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# Stabilization and Utilization of Seafood Processing Waste as a Slow Release Nitrogenous Fertilizer for Production of Cabbage in Florida, USA and Mushroom in Ghana, Africa

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**Abstract:** Seafood wastes were evaluated for the production of cabbage and mushrooms as a means of managing the vast amounts of organic waste currently being generated by the fast growing seafood industry in Florida, USA and Ghana, Africa. Seafood wastes are presently being disposed of by burning, dumping in landfills or out into the sea, thereby creating an unsustainable environmental problem. Utilizing bioconversion technology such as the slow release of nutrients for agriculturally based activities like producing mushroom will profitably reduce seafood waste while enhancing environmental quality. In this study, seafood wastes were stabilized with citric acid to produce mixtures of 3%, 5% and 10% concentrations. Molasses were also used as a waste treatment to generate a 5% concentration of the additive and intensity of the waste odor was monitored over six weeks. Sawdust was separately mixed with fresh fish waste (FFW) and cooked fish waste (CFW), placed in heat-resistant transparent polyethylene sachets and compared for their effectiveness to promote mushroom growth. Each sterile bag was then aseptically inoculated with three different varieties of oyster mushrooms (*Pleurotus species*) which included *Pleurotus eous*, a hybrid of *Pleurotus eous* and *Pleurotus oestreatus*. The bags were then incubated for five weeks under ambient temperature and controlled humidity. Mycelia growth was determined at 3 day-intervals. The results indicated that the growth of oyster mushrooms was fastest with FFW when compared to CFW and the control. *P. eous* and *P. aestreaus* exhibited uniform spread of mycelia in the compost bags, oyster mushrooms produced bigger and firmer fruiting bodies compared to a control substrates of rice brand (CRB). The fastest mycelia growth was obtained for *P. eous* which completely colonized FFW and CFW substrates within 26 days. The cabbage fertilization was based on the plant nitrogen requirement and nitrogen content of fish waste (organic) and commercial (inorganic) fertilizer used. The stabilized fish waste acidified the soil and generated plants with yields significantly lower ($p<0.05$) than the commercial treatment. Nitrogen release from the fish waste was mainly in the form of nitrate, which appeared to be rapid in the early stages of the plant growth and was almost exhausted at harvest time showing potentials of reducing nitrogen pollution of ground water. The implications of this study are that seafood waste could be used to cultivate a very nutritious food substance while at the same time promoting environmental sustainability.

**Key words:** Seafood wastes · organic fertilizer · mushroom production · sustainability

## INTRODUCTION

Seafood processing activities have raised serious waste production and disposal concerns all over the globe. Commercially, fishing and aquaculture usually generate large amounts of waste that must be disposed [1]. The waste may be as high as 80% or higher when landed catches are found to be unfit as food, when there are massive kills in aquaculture or when only roe (eggs) are harvested from herring or other fishes [2]. The common practice of disposing the residues of the seafood industry into natural open bodies of water and landfills

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heightened environmental concerns. Most of the objections to off-shore dumping of waste were based on odor problems, floating debris and visible surface slick, attractant of undesirable predator species, increased turbidity and dissolved oxygen depression of bodies of water [3]. In response to these concerns, laws have been enacted mandating the exploration of alternatives to landfilling [4].

To regulate the water disposal problems, a fish waste management program was established. The measures promoted sound fish waste management through a combination of fish-cleaning restrictions, public education and proper disposal of fish waste which were to be implemented by various states to marinas where fish waste was determined to be a source of water pollution. The program development and approval guidance was published by the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) [5] of the U.S. Department of Commerce.

In the state of Florida, these measures appeared to have made landfilling a more attractive choice for seafood waste disposal. In fact, seafood waste disposal accounted for as much as 25% of the annual operating budget of some landfills in Florida [6]. This alternative created numerous landfill management and environmental problems and especially, increasing level of nitrates in ground water. In response to these concerns, a law was enacted by the State of Florida, (88-130 Florida Status) [7] mandating the exploration of alternatives to landfilling. The new regulation generated and stimulated research ideas and uses for fish waste. For instance, in-plant methods (wet extrusion, compacting and anaerobic bioconversion) and composting of blue crab and calico scallop residues were investigated. The composting project showed an encouraging potential to serve as an alternative waste disposal method, but only for the shelled seafood [6]. The in-plant methods encountered numerous problems needed resolving before they could be recommended as alternatives to landfilling. Therefore this research project was developed to investigate the stabilization and nitrogen release of waste from processed fish treated with selected additives.

In Ghana, artisanal fishing activities carried out along the coastal regions, generated large amounts of wastes as well. These seafood wastes, not adequately disposed of, result in gross environmental hazards, such as foul odor, under the prevailing high temperatures [8]. The fast decomposing proteinaceous materials serve as a potential source of diseases to inhabitants in the vicinity. In addition, domestic animals roaming the dumpsters may spread contaminants to humans and their homes. During the rainy season, an increased attendance to local health centers has been registered, due to rampant illnesses partly caused by pathogens in flood prone areas. To ensure pollution control, enforcement of pollution laws combined with waste recycling, would be beneficial to a large portion of the population. Recycling would include utilization of agricultural residues as potential substrates for the cultivation of edible and medicinal mushrooms.

Mushroom is an important food item in the diet of Ghanaians. Depending on the variety, mushrooms have high vitamin B content (B1, B2, B6 and B12), which are the major regulators of metabolism and are responsible for the breakdown of fats, carbohydrates and proteins to supply energy (Protein: 20-40% dry weight) [9]. All over Africa, mushroom is known to increase the nutritional value of infant food, when used as a dried powder. A lack of protein in children nutrition has been linked to several diseases, such as Kwashiorkor and anemia, therefore the Food and Agricultural Organization of the United Nations, recommended an increase in mushroom availability as a food and protein source [10]. Fauzia *et al.* [11] showed that on a dry weight basis, mushroom has higher nutritional values than fish or beef. Mattila *et al.* [9] suggested that a diet rich in mushrooms provides all the essential amino acids usually available in fruits and vegetables. In light of these findings, the current study was designed to use seafood wastes as slow release organic nitrogen fertilizer for cabbage and mushroom production. The aim of the study was to reduce environmental pollution while producing edible and medicinal food. In addition, a novel technology will be disseminated throughout the coastal region of Ghana, which in turn will create jobs and sustainability for the youth along these coastal communities.

## MATERIALS AND METHODS

**Source of Fish Waste:** The fish waste included whole waste fish, remains from filleting, heads, skin, gills, fins, scales, tails and backbones. It was obtained from Lynn Seafood & Oriental Market and Langston's Seafood Inc for the stabilization study and from Mineral Springs, My-Way and Rocklanding seafood depots in Panacea and the Water Street Seafood processing plant in Apalachicola, Florida for the composting field study. In Ghana, Pioneer Food Cannery, a fish processing company in Tema, provided the needed seafood waste.

**Experimental Procedure for Stabilization Study:** From the area of collection, fish wastes were placed in polythene bags on ice and immediately taken to the respective laboratories for processing. The waste was chopped into

Table 1: Nitrogen Content of Fish Waste Treatment for Composting Study

| Type of Fish Waste Treatment | Percentage Nitrogen |
|---|---|
| 10% Citric Acid | 7.7 |
| 10% Molasses | 6.3 |
| 1.5% Formaldehyde | 6.9 |

The values listed represent average counts of the replicates

fine pieces to produce a pasty substance using an electrical blender. The treatments were prepared by combining and thoroughly mixing measured quantities of additives and chopped fish waste in zip-lock bags (Table 1). The sealed bags were stored at average temperature of 32.5°C for six weeks. Each treatment was prepared in triplicate. In Ghana, the treatments consisted of Fresh Fish Wastes (FFW) and Cooked Fish Wastes (CFW). A control treatment composed of rice bran (CRB) was used. Three different heaps were made by mixing the seafood wastes with sawdust from the wood species, *Tryplochyton scleroxylon*, known as Wawa tree in Africa.

For the Cabbage experiment, the moisture content was determined using standard procedures outlined by the Association of Official Analytical Chemist (A.O.A.C.) [12]. The stabilization study proceeded in two phases. In the first phase, a control, the 3% citric acid and 5% molasses treatments were analyzed for odor intensity and judged by students. In the second phase, the same type of treatment analysis and judging occurred, but this time, 3%, 5%, 10% citric acid and control treatments were evaluated. All treatments were stored in the greenhouse where their odor was monitored every four days for a period of six weeks. A random group of between 5-10 students smelled the content of each bag and scored the odor using a scale of 1-5 where one represents little or no offensive smell and five represents unbearable stench. Coffee bean aroma was provided to each student to clear their nostrils from previous pungency before smelling each new treatment. The score sheet results were later tallied and statistically analyzed. The treatments scoring in the ones and twos category were selected for the composting field study.

**Handling of Processed Fish Waste for the Field Composting Study:** Fish waste for the composting field study was chopped using machete, weighted, placed into 32-gallon plastic containers and mixed with respective additive to make concentrations of 10% molasses, 10% citric acid and 1.5% formaldehyde as a positive control. Each container was covered and stored in the shade for no less than twelve weeks before use. In Ghana, the heaps were left to ferment for 30 days during which they were turned over every four days. Temperature readings were monitored daily.

To determine the nitrogen contents, the samples were oven dried at 65°C for four days. Duplicate 1.4 grams samples of the material were wrapped in No.2 Whatman's filter paper and placed into Kjedahl flask. Ten grams of 95:5 mixture of $K_2SO_4$: $CuSO_4.5H_2O$ was added, followed by 25 ml of concentrated $H_2SO_4$. The flask was then placed on a digestion apparatus and boiled until the solution became clear and boiled for one hour after that. The solution was cooled to room temperature and 100 ml of deionized water were added to each flask, which was stoppered, covered with aluminum foil and left overnight. 50 ml of 4% boric acid solution (5% boric acid and 0.2 g methyl red in 100 ml ethanol) was added to each of a series 500 ml Erlenmeyer flask and placed on the distillation apparatus. Carefully, 80 ml of 50% sodium hydroxide was added to each of the digested solutions before distillation. During the distillation of the digested solution 100 ml of distillate was collected in each flask containing boric acid solution which was then titrated against 0.1 normal (N) hydrochloric acid (HCl).

The field plot was 30.5 m x 19.8 m, soil samples were collected and analyzed for pH, moisture, nitrogen and organic matter content, prior to the field planting and sample application. Cabbage seedlings at eight-leaf stage were planted 1 m by 1 m. The cabbage was mulched with pine straw. A maximum of 10 cabbage plants per treatment were placed in three blocks using the Complete Randomized Block Design. The following treatments were used: 10% molasses treated fish, 10% citric acid treated fish, 1.5% formaldehyde treated fish, commercial fertilizer 12:6:6 (NPK), control (no sample, no fertilizer).

The band method of treatment application was employed in which the additives were placed 10-15 cm away from the plant stem at a depth of 5-7 cm. The treatments were then lightly covered with soil and mulched with pine straw. Each cabbage plant received 312 grams of the fish waste treatment while 170 grams of the commercial fertilizer was applied to untreated plants as control. The amount of fish waste sample was determined by matching the amount of nitrogen required by cabbage and the amount of nitrogen in the sample.

The cabbage plants were irrigated twice a day and once sprayed with an insecticide. Data collection commenced one week after sample application and continued every other week. Measurements taken were height and stem thickness. After thirteen weeks of plant growth, the plants were harvested including the roots and weighted. The nitrogen content of three plants for each treatment was determined. Soil samples for each treatment area were taken to a depth of 20.3 cm for nitrogen content, moisture and pH determination.

In Ghana, equal numbers of sterile bags from the different treatments (FFW, CFW and (CRB) were aseptically inoculated with three different varieties of oyster mushrooms spawns (*Pleurotus species*); namely *P. eous* (EM1), a hybrid of *P. eous* (P21) and *P. oestreatus* (P34). The bags were subsequently incubated for 5 weeks at ambient temperature, during which mycelia growth was measured at 3-day intervals. After the incubation period, the mature compost bags were transferred to the cropping house where they were opened for the fruiting bodies to emerge.

## RESULTS AND DISCUSSION

The results of the stabilization study showed a higher anti-odor efficiency for the molasses treatment compared to the citric acid. Only the 5% molasses treatment seemed to have acceptable scores of ones and twos. The second phase of the study comparing the effectiveness of different concentrations of citric acid for stabilization of the fish waste concluded that 10% citric acid concentration is most efficient in eliminating odors. Comparison between 5% molasses and 10% citric acid showed that there was no significant difference ($P<0.05$) between these two additives at the given concentration.

The results of fish waste and soil analysis prior to composting are shown in Tables 1 and 2.

After 12 weeks a significant height difference between the control and the untreated plants was observed. There were very small statistical differences ($P<0.05$) between the commercially treated plant and those treated with fish waste. There was no height difference ($P<0.05$) between commercially and citric acid fish waste treated plants (Table 3).

The commercial treatment produced the highest yield in terms of harvested weight. There was a significant difference ($P<0.05$) between the final yield of plants fertilized with commercial fertilizer and those fertilized with treated fish waste. Among the organic treatments, citric acid showed a much better yield than molasses and formaldehyde treatments, which were not significantly different from the untreated control plants (Table 4).

Table 2: Results of Soil Analysis Prior to Planting

| Type of Analysis | Cabbage Plot |
|---|---|
| Moisture Content | 6.63% |
| Organic Matter Content | 0.29% |
| Nitrogen Content | 5.74 mg/L |
| pH | 6.4 |

The values listed represent average counts of the replicates

The analysis of the harvested plant tissues for nitrogen content showed that the plants treated with the organic source fertilizer had higher amounts of both ammonium and nitrate nitrogen than commercially fertilized plants, while the difference in ammonia nitrate was not statistically significant ($P<0.05$). The nitrogen content of the soil showed significant differences between the organically and inorganically treated areas. The commercially treated soil samples had 31 times higher amount of total nitrogen than the organically treated soil areas, which also contain twice less nitrogen than the unfertilized areas on the plot (Table 5). This would indicate that the nitrogen was slowly released from the seafood waste applied to the soil around the cabbage plants.

In Ghana, a rise in temperature was observed during bags incubation at spawning. Higher temperatures were generated in the bags prepared with fish wastes as compared to CRB. Temperature ranges between 37-52°C, 38-52°C and 33-45°C for CFW, FFW and CRB respectively. This was certainly the results of nutrient increase, such as carbohydrates and nitrogen, which in turn promoted bacterial growth, as demonstrated by Atipko *et al.* [14]. Temperature increases between 40 and

Table 3: Growth parameters for cabbage treated with various additives

| Growth Parameter | Molasses Waste Fertilized Plants | Citric Acid Waste Fertilized Plants Acid | Formaldehyde Waste Fertilized Plants | NPK Fertilized Plants | Control |
|---|---|---|---|---|---|
| Starting Height [cm] | 3.8±0.8 | 4.3±0.8 | 3.3±0.8 | 3.8±0.8 | 4.3±0.8 |
| Final Height [cm] | 11.2±2.3 | 14.0±2.3 | 12.2±2.3 | 15.5±2.3 | 9.1±2.3 |
| Starting Stem [cm] | 0.5±0.0002 | 0.5±0.0002 | 0.5±0.0002 | 0.5±0.0002 | 0.5±0.0002 |
| Final Stem [cm] | 1.8±0.05 | 2.3±0.05 | 2.0±0.05 | 2.3±0.05 | 1.3±0.05 |
| Starting Leaf No. | 8.0±3.0 | 9.0±3.0 | 9.0±3.0 | 9.0±3.0 | 8.0±3.0 |
| Final Leaf No. | 15.0±7.0 | 17.0±7.0 | 16.0±7.0 | 18.0±7.0 | 13.0±7.0 |

The values listed represent average counts of the replicates

Table 4: Average Yield of cabbage plants for various treatments

| Stabilization Treatments | Average Yield [kg] |
|---|---|
| 10% Citric Acid | 0.445±0.09 |
| 10% Molasses | 0.141±0.09 |
| 1.5% Formaldehyde | 0.154±0.09 |
| Commercial Fertilizer | 0.594±0.09 |
| Control | 0.059±0.09 |

The values listed represent average counts of the replicates

Table 5: Post harvest soil results for each treatment for pH and total nitrogen

| Type of Analysis | Citric Acid Treatment | Formaldehyde Treatment | Molasses Treatment | Fertilizer Treatment | Control |
|---|---|---|---|---|---|
| Soil pH | 5.7 | 5.5 | 5.9 | 7.7 | 6.3 |
| Soil Nitrate [ppm] | 0.003 | 0.005 | 0.005 | 0.61 | 0.041 |
| Soil Ammonium [ppm] | 0.001 | 0.003 | 0.003 | 0.014 | 0.005 |
| Soil Total Nitrogen [ppm] | 0.004 | 0.008 | 0.008 | 0.624 | 0.046 |

The values listed represent average counts of the replicates

60°C is known to adversely affect mycelia production [13]. However, this phenomenon was not observed in the course of our study. A delayed release of supplements might have occurred, providing nutrients in stages and subsequently utilized for growth. The results of the mycelia growth are listed in Figures 1/2/3. The growth of mycelia in the three different substrates generated a similar pattern. Comparative analysis of the growth of the three types of mushroom showed that *P.eous* hybrid exhibited the fastest mycelia growth, completely colonizing the substrate during the growth period.

A thorough amalgamation of additives such as molasses and citric acid with fish waste separately as a stabilization method has proven to be a time consuming operation particularly when large volumes of waste must be shredded. The method however, has demonstrated encouraging success in reducing the decomposition of the organic material. Concentrations of 5% molasses and 10% citric acid have made the odor of discarded fish tolerable to over 80% of a group of students; however, the effects of the stabilized waste as a plant fertilizer are uncertain.

The response of cabbage plants to the treated fish waste showed that citric acid produced the highest yield for organic treatments. Nitrogen release from the waste may have accounted for that result. The nitrogen release, mainly in the form of nitrate, appeared to be rapid in the early stages of plant growth. Its absorption by the plants decreased with time and was almost totally exhausted from the organically treated soil at harvest time.

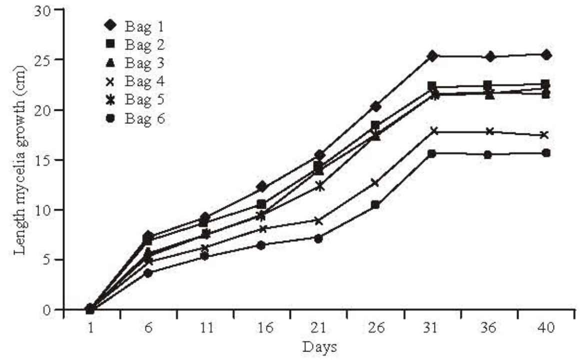


Fig. 1: Mycelia growth of *Pleurotus eous* in compost bags of rice bran mixed with sawdust

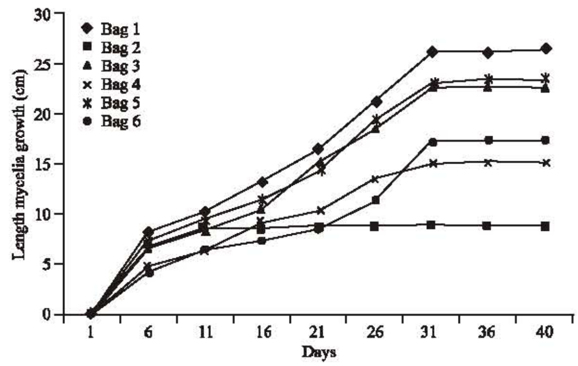


Fig. 2: Mycelia growth of *Pleurotus eous* in compost bags of fresh fish waste mixed with sawdust

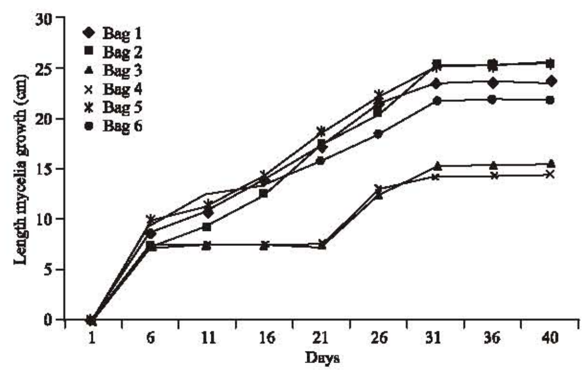


Fig. 3: Mycelia growth of *Pleurotus eous* in compost bags of cooked fish waste mixed with sawdust

Plants fertilized with molasses and formaldehyde treatments showed similar performance to the untreated plants. The commercial fertilizer increased the pH of the soil, while the organic fertilizers acidified the soil, which may have affected soil nutrient availability to the plants. It appeared that certain nutrient deficiencies resulting from the acidic condition may have affected the nitrogen assimilation process in plants generated from the stabilized waste. The high amounts of nitrogen found in our samples are comparable to plants suffering from molybdenum deficiency. The organic fertilizer also recorded the lowest residual nitrogen in the soil after the harvest, which is a great advantage considering the ground water nitrogen pollution caused by commercial fertilizers.

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