in this document.

Fourteen days after ethoprop application soil samples were taken for moisture determination and half of the lysimeters were leached. For leachate collection, one lysimeter at a time was watered simulating a 8-9 cm rainfall intensity storm. Leachate was collected from the bottom port at 2 minute intervals. When the leachate started slowing, more water from the top was added. This process of leachate collection was continued until 4-5 liters of leachate was obtained. Leachate was centrifuged and filtered to remove solids. A sub-sample of the leachate was immediately forwarded to the Tennessee Valley Authority Lab for analysis of ethoprop concentration. Other sub-samples were frozen to await the results of sample analysis from an incubation study to determine the most important contaminants for which to test. The leaching procedure was repeated again at 28 days.

Results

In the factorial analysis of ethoprop concentration, no significant interaction between time of leaching and crab compost level was observed. Both 15 and 30% crab compost levels produced significantly lower concentrations of ethoprop in the leachate and total ethoprop leached, when compared to the 0% crab compost level. Levels of ethoprop leached were significantly higher at 28 days than at 14 days after application (Table 9.1).

The Geological Survey, U.S. Department of Interior, conducted the incubation portion of this work with the results summarized as follows (personal communication, Hilda Hatzell, USGS, and letter from Irwin H. Kantrowitz, USGS to Rodney Deltan, Florida Department of Environmental Regulation, November 30, 1990).

The incubation study was an experimental means of determining if water-soluble organic and inorganic constituents could be removed from samples of crab compost, soil and ground crab. These materials were decomposed by subjecting them to a series of wetting and drying cycles in the greenhouse.

Table 9.1 Effect of crab compost level and time of leaching on the retention of ethoprop in soil.

	Ethoprop conc.[a] in leachate (ug/l	Total ethoprop leached (ug)
% Crab Compost[b]		
0	443	2395
15	162	863
30	83	461
Time of Leaching[c]		
14 days	177	832
28 days	283	1644

[a] Ethoprop concentration was analyzed by Tennessee Valley Authority.

[b] Individual means within columns differ significantly when contrasted to the 0% crab compost level ($P \leq 0.001$).

[c] Means within columns differ significantly ($P \leq 0.001$).

After the greenhouse incubation, samples were extracted with deionized water. The extraction process was an experimental procedure designed to evaluate the concentrations of organic and inorganic compounds that might be expected in leachate water in field conditions. A dry weight of 100 grams of sample was added to 500 milliliters of deionized water and placed on a gentle-action reciprocating shaker for 30 minutes. The sample was then centrifuged at a rate of 10,000 rpm for 5 minutes. The supernatant solution from the centrifuged suspensions was designated as the water extract and was analyzed for total concentration of selected chemical constituents. A small subsample of the supernatant solution was filtered through 0.45 micron paper and analyzed for dissolved concentrations of selected constituents.

The concentrations of selenium in the unfiltered water extract from the incubated compost and from the incubated ground crab samples are greater than the guidance concentration for the Florida Primary Drinking Water Standard (Chapter 17-550.310-320, F.A.C.). The concentrations of arsenic in the unfiltered water extract for the incubated ground crab exceed the guidance concentration for arsenic. Unfiltered water extracts for the incubated ground crab contain concentrations of iron and manganese that are greater than the guidance concentrations for the Florida Secondary Drinking Water Standards for iron and manganese. The concentration of iron in the filtered water extract of the compost is equal to the guidance concentration for iron.

These data indicate that levels of arsenic, selenium, and manganese in the crab compost could be at significant levels to create a potential hazard. However, others argue (William Brinton, personal communication) that these levels result from laboratory conditions which do not resemble field conditions. Some attempt should be made to determine the amount of compost that would need to be used at actual rainfall and/or water use levels to reach these concentration levels at the soil surface, and subsequently, at ground water levels, before a problem would occur. This is an area where more analysis would certainly be useful.

X. REFERENCES

Introduction

Andree, S. 1988. Alternatives for Wakulla County management of blue crab processing solid waste. Florida Sea Grant Technical Paper 53, University of Florida, Gainesville. 16 pp.

Cato, J. C. 1989. A summary of demonstration projects - seafood processing by-products and waste management alternatives for blue crabs and scallops. Florida Sea Grant Mimeograph, University of Florida, Gainesville. 10 pp.

Cato, J. C., K. Clayton, B. Durden, J. Fisher, and J. Gordon. 1977. A report on alternatives for managing solid crab waste in Wakulla County. Florida Sea Grant Extension Mimeograph Report, University of Florida, Gainesville. 23 pp.

Myer, R. O., D. D. Johnson, W. S. Otwell, and W. R. Walker. 1987. Potential utilization of scallop viscera silage for solid waste management and as a feed stuff for swine. Proceedings of 1987 Food Processing Waste Conference, Georgia Tech Research Institute, Atlanta, Georgia. 17 pp.

Otwell, W. S. ed. 1981. Seafood waste management in the 1980's: conference proceedings. Florida Sea Grant Report Number 40, University of Florida, Gainesville. 365 pp.

In-Plant Methods for Handling Blue Crab Scrap

Abazinge, M. D.A., J. P. Fontenot, and V. G. Allen. 1986. Digestibility, nitrogen utilization and palatability of ensiled crab waste-wheat straw mixtures fed to sheep. Animal Science Research Report No. 5, Virginia Tech Livestock Research Report, Blacksburg. pp. 100-106.

American Public Health Association. 1989. Standard methods for the examination of water and wastewater. 17th Edition.

Andree, S. 1988. Alternatives for Wakulla County management of blue crab processing solid waste. Florida Sea Grant Technical Paper 53, University of Florida, Gainesville. 16 pp.

Brinsfield, R. 1981. Crab scrap disposal in Maryland. In: Crab by-products and scrap, 1980. M.B. Hatem, ed. University of Maryland Cooperative Extension Service, College Park. pp. 1-20.

Eilers, James R. 1990. Anaerobic wastewater treatment reduces BOD more than eighty percent. Food Processing, August, 72, 74.

Mankau, R. and R. J. Minteer. 1969. The influence of chitin amendments on Meloidogyne incognita. J. Nematology. 1:15-16.

Owens, W. F., D. C. Stuckey, J. B. Healy, L. Y. Young, and P. L. McCarty. 1979. Bioassay for monitoring biochemical methane potential and anaerobic toxicity. Water Res 13, 405-492.

Composting of Florida Blue Crab Scrap

Brinton, W. F. and M. D. Seekins. 1988. Composting fish by-products: a feasibility study. Time and Tide Resource, Conservation and Development Mid-Coast Compost Consortium, Waldoboro, Maine. 65 pp.

Frederick, L. 1989. The compost solution to dockside fish waste. University of Wisconsin Sea Grant Institute, Madison.

Calico Scallop Viscera Composting

Bailey, G. and W. Brinton. 1991. Rotating drum composting of salmon mortalities. Maine Aquaculture Innovation Center, University of Main, Orono.

Bonaker, L. A., et.al. 1991. Production and testing of seafood wastes sawdust compost. Pacific Economic Development Council, Seattle, Washington.

Brinton, W. F. and M. D. Seekins. 1988. Composting fish by-products: a feasibility study. Time and Tides Resource, Conservation and Development Mid-Coast Compost Consortium, Waldoboro, Maine. 65 pp.

Brooks, J. 1986. Composting fish waste with peat. University of Maine Department of Civil Engineering, Orono, Maine.

Raw and Composted Blue Crab Scrap as Soil Amendments Supporting the Growth of Sorghum/Sudungrass

Bingham, F. T. 1982. Boron. in A. L. Page (ed) Methods of Soil Analysis (2nd ed). Part 2, Chemical and Microbiological Properties, Amer. Soc. Agron., Inc. and Soil Sci. Soc. Amer., Inc., Madison, Wisconsin. pp 431-447.

Bremner, J. M. and D. R. Keeney. 1965. Steam distillation methods for determination of ammonium, nitrate and nitrite. Anal. Chim. Acta. 32:485-495.

Bremner, J. M. and C. S. Mulvaney. 1982. Nitrogen - Total. in A. L. Page (ed) Methods of Soil Analysis (2nd ed), Part 2, Chemical and Microbiological Properties, Amer. Soc. Agron., Inc. and Soil Sci. Soc. Amer., Inc., Madison, Wisconsin. pp 595-624.

Caldwell, R. E. and R. W. Johnson. 1982. General Soil Map of Florida. USDA/SCS and University of Florida, Gainesville, Florida.

Environmental Protection Agency. 1982. Test Methods for Evaluating Solid Waste. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. (2nd ed).

Murphy, J. and J. P. Riley. 1962. A modified single solution method for determination of phosphate in natural waters. Anal. Chim. Acta. 27:31-36.

Olsen, S. R. and L. E. Sommers. 1982. Phosphorus. in A. L. Page (ed) Methods of Soil Analysis (2nd ed), Part 2, Chemical and Microbiological Properties, Amer. Soc. Agron., Inc. and Soil Sci. Soc. Amer., Inc., Madison, Wisconsin. pp 403-430.

Sippola, J. and R. Ervio. 1978. Determination of boron in plants and soils by azomethine-H method. Finn. Chem. Lett. 130-140.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. Iowa State University Press, Ames, Iowa.

Suppression of the Javanese Root-Knot Nematode Using Blue Crab Compost

Brinton, W. F. and M. D. Seekins. 1988. Composting fish by-products: a feasibility study. Time and Tide Resource Conservation and Development Mid-Coast Compost Consortium, Waldoboro, Maine. 65 pp.

Godoy, G., R. Rodriguez-Kabana and G. Morgan-Jones. 1983. Chitin amendments for control of Meloidogyne arenaria in infested soil. II. Effects on microbial populations. Nematropica 13:63-74.

Hussey, R. S. and K. R. Barker. 1979. A comparison of methods of collecting inocula of Meloidogyne spp., including a new method. Plant Disease Reporter 57:1025-1028.

Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

Mankau, R. and S. Das. 1974. Effect of organic materials on nematode bionomics in citrus and root-knot nematode infested soil. Journal of Nematology 4:138-151.

Mian, I. H., G. Godoy, R. A. Shelby, R. Rodriguez-Kabana, and G. Morgan-Jones. 1982. Chitin amendments for control of Meloidogyne arenaria in infested soil. Nematropica 12:71-84.

Rodriguez-Kabana, R. 1986. Organic and inorganic nitrogen amendments to soil as nematode suppressants. Journal of Nematology 18:129-135.

Rodriguez-Kabana, R., G. Morgan-Jones, and B. Ownley Ginitis. 1984. Effects of chitin amendments to soil on Heterodera glycines, microbial populations and colorization of cysts by fungi. Nematropica 14:10-20.

Taylor, A. L and J. N. Sasser. 1978. Biology, identification, and control of root-knot nematodes, Meloidogyne species. International Meloidogyne Project. Department of Plant Pathology, North Carolina State University, and U.S. Agency for International Development. Raleigh, North Carolina. 111 pp.

Leaching of Selected Chemical Constituents From Soil Amended With Crab Scrap Compost

Mathur, S. P., J. Y. Daigle, M. Levesque and H. Dinel. 1986. The feasibility of preparing high quality composts from fish scrap and peat with seaweeds or crab scrap: Biological Agriculture and Horticulture, v. 4, pp. 27-38.

Houzim, V., J. Vavra, J. Fuksa, V. Pekny, J. Vrba and J. Stribral. 1986. Impact of fertilizers and pesticides on ground water quality, in Vrba, J. and Romijn, E., eds., Impact of agricultural activities on ground water: International Association of Hydrologists, v. 5, pp. 89-132.

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