FISH WASTE MANAGEMENT: TURNING FISH WASTE INTO HEALTHY FERTILIZER

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Introduction

In recent decades there has been a constant increase in global populationwhich generates the gigantic challenge of providing food and livelihoods to a population well of greater than 9 billion people by the middle of twenty-first century (FAO, 2018). Fisheries sector plays a key role in providingfoodsafety and employment formany people. Global fish production has touched about 171 million tonnesby 2016 (FAO, 2018) and further increase in fish production through growing aquaculture industry is expected in coming decades. On contrast, of the overall worldwide fish production, almost 75% is only used for human consumption (FAO, 2007).The abandons from the world's fisheries exceed 20 million tons annually(equivalent to 25% of total production) which include "non-target" species, fish processing wastes and by-products. Most of these are simply disposed off in landfills, by incineration, or dumping at sea or lands.Considering the high organic content fish waste is categorized as "certified waste" that is even more costly to dispose. Management of fish waste is coming under increased scrutiny to environmental issues

(Jesperson et al., 2000) and is an emergingalarm and cost burden to whole fish industry (Anon, 2002).Considering the present and future intensity of fish production, the ultimate disposal of fish waste willturn out to be a serious problem for environment. Utilization of fish wastes help to eliminate harmful environmental aspects and improve the income for fish farmers, demanding the criticalnecessity to find ecologically acceptable means for reutilization of these wastes.

The burden of fish waste in India

Fisheries is an important economic activity in India and presently, the country occupies the second position globally in whole fish production with annual production of about 11.41 million tonnesduring 2016-17.Fishery sector funds about 0.9% to National GDP and 5.17% to agriculture GDP (DADF, 2016). Theimpactmight have been much improved if fish wastes and byproducts had been effectively utilized (Jayathilakan et al., 2012). Fish markets and fish processing industries of India generates enormous quantities of discarded fish waste which are presently considered as loss and discarded without recovery of any useful product (Nurdiyana and Mazlina, 2009). It is estimated that India generates >2 metric million tons of waste from fish processing plants only (Mahendrakar, 2000).Among various maritime states, the largest amount of fish wastes were found to be produced from Gujarat (30.51%) followed by Maharashtra (23%) and Kerala (17.5%) (Zynudheen, 2008). As these wastes are rich in nutrients, unless efficientlymanaged, are likely to be dumped in environment making pollution and health related complications (Selvi et al., 2014). Adverse environmental effects associated with fish waste include, accumulations of waste sludge and whole fish parts in near-shore locations, generation of toxic hydrogen sulfide, ammoniaand greenhouse gases such as carbon dioxide and methane (Tchoukanova et al., 2012), increased gathering of scavengers in discharge locations and noxious conditions caused by odours, bacteria and waste decomposition (U.S. Environmental Protection Agency Report, 2010). Similarly, if fish wastes are discarded in ocean itself, aerobic bacteria of water decompose

these organic matter using oxygen so that a considerable reduction of oxygen in water occurs. Apart from the release of toxic gases, the waste also overloads nitrogen, phosphorous and ammonia, leading to pH variation increased turbidity of water resulting in low productivity. Apart from increased phytoplankton production, eutrophication can cause many other effects such aschanges in energy and nutrient fluxes, pelagic and benthic biomass and community structure, fish stocks, sedimentation and nutrient cycling (Fang et al., 2004). Besides, inadequate handling of fish waste can have serious consequences to human health such as contamination of water supply, increasedincidences and spread of many infectiousdiseases, deterioration groundwater and other local ecosystemsetc.

Fish waste management and utilization for by-products

An important waste reduction strategy is the recovery of marketable byproducts and value-added products through bioconversion from fish wastes. The common methods for fish waste utilization include production of organic fertilizers, animal feeds (especially fish, swine and poultry feed) and feed supplements (fish oil, fishmeal, fish silage, calcium supplements), source of biodiesel and biogas, extraction of natural pigments, industrial enzymes (proteases, alkaline phosphatase, hyaluronidase, acetylglucosaminidase and chitinase), cosmetics, pharmaceutical products such as collagen, fish bone extracts, and polyunsaturated fatty acids. Fish protein hydrolysate can be used as a milk replacer and food flavoring agent. Other options includes production of short-chain organic fatty acids, substrates for microbial culture media, production of attractants for economically important flies, production of surgical sutures from fish gutand use of fish scales as natural adsorbents, in ornamental uses and organic wastewater coagulant for sedimentation of small particles, fish glue production from fish skin and heads (Gumisiriza et al., 2009).

Bioconversion into plant fertilizer by composting

High concentration of nitrogen, phosphorus and sulphur in fish waste marks its potential to be used as a plant fertilizer.

However, its sensory characteristics, especially due to odoriferous nitrogen and sulphurcompounds work against this use. Biological management known as composting can be the most cost effective, environment friendly method for bioconversion of fish waste into valuable organic fertilizers (Coker, 2006). Composting is the biological conversion of waste materials, under controlled conditions, into a hygienic, humus rich, relatively biostable product that conditions soils and nourishes plants (Mathur, 1991) Fish wastes have some specific characteristics that could affect the success of a composting operation and if these relevant features are considered during composting process, it may result in a unique composting performance and superior quality organic fertilizer that are different from other waste materials.

General characteristics of fish wastes

Fish frames, guts, heads and fins generally constitute the largest quantity of seafood wastes from finfish. The only difference in shell fish waste from fin fish waste is that it contains large amount of chitin due to the presence of shell residues. Compared to other organic wastes, fish waste contains a large amount of readily digestible protein and release ammonia and H2S during composting process (Selvi et al., 2014). Moreover, release of ammonia and other nitrogen-containing gases will make the process meaningless as the main element contributed by protein i.e. nitrogen, will be lost in the gas. Therefore, conversion of ammonia and sulphur compounds into plant utilizable forms the major target during composting of fish waste. The high salinity of sea food waste and high chitin content due to shell residues of shell fish (Hu et al., 2009) also have to be taken consideration during composting process. Another characteristic of protein rich composting mixtures is that, it tends to have a low C/N ratio. Hence, another main ingredient known as "bulking agent" is required for an adequate carbon to nitrogen ratio (Frederick et al., 1989; Imbeah, 1998). Examples for bulking agents include forestry and wood processing wastes (such as size-reduced or shredded brush, bark, wood chips, sawdust), agricultural wastes, and peat. Rapid release of ammonia from protein degradation of

seafood wastes and of calcium from fish bones, tends to shift the pH of the compost mixture towards the alkaline range. Therefore, if the bulking agent employed has some acidic characteristics, it can contribute to decrease its pH.Another requisite for the bulk agent is water absorbing character, as seafood wastes generally tend to have high moisture contents (Mathur et al., 1986).

Operational parameters in composting process

1. Aeration: Presence of air as a supplier of oxygen is needed for the multiplication and other metabolic activities of many aerobic microbes responsible for bioconversion. An insufficient supply of oxygen will lead to the adoption of anaerobic degradation processes ultimately leading to the release of malodorous gases. Aeration also helps to preserve an adequate moisture level and to control temperature by dissipating the heat generated in degradation reactions. On contrast, excessive aeration result in low temperatures unsuitable for the composting process and, also will dry out the mixture. It is recommended to turn the compost pile weekly during the first two months and every 15 days during the last two months if total composting period is 4 months.

2. Carbon to nitrogen ratio (C: N): To maintain an active microbial population in a composting process, available carbon to nitrogen ratio should be kept at appropriate levels. Lower ratios will result in losses of nitrogenous compounds, Whereas, higher ratios will delay the composting process (Inbar et al., 1991)

3. Moisture level: Hobson and Wheatley (1993) indicated that optimum moisture range for composting operations is 40-60% to 20% oxygen. Water is essential to the viability of microbial populations and is a medium for the bioconversion reactions in compost mixture. While low moisture levels will affect the speed of degradation in compost, flooding of compost site will interfere with the gas exchange required in aerobic processes.

4. Temperature: Influences type of microbial population and bioconversion rates in composting process. It also sanitizes the compost. A temperature of 130-150° F or 54-65° C for three successive days is generally recommended.

5. pH:A pH of 6-8.5 is generally recommended for good composting performance. Release of carbon dioxide and ammonia during degradation of protein rich wastes such as fish waste will impart acidic and alkaline characteristics respectively, which tend to neutralize pH value of compost without the need for external modification (Haug, 1993).

Major processes that occur during composting process of fish waste include

Process	Requirement	Impact
Carbon dioxide production	Appropriate carbon to nitrogen ratio	Able to enhance soil conditions
Heat generation	Appropriate moisture content. Raise in temperature stops when the composting process is finalized	Improve nutrient content. Pasteurize the compost
Microbial degradation of organic matter	Appropriate pH and microbes	Improve nutrient content
Oxidation reactions a. Ammonia oxidation b. Nitrite oxidation c. Suplhur oxidation d. Phosphate solubilization	Solid state and specific microbes	Improve nutrient quality and removes bad odour

A glance on reactions during composting process

Settingup a composting facility: The composting facility should be located a sufficient distance from residential areas to ensure protection from odours (EPA, 1996) and at least 100 metres from surface waters. The compost area must be placed on an impermeable base (such as concrete) that is graded to ensure runoff and leachate drains to a collection tank or pit of sufficient size to prevent overflow.

Minimization of odour: Anaerobic conditions settled within the compost piles are the major reason for odourformation from fish waste composting facilities. Under aerobic conditions, the main gas generated from composting is odourless carbon dioxide, while under anaerobiasis, odorous gases (ammonia, methane and hydrogen sulphide), organic sulphides and volatile fatty acids are produced. Odours can be reduced by includingfish wastes into composting method on the similar day of their production.Together, odour management needspreservation of aerobic conditions by regular turning of compost pile or using any ventilation facilities. Odour can be further minimized by keepingthe appropriate carbon to nitrogen ratio in compost.

Minimization of dust formation: Dust is generallyproduced by the movements of dry materials by machinery, wind, trucks and other equipment which can be effectively managed by light water spraying. Although dust production is improbable due to high water content of compost, its occurrence can be taken as a sign of inadequate moisture in compost.

Assembly of compost windrows: Two simple requirements for composting fish waste are a source of carbon (wood chips, bark, sawdust, leaves etc.) and a source of nitrogen (from fish waste). A simple formula is adding three or two parts carbon to one part of nitrogen. In simpler words, while composting, the fish waste is mixed with plant waste and after complete composting process, a nutrient wealthy fertilizer for soil amendment will be formed. The compost pile may vary in size according to available space; the minimum recommendation for productive degradation is approximately, 10 cubic feet, or 3 feet × 3 feet × 3 feet. For very small volumes of waste, an ordinary compost bin can be used for composting. The base of compost windrow is formed by establishing a 200 mm thick base layer of any source of absorbent material (such as sawdust). Upon this base, alternating layers of fish waste and sawdust are added in a volume ratio of 1:2 of fish waste to sawdust. Such windrows can be up to 3 mwidth and 1.5 mheight. When the full height of the windrow is reached, it may be extended lengthwise. Compost pile must be capped with a 150 mm deep layer of new sawdust or mature compostas the thick outer-covering layer will reduce odours, flies and birds. It is essential that all fish wastes are completely covered with sawdust and kept within the pile. Approximately 2 tonnes of fish waste will create a compost windrow measuring 3 m wide by 10 m long containing four layers of waste.If abundant sawdust is available, using additional sawdust results in compost that is highly absorbent and can be re-used along with new sawdust in subsequent piles. Seasonal effects can influence the relative amounts of fish wastes and sawdust required. In rainy periods, extra sawdust should be added to increase absorbency while slightly less sawdust may be necessary during dry periods.

Compost windrows should be left uncovered to maintain aeration and suitable moisture levels within the pile. Depending on the structure of the pile and the type of materials used, unturned compost will sufficiently mature to spread over pasture or gardens in about one year. Turning the compost windrow three to four times will help maintain an even temperature throughout and will hasten the decomposition process. To reduce the spread of odours downwind from the composting site, avoid turning windrows on windy days. A temperature greater than 55oC should be maintained throughout the windrow for at least three consecutive days to prevent proliferation of pathogens (EPA, 1996).Once the compost was considered mature, it is sieved using a 20- mm mesh screen.

Role of microorganisms in composting

The biological phase of the operationcomprises microbes

involved in various reactions and hydrolytic enzymes present in plant materials and animal tissues. It is the biological phase thatregulates the outcome of whole process. Even though the degrading enzymes present in fish viscera are significant, theycan work only at the beginning of composting process, as enzymes will be inhibited and damaged as biological degradation process. Consequently, microbes remain as the main contributor to the composting method. Therefore, utilization of metabolic versatility of beneficial microbes is valuable in fish waste composting, as the actual number of degraders in natural composting process denotes only 5-10% of whole microbial community (Sayler et al., 1984). Therefore, conventional composting without using competent microbial consortium tends to very tiresome, less efficient and may result in less valuable soil amendment. An easier mode to achieve beneficial microbes is addition of small amount of not totally matured compost from a different composting process.

Microbes for turning fish waste to fertilizer

Microbes play a crucial role by acting as a bridge that connects fish waste to fertilizers. Numerous studies have shown that insufficient quantity or biological activities of the indigenous microbes might lead to undesirable composting proficiency, while strengthening indigenous microbes through application of beneficial microbes can improve the composting process (Wei et al., 2016a; Xi et al., 2015). Microbial consortiathat are essential for transformation of fish waste to fertilizer should include

1. Ammonia oxidizing bacteria
2. Nitrite oxidizing bacteria
3. Sulphur oxidizing bacteria
4. Proteolytic bacteria
5. Chitinolytic bacteria
6. Lipolytic bacteria
7. Phosphate solubilizing bacteria

Altogether, these bacteria degrades the organic matter in fish waste, removes toxic components and transform various components in to accessible plant nutrients. As fishwaste contains huge quantities of ammonia that is toxic to plants, conversion of ammonia to nitrite by ammonia-oxidizing bacteria is an essential step in composting. Further oxidation of nitrite to nitrate, the form of nitrogen mainly assimilated by plants through nitrite oxidizing bacteria is also another essential step. As ammonia oxidation is often the rate-limiting step during composting process, addition of AOB and NOB, as well as providing favorable conditions for the activity of ammonia-oxidizing bacteria can improve the quality of the compost product. Sulphur is now being recognized as the fourth major nutrient for plants in addition to nitrogen, phosphorus and potassium. The action of sulphur oxidizing bacteria in compost results in the formation of sulphate, which can be used by the plants, while the acidity produced by oxidation helps to solubilize plant nutrients and improves alkali soils (Vidyalakshmi et al., 2009). Thus addition of SOB during composting also have the potential to improve the quality of final product as a soil ammendment. Similarly, many bacteria and fungi are able to improve plant growth by solubilizing sparingly soluble inorganic and organic phosphates and these are named as Phosphate-solubilizing bacteria (Delvasto et al., 2006). Therefore, the use of phosphate-solubilizing microbial inoculants in agricultural practice would not only offset the high cost of manufacturing phosphatic fertilizers but would also mobilize insoluble phosphorus in the fertilizers and soils to which they are applied. Additionally, use of microbes that can degrade the organic components of fish waste namely, protein, lipid, chitin and cellulose of bulking materials may be the best option for the efficient conversion of fish waste to a valuable fertilizer in near future.