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Composting of fish waste: A review

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Abstract
The seafood processing plant and capture fisheries produce huge amount of solid waste. The waste from fishes are viscera, offal, skin, scales, shells and other body parts are rich in variety of plant nutritive elements and devoid of hazardous contaminants and pathogens. Disposal of solid waste generated from seafood processing plant has always been a problem for seafood processors. The inappropriate disposal of solid fish wastes may result in environmental problems, such as groundwater and surface water pollution through the leaching due to its high nutritive content. These wastes could be converted into eco-friendly compost through bioconversion process. Composting is a biotechnological process by which different microbial communities acted upon complex organic matter and convert it into simpler nutrients. Composting of fish waste is a relatively new, practical and an environmentally sound alternative to fish waste disposal. It is economical, fairly odourless and a biologically beneficial practice for seafood operations. Composting relies upon an indigenous population of microorganisms from the environment and is carried out with the help of many organic materials. Microorganisms play critical role in the composting process. This article discusses on composting, factor affecting the process and microorganism involved in the composting process.

Keywords: composting, fish waste, microorganism, C/N ratio

1. Introduction

India is one of the global leaders in fish production wherein the quantum of fish export reached 11, 34,948 tonnes in 2015 - 2016 of which roughly 50% i.e., 5, 67,474 tonnes has been left off or disposed as wastes. Fishing generates large quantities of waste daily in fish markets and fish processing industries (canneries, fresh and frozen fish processing plants, etc). Wastes of finfish and shellfish such as viscera, offal, skin, scales, shells and body parts are rich in variety of plant nutritive elements and devoid of hazardous contaminants and pathogens (Mathur, 1993) [54]. The wastes generated through processing of fish, crab and shrimp amount to 30-60%, 75-85% and 40-80% respectively.

Disposing of wastes generated in seafood processing plants has always been a problem for seafood processors. Just like any other industry, the seafood industry also contributes to the production of CO_2 in all the stages of its production, beginning from farming until it reaches the retailer's shelf. Direct disposal of these seafood solid waste leads to environmental pollution owing to its high nutritive content. The inappropriate disposal of organic wastes may result in environmental problems, such as groundwater and surface water pollution via the leaching of nitrates and other pollutants in the manure (Gao *et al*. 2010) [29]. These wastes could be converted into eco-friendly compost through bioconversion process. Capture and culture fisheries too generates a significant amount of waste. It has been estimated that for each tonne of fish eaten, an equal volume of fish material is discarded either as waste or as a low value by-product. Composting converts organic wastes into a product to be used as a soil conditioner and organic fertiliser (Brake, 1992) [11].

Composting is a biotechnological process by which different microbial communities decompose organic matter into simpler nutrients. (Barrena *et al*., 2006) [8]. Fish wastes have also been traditionally used as fertilizer, given their wealth of nutritive elements (principally N and P) and their rapid decomposition. Composting initiatives using fish offal derived mainly from aquaculture have been carried out in various parts of the world in search of alternative and viable techniques for transforming fish waste into useful agricultural products (Lopez-Mosquera, *et al*., 2011) [51]. Composting of fish waste is a relatively new, practical and an environmentally sound alternative to fish waste disposal. It is economical, fairly odourless and a biologically beneficial practice for seafood operations. A commitment to proper management of the compost bins is the key to successful composting. Composting resolves the disposal problem and produces a valuable product, a humus-like material that has several marketable uses from soil conditioner to horticultural growing medium. Composting is an environmentally sound practice and it decreases the potential for surface and groundwater contamination. Composting destroys disease-causing organisms and fly larvae. Compared to other disposal options, composting is not a costly method of fish waste disposal.

Composting relies upon an indigenous population of microorganisms from the environment and is carried out with the help of many organic materials. Microorganisms play critical role in the composting process (Ahmad *et al*., 2007) [3]. Microorganisms such as bacteria, fungi and actinomycetes account for most of the decomposition that takes place in a compost pile. The increasing demand for composts has intensified the search for microorganisms producing high levels of enzyme activity and for improved composting processes.

2. Composting: An overview

Waste management has become a critical area of practice and research due to the increasing concerns of environmental pollution and resources shortage (Brewer, 2001) [13]. The wastes generated through processing of fish, crab and shrimp amount to 30-60%, 75-85% and 40-80% respectively. Waste management is the collection, transportation, processing, treatment, recycling or disposal of waste materials to reduce their adverse effects on human health or amenties. Waste management technique take place in many ways viz., landfill, incineration, pyrolysis and gasification, composting and anaerobic digestion (Adewale *et al*., 2011) [1].

The waste disposal is mainly done by landfills and incineration which leads to release of harmful gas to the environment. But in recent year's interest has grown in disposal methods which take recycling into consideration. The concept of recycling waste nutrients and organic matter back to agricultural land is feasible and desirable. Land application represents a cost effective outlet for the producers of compostable wastes and a potential cheap source of organic matter and fertilizer elements for land owners. The problems are like hundreds of tons of biodegradable organic waste are being generated in cities and towns in the countries and creating disposal problems. Such as every day, grocery stores discard perishable products such as fruits, vegetables, bread, pastries, milk products, fish, seafood and other frozen products can use for composting process (Tweib *et al*., 2012) [82].

According to Otwell (1990) [63], the average processed yield for whole seafood is approximately 50% and half of the catch meant for processing export becomes waste. As such wastes are dumped in the vicinity of seafood processing plants they may pose environmental problems and hence ways and means of utilizing these wastes for productive purposes need to be determined. Solid wastes of finfish and shellfish in seafood processing plants and the sludge generated in the waste water treatment units of these plants could be converted into manure through composting, a bioconversion process. Such manure could find use in back yard agricultural crop cultivation, commercial green houses and in aquaculture operations (Otwell, 1990 & Mathur, 1993) [63, 54].

Composting is a natural process that turns organic material into a dark rich substance called compost which is a wonderful conditioner for soil. During composting process microorganisms such as bacteria and fungi break down complex organic compounds into simpler substances and produce carbon dioxide, water, minerals and stabilized organic matter (compost). The process produces heat, which can destroy pathogens (disease causing microorganisms) and weed seeds (Tweib *et al*., 2012) [82]. Vermicomposting involves bio-oxidation and stabilization of organic material through the interactions between earthworms and microorganisms. Although microorganisms are mainly responsible for the biochemical degradation of organic matter, earthworms play an important role in the process by fragmenting and conditioning the substrate, increasing the surface area for growth of microorganisms, and altering its biological activity (Dominguez and Edwards, 2004) [22].

Composting process is an aerobic biological breakdown of unstable organic matter which results in formation of a more stable end product (compost) (Liang *et al*., 2003) [48]. Insam and de Bertoldi, (2003) describes the four main stages of composting process which include an initial mesophilic, then thermophilic, a second mesophilic and finally maturation (stabilization) phases. During the process, microorganisms use the crude organic matter as a source of food thereby producing heat, carbon dioxide, water vapor and humus (Tiquia, 2005) [79]. This aerobic bio-decomposition self-heating activity results in the reduced volume of 40-50% of the original waste, which becomes safer for use in improving soil fertility and its water holding capacity (Finstein and Morris, 1975; Pare *et al*., 1999) [27, 65]. The compost matrix consists of the organic material, which serves as a source of nutrients for microbial growth, a sink for metabolic products, and a site for gas exchange and insulation of heat (Rodrigues and Lopez-Real, 1999) [70]. The study done by Epstein, (1997) [25] shows that the end product should not contain pathogens or viable seeds to make it suitable for use as a soil amendment. Larney and Blackshow, (2003) [47] found that most bacterial and fungal plant pathogens are destroyed by the heat generated during the thermophilic composting phase. In ideal conditions, this process typically takes about 4 to 6 weeks to reach stabilized products. Complex polymeric matter in the organic waste is hydrolyzed to monomer, such as cellulose to sugars and proteins to peptides or amino acids, by hydrolytic enzymes (lipases, proteases, cellulases, amylases, etc.) secreted by microbes (Verma, 2002) [83].

The composting method of biological wastes suffers from the disadvantage of methane production during the process. Approximately 15% of the total global methane emissions are reported to be from composting (West *et al*., 1998) [86]. Aquatic byproducts/wastes from fish processing plants have been considered of low value and are disposed (Turchini *et al*., 2009) [81]. Composting is one of the best alternatives for the beneficial land use of biosolids and fish offals. Mathur, (1993) [54] evaluated the feasibility of seafood waste composting. Direct use of fish waste for land manuring has been discouraged due to the uniquely obnoxious odour of putrefying fish. Mathur, (1993) [54] evaluated C: N ratio of herring waste and crab and they are 3.30 and 5.34 respectively. As fish waste have narrow C: N ratio and alkaline in nature, they need to mixed with acidic or acidogenic materials with wide C:N ratio (Mathur, 1993) [54]. This problem was mitigated when wood wastes and peat were used in combination with fish waste (Mathur, 1993) [54]. Composting is a biological process that depends on providing an environment favorable for microbiological decomposition. Developing a composting unit is time, labor and cost extensive. But once a composting system has been set up, it will not require much labor.

Liao *et al*. (1995a) [49] studied the full scale in vessel system for composting of fish waste with sawdust as bulking material. The mixing ratios of fish waste with sawdust were calculated to achieve carbon- to-nitrogen ratio (C/N) of 25/1 to 26/1. Liao *et al*. (1995b) [50] used volatile fatty acids (VFA) and ammonia as the major indices of decomposition for the fish-waste composting process. Temperatures remained above 55°C for a period of 8 days, satisfying the regulatory requirement for the destruction of pathogen destruction. At temperatures exceeding 60°C, the process becomes less efficient (Golueke, 1991) [31]. Liao *et al*. (1995a) [50] found that the increase in the pH level during composting resulted from an increase in the volume of ammonia released due to protein degradation. Balachandran, (2000) reported on the various methods of converting fish waste into fertilizer such as acid digestion and solublization of fish waste with urea. However, he also reported that the fertilizer produced through the above methods showed poor balance between components like nitrogen, phosphorous and potassium. According to Mathur, (1993) [54] Passive Aeration Windrow (PAWS) system technology seemed to be the effective method of composting of fish waste in different temperature conditions.

3. Factors affecting the composting process

Composting is a natural aerobic process of biological stabilization of organic waste that achieves both weight and volume reduction and provides the nutrients required for plant growth (Banegas *et al*., 2007) [6]. Composting generates considerable heat, CO_2 and water vapour into the air while organic matter (OM) is converted into a potentially reusable soil amendment (Renkow and Rubin, 1996). The microbial activity is mainly affected by moisture and oxygen; the aerobic composting process produces the compost, water and carbon dioxide (Epstein, 1997) [25].

There are various factors that affect the composting processes and determine the level of biological activities. The main factors are moisture, pH, C/N ratio, oxygen and temperature (Zucconi and de Bertoldi, 1987; Miller 1993; Berthe *et al*., 2007; de Guardia *et al*., 2008) [20, 56, 10, 19].

3.1 Carbon/Nitrogen ratio

C/N ratio is one of the most important parameters that determines the extent of composting and degree of compost maturity. The reduction in C/N ratio is regarded as a main criterion in the maturity of compost. Hence, maintaining the correct C/N ratio is important to obtain good quality compost (Young *et al*., 2005) [88]. According to Golueke, (1992) [32] rapid and entire decomposition of substrates by the microorganisms primarily depends on it initially having a C/N ratio between 25 and 35. Brito *et al*. (2008) [14] observed that the C/N ratio decreased from 36 to a value of 14 towards the end of composting. The ideal finished compost should have a C/N ratio between 15:1 and 25:1 (Naylor, 1993) [60]. Carbon serves primarily as an energy source for the microorganisms, while a small fraction of the carbon is incorporated in the microbial cells. Nitrogen is critical for microbial population growth (Gajalakshmi and Abbasi, 2008) [28]. If nitrogen is a limiting factor, microbial populations will remain small and decomposition rates for available carbon will be lower. Excess nitrogen is lost from the system as ammonia gas (de Guardia *et al*., 2008) [19]. Sangeeth and Padmaja, (2008) [73] obtained drastic reduction in C/N ratio from 43:1 to 16:1 in Effective Microorganism inoculated solid waste after 60 days of decomposition. Sengar *et al*. (2009) [74] found that C/N ratio of *Paecilomyces variotti* and *Chaetomium globosum* inoculated bagasse sample narrowed down from 49:1 to 17:1 after 60 days of decomposition. Kumar *et al*. (2010) [45] maintained the initial C/N ratio is 19.6 in Co-composting of green waste and food waste. Guo *et al*., (2012) [36] recommended the C/N ratio of 18 for the best composting process.

3.2 Moisture content

The moisture content of compost mixture at the starting of composting is an important factor influencing the composting process (Epstein, 1997) [25]. Depending on the type of composting material, the moisture content varies from 50 to 85% (Zucconi and de Bertoldi, 1987) [20]. According to Haug, (1980) [37], composting was possible for mixtures of vegetable trimmings at initial maximum moisture contents as high as 85% when using straw as a bulking agent, and 76% when using paper as bulking material. According to Pace *et al*. (1995) [64], the composting mixtures should be maintained within a range of 40% to 65% moisture and preferably 50- 60%. A moisture level below 45% is considered as limiting factor and under 20%, no biological processes are possible (Day and Shaw, 2001) [18]. According to Gajalakshmi and Abbasi, (2008) [28], moisture content was indispensable for the decomposition process, because in the decomposition process which takes place in the thin liquid layers on the surfaces of particles, moisture essentially affects microbial activities. Adhikari *et al*. (2009) [2], successfully composted organic waste with initial moisture of 80%. The importance of water was not only that, it was a necessary medium for metabolic reactions for microorganisms and the transportation of nutrients, but also established the necessary connection between microbial cells and contaminants as well. When moisture content was low, it led to dehydration of microbes. Therefore, the metabolic and physiological activities of microbes were defined by moisture content. In the study Kumar *et al*. (2010) [45] maintained the 60% initial moisture content and at the end of the study the moisture level decreases to 35%. Guo *et al*. (2012) [36] recommended 65-70 % of moisture content is efficient for composting process.

3.3 Temperature

Temperature is generally a good indicator of the biological activity (Epstein, 1997) [25]. The temperature change during the composting has a profound effect on the efficiency of the composting process. The temperature within a composting mass determines the rate at which many of the biological processes take place and plays a selective role on the evolution and the succession of the microbiological communities (Mustin, 1987) [58]. The composting stages are defined by various temperature ranges evolved during the process. According to Diaz *et al*. (2007) [87], composting stages are categorized by four-temperature ranges namely mesophilic; thermophilic; cooling (second mesophilic stage) and maturation stages. Smith and Jasim, (2009) [75] reported that home composting of organic waste takes place within three temperature ranges known as psychrophilic (0 to 20°C), mesophilic (20 to 40°C) and thermophilic (over 45°C). Although mesophilic temperatures allow effective composting Pace *et al*. (1995) [64] suggested to maintain thermophilic condition for few days, because they destroy pathogens, weed seeds and fly larvae. Adhikari *et al*. (2009) [2] reported that thermophilic temperatures above 45°C should be reached within a few days. Temperatures above 60-65°C may kill microorganisms that are more sensitive and the decomposition process may be slowed. Zucconi and de Bertoldi, (1987) [20] suggested that continuous high temperature of 55-60°C, lasting beyond 5 to 6 weeks, indicates an abnormally prolonged decomposition and a delayed transition to the maturation stage. The study by Nolan *et al*. (2011) [62] showed that temperatures above 60°C were achieved by Day 2, followed by a thermophilic phase (50–60º C), which lasted for 1 to 2 weeks followed by a cooling phase.

3.4 pH

pH also significantly affects the composting process (Sundberg and Jönsson, 2008). pH generally gives an approximate index of compost maturation (Dick and McCoy, 1993) [21]. Changes in pH have been found to occur during the composting period and therefore considered as a possible indicator of biological activity. The pH of initial compost mixture varying from 5 to 6.5 can be composted (Day and Shaw, 2001) [18] due to the natural buffering capacity of the composting material (Willson, 1993) [87]. Zorpas *et al*. (2003) reported that the range of pH values suitable for bacterial development is 6.0-7.5; while fungi prefer an environment in the range of pH 5.5-8.0. Hughes, (1980) [41] reported that the pH level drops below 5 at the beginning of the composting process because of the acids formed by the acid-forming bacteria, which initialize the process by breaking down complex carbonaceous materials. The later break down of proteins and liberation of ammonia account for the subsequent rise in pH (Zucconi and de Bertoldi, 1986). According to Pace *et al*. (1995) [64] the preferred range of pH is 6.5 to 8.0. The finished compost may have pH above 7, between 7 and 8.5 (Day and Shaw, 2001) [18]. Gebeyehu and kibert, (2013) [30] the pH value at the early stage of composting was below 5.0 this due to release of ammonia by proteolytic process and pH continued to increase to 7.6 at the end of process.

3.5 Aeration/ Oxygen concentration

One of the main parameter to be controlled in the composting process is aeration. If the aeration rate is insufficient, oxygen will decrease and lack of oxygen during composting results in anaerobic conditions; on the other hand, if the aeration rate is too high, the compost pile cools and lowers the composting rate (Rasapoor *et al*., 2009) [66]. Continued metabolism of microorganism depends on aeration. Average oxygen concentration inside the compost mix is 15 to 20%, while CO_2 is 0.5 to 5%. As a result, malodorous fatty acid sand methane levels may increase (Druilhe *et al*., 2002) [24]. Because oxygen consumption is a function of microbial activity, oxygen levels are also related to substrate temperatures. Oxygen demand is very high during the initial decomposition stage, because of the rapidly expanding demand is very high during the initial decomposition stage, because of the rapidly expanding microbial population and the high rate of biochemical activity. After this initial high level of activity that generally lasts for one to two weeks, oxygen demand decreases (Zucconi and de Bertoldi, 1987) [20].

Nickolas and Young, (2002) [61] proposed the rate of aeration in the composting is 0.06 to 0.4 L (min)-1 (kg of waste)-1. Rasapoor *et al*. (2009) [66] also suggested that the aeration rate of 0.6 L (min)-1 (kg of waste)-1 during first 2 months of the process and continuing at a rate of 0.4 L (min)-1 (kg of waste)-1 until the end of composting for effective decomposition. The natural aeration provided from the holes at the bottom and top of composting bin produces better results for home composting of organic waste compared to the bins without top and bottom perforations (Karnchanawong and Suriyanon, 2011). Guo *et al*. (2012) [36] recommended the aeration rate of 0.48 L kg^{-}1 DM min^{-}1for the efficient composting.

4. Role of microorganism in the composting process

Composting involves a group of microorganisms that are active during mesophilic and thermophilic stages of composting. Macdonald and Griffin, (1981) [52] noted that the composting process is brought about by several organisms such as bacteria, fungi, actinomycetes and protozoa and may also involve invertebrates such as nematodes, earthworms, mites and various other organisms. Bacteria are the dominant population in the entire composting process and they play most important roles especially at the peak during thermophilic stage (Rebollido *et al*., 2008) [67].

Gray and Biddlestone, (1981) [34] identified four main categories;

- Mesophilic: Microbiological breakdown commences and heat is generated; temperatures increase; organic acids are produced and pH falls.
- Thermophilic: Thermophilic organisms, primarily actinomycetes and spore forming bacteria take over the breakdown process. High temperatures neutralise pathogenic organisms and weed contaminants. Ammonia is liberated from proteins and pH rises.
- Cooling: The temperature falls as the reaction rate drops, Mesophilic organisms reinvade, polymers breakdown.
- Maturing: After the initial stages, there follows a long period where the compost matures, microorganisms deplete the readily available nutrients, antibiotics and humic acids are formed.

Gray *et al*. (1971) [35] reported that different microbial communities predominate during the various composting phases, each of which being adapted to a particular environment. Hudson, (1986) [40] described succession in the aerobic process, noting that the composition of active microflora of composting wastes normally shifts from predominant mesophile in the early stages of thermogenesis to thermophiles at the peak of the heating cycle.

Highest microbial diversity is found in the initial mesophilic stage. Communities are dominated by fungi and gram-negative bacteria in the initial mesophilic stage. These are replaced by gram-positive bacteria and actinomycetes in the thermophilic stage (Cahyani *et al*., 2002) [15]. Sundh and Ronn, (2002) [78] reported that actinomycetes found after the initial thermophilic stage. Actinomycetes persist into the curing stage alongside re-colonisation by gram negative.

Ryckeboer *et al*. (2003a) [71] found few mesophilic fungi in source-separated household waste, but numerous thermophilic fungi and bacteria. Mesophilic and/or thermotolerant fungi and bacteria are the dominant active degraders at the initial stage of composting process (20-40 °C).

Gray *et al*. (1971) [35] reported that microorganisms rapidly break down soluble and easily degradable carbon sources, resulting in a pH drop due to organic acids. The high surface/volume ratio of bacteria allows a rapid transfer of soluble substrates into the cell. Bacteria are responsible for most of the initial decomposition and heat generation in compost. Golueke, (1992) [32] reported that the optimal moisture content for bacteria ranges from 50 to 60% and they favour a near-neutral pH. Actinomycetes develop more slowly than most bacteria and fungi and are rather ineffective competitors when nutrient levels are high (Lacey, 1973).

According to Cooney and Emerson, (1964) thermophilic microorganisms require a maximum temperature for growth at or above 50^0 C and a minimum temperature for growth at or above 20^0C. Wali *et al*. (1979), reported that there is a higher rate of breakdown of soluble proteins in thermophilic fungi as compared to that of mesophiles.

Ishii *et al*. (2000) analyzed the microbes present in the compost using Density Gradient Gel Electrophoresis (DGGE) of the 16s subunits of rRNA and reported 87% of the microorganisms in the thermophilic phase of composting were identified as belonging to the genus Bacillus. Nakasaki *et al.* (2005) [59] observed the changes in the 16s rDNA restriction fragment length polymorphism (RFLP) patterns in a compost held at 60^o C for 14 days. Ryckeboer *et al.* (2003a) [71] found that the genus Bacillus was most prevalent throughout the composting of vegetable, fruit, and garden wastes, especially in the thermophilic phase. Steger *et al*. (2005) reported that when composting organic household waste and wheat straw under aerobic conditions (16% oxygen), the increased temperature in the compost was attributed to a thermophilic bacterial community comprised of members of the genera Bacillus and Thermus. This determination was made as the two genera have similar fatty acid compositions. Ishii *et al*. (2000) [43] and Ryckeboer *et al*. (2003b) [72] reported that microbial diversity increases after the thermophilic phase to include members of the Bacillus sp., various Gram-positive and Gram-negative organisms, and fungal species.

Thermal inactivation of pathogens is required to obtain safe products, both in terms of phytohygiene and human diseases. Generally, higher the temperature, the more efficient will be the destruction of pathogens (Ryckeboer *et al*., 2003a) [71]. Millner *et al*. (1987) [57] also reported that *Salmonella spp*. was suppressed more efficiently in composts produced at 55 °C.

Crawford, (1983) suggested that the ability of fungi to degrade cellulose and lignin is higher than that of actinomycetes, and bacteria. Temperature is one of the most important factors affecting fungal growth. The majority of fungi is mesophilic (5 °C to 37 °C), with an optimum temperature of 25-30 °C. Thermophilic fungi are generally less tolerant to high temperatures than actinomycetes. The optimal temperature for thermophilic fungi is 40 to 55 °C, with a maximum at 60 to 62 °C. Ryckeboer *et al*. (2003b) [72] reported that at temperatures above 60 °C, fungi are killed or transiently present as spores. Yeasts disappear during the thermophilic phase of composting, but when the temperature cools down to 54 °C, they can be found again (Ryckeboer *et al*., 2003b) [72]. A few Basidiomycota grow well at elevated temperatures, for example the white-rot fungus *Phanerochaete chrysosporium* (an amorph *Sporotrichum pulverulentum*) which has an optimum temperature around 36 to 40 °C and a maximum temperature of 46 to 49 °C (Tuomela *et al*., 2000) [80].

Once the activity of the thermophilic organisms ceases due to exhaustion of substrates, the temperature starts to decrease (cooling or second mesophilic phase). Mesophilic organisms start to re-colonise the substrate, either originating from surviving spores or from external inoculation. Herrmann and Shann, (1997) [38] reported that high numbers of diverse mesophilic and thermo tolerant actinomycetes and yeasts reappear. Ryckeboer *et al*. (2003a) [71] reported that the decline in temperature, the lower water content and their ability to attack and/or degrade natural complex polymers (e.g. cellulose, hemicellulose, lignocellulose, and lignin) also favour mesophilic and thermo tolerant fungi during the cooling phase.

Hoitink and Boehm, (1999) [39] that a high percentage of lignin, lignocellulose and other components during maturation phase the compost from tree bark, yard wastes, agricultural wastes composting. Most of the fungi, predominant cellulose and lignin degraders, are isolated during the maturation phase (Von Klopotek, 1962) [84]. It was reported that bacteria related to the genus *Arthrobacter* form a numerically important fraction of the natural bacterial flora of soils and their presence and numbers in mature composts could be used as an additional microbiological parameter in evaluating the maturity of the compost.

Some of the prokaryotes reported in mesophilic and thermophilic stages during the composting process were *Actinomyces* sp. (Golueke, 1977) [33], *Flavobacterium* sp.(Fermor *et al*., 1979) [26], *Thermoactinomyces* sp. (Amner *et al.*, 1988), *Acidovorax facilis* (Mergaert *et al*. 1994) [35], *Acinetobacter* sp. (Droffner *et al*., 1995), *Arthrobacter* sp. (Beffa *et al*., 1996) [9], *Pseudomonas* sp.(Mannix *et al*., 2001) [35], *Azotobacter* sp., *Cellulomonas* sp., *Nitrobacter* sp. & *Nitrosomonas* sp.(Rocha *et al*., 2002) [69], *Bacillus cereus, Bacillus subtilis & Bacillus thuringiensis* (Ryckeboer *et al*., 2003b) [72].

Some of the fungi reported in mesophilic and thermophilic stages during the composting process were *Botryosporium* sp. (Golueke, 1977) [33], *Trichurus spiralis (*Breitenbach, 1998), *Aspergillus fumigatus, A. niger, A. versicolor, Chrysosporium indicum, Fusarium* sp, *Trichoderma viride* (Anastasi *et al*., 2002) [5], *Chaetomium* sp. (Rocha *et al*., 2002) [69], *Mucor* sp, *Trichothecium* sp. and *Verticillium* sp. *(*Ryckeboer *et al*., 2003b) [72].

5. Conclusion

Solid waste of fish from seafood processing plant contain high amount of organic load. Those waste can be converted eco-friendly compost by bioconversion process. This compost is rich in nutrient, environment friendly and toxic free. It can be used as organic fertilizer instead of chemical fertilizers. During the composting process use of microorganism which will helpful in quicken the composting process.

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