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Recycled fish processing waste for welfare of aquaculture industry: A review

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Abstract

Fish processing waste could be regarded as processing the renewable biomass resource for bio-refinery. Hydrolysis of fish waste through natural cold fermentation is aimed primarily at industrial application. Fish hydrolysate generally shows a beneficial effect on growth performances and feed utilization at low inclusion levels. The performance is postulated to be due to balance of free amino acids, fatty acids, macro and micro nutrients which are digested, absorbed and utilized. Wet fish waste is acidified with molasses, fermentation causes hydrolysis of fish waste is called “Fish Hydrolysate”.

Keywords: fish hydrolysate, bio-refinery

Preamble

Turning fish processing waste into commercial organic feed and fertilizer products is a novel proposition.

Disposal and reuse of fish processing waste has long been a challenge for fish processing industry.

Million tonnes of waste from fish processing plants, fish markets are generated annually.

“Fish waste to Wealth” is a visible solution to handle fish processing waste and convert them to self-stable organic fertilizer and feed supplements. Multiple all natural liquid fish formulations have been developed resulting in Planktofert, Bio-fert and shelfi-fert from fish processing waste for conventional crop, horticulture, vegetable, aquaponics, hydroponics, aquaculture, animal and fish feed materials have been developed.

Introduction

Consumer demand for fish and fishery products are increasing considerably. This has been caused due to health concerns and the perception of fish as healthy food with high levels of digestible protein, PUFA and cholesterol lowering capabilities.

Million tonnes of fish waste is produced daily from fish processing and retailing and ending up as little more than land fill.

Disposal of wastes by fish processing industry produces large quantities of fish waste and fish offals so also the prawn processing wastes. If everybody wants and strives to use 100 percent of the resources so so there is no waste (Arvanitoyannis and Kassaveti, 2008) [3].

Fish intestine, gills, muscles, fat and prawn processing wastes contains mixed cultures of beneficial and natural occurring micro-organisms and enzymes that are used in many systems pertaining to sustainable practices in agriculture, aquaculture and environmental management (Rai *d*., 2010) [2].

Effective microorganisms comprise mixture of beneficial, naturally occurring micro-organisms in fish used as inoculants to soil, waste, fish, plant and animal eco-system for increasing the microbial diversity of plants and animals for improving quality, health and for enhancing the growth, yield and quality of the “ecosystem”.

“Planktofert” and “Shelfifert” natural liquid fish fertilizer or fish hydrolysate is a balanced nutrient and bio-stimulant containing over 40 trace minerals and elements. The underutilized fish processing waste forms an excellent resources material for production or value added organic fertilizer and bio supplements. These waste material would not only eliminate all environmental concerns of waste disposal but also improves the overall economics of commercial aquaculture in a sustainable manner (Berge, 2007) [1].

Currently a resurgence of interests in the use of natural bio-active product (nutriceutical) for plant and animal welfare is in increase. The beneficial chemical composition of the product is that, it maintains the integrity of naturally occurring amino acids, fatty acids, vitamins, hormones and enzymes in the final product.

Self-stable hydrolysates can be prepared at ambient temperature Fermaintation with equal quantity of molasses. 5-7 days are necessary before pH drop becomes significant with desirable flora like lacto bacillus bacteria (LAB) and to the conditions of fish molasses mixture, in particular this high soluble carbo hydrate (Sucrose) in molasses. Relatively high ratio of molasses in the starting plays a beneficial role via the osmotic pressure. Effect in inhibiting the growth of some spoilage bacteria (Sahu, *et al.*, 2014) [20].

Addition of carbon compounds to shrimp and fish pond waste stimulate ammonia uptake by heterotrophic bacteria (Samocha *et al*., 2007 and Janeo *et al*., 2009) [24, 27] and provide single cell source of protein (Avnimelech *et al*., 1989).

Molasses play an important role in shrimp, prawn and fish farming, since it has been widely used as carbon source for denitrification, anaerobic fermentation and aerobic waste conversion. Molasses are reported to reduce environmental ammonia concentration, stimulate plankton production. 1.25 g/cum molasses per week organic fertilization induced highest survival and production levels. Lower total ammonia-N concentration, increased nitrogen level and increased phyto plankton abundance (Esparza-Leal *et al*., 2016) [23]

Proteins and Amino acids in Fish Hydrolysate

The fish protein hydrolysate contains 75-80% protein constituents (60% peptides and 40% amino acids). The major amino acid constituents of this product are glutamine (14-16% of total), asparagines (10%) and lysine (10%). The combined contribution of branched Chain amino acids (Lysine, Leucine and Isoleusine) is comprised of 23%. Increase in non-protein nitrogen (NPN) during fermentation indicate protein breakdown leading to release of amino acids and other metabolites originating from proteins (Himonides *et al*., 2011) [5].

Natural fermentation process of fishery waste results in continuous removal of trimethylamine produced by production of gas by yeast culture or to a delay in fermentation of trimethylamine by creating conditions in the product unfavorable for microorganisms involved in transforming the protein in such compounds (Clausen *et al*., 1985) [4].

Fish hydrolysate is bio-chemically a concentrated mixture of various amino acids, oligo peptides, neucleosides and their respective bases, short chain organic acids, aldehydes and easters together with vitamins and minerals. (Chalamaiah *et al*., 2012). Enzymatic hydrolysis of fish frames utilizing papain in a pilot scale plant produced fish protein hydrolysate. Amino acid profile of fish protein hydrolysate was identical to that of parent substrates (fish frames) (Himonides *et al*., 2011) [5].

Fish by-products contains the same valuable protein as the fish muscle. Recovery and alteration of protein present in the fish by-product is a feasible alternative. By using fermentation and enzyme technology, it may be possible to produce a broad spectrum of food, feed and fertilizer ingredients for wide range of applications. (Rustad *et al*., 2011) [6, 16].

Fish processing plants, its surrounding area and fish retailing witness serious pollution issues. High nutritional value of fishery waste generated can be converted into a gold mine of organic nutrients and fertilizer by low cost and ecofriendly manner for promotion of organic farming which is an excellent source of plant nutrition, animal feeding and fish feed. Foliar fertilizer formulations used as foliar spray showed excellent results in agri-horti-vegetable farming.

Fermentation technique for utilization of fish and prawn processing waste

Traditional fermentation depends upon naturally occurring micro-organism and enzymes. Spontaneous fermentation is optional through back slopping i.e. inoculation of raw material with a small quantity of previously performed successful fermentation. Spontaneous fermentation and back slopping is a cheap and reliable preservation method. Probably this is one of the oldest biotechnological process rooted in cultural history of mankind (Hassan and Health, 1986) [35].

Fish hydrolysates as a source of micro nutrients and trace minerals

Micronutrients are very important for facilitating many critical plant and animal functions. Most critical of these micronutrients are Boron (B), Zinc (Z), Manganese (Mn), Copper (Cu), Cobalt (Co), Molybdenum (Mo) and Sulphur(S). Many trace minerals have proven to be critical in enabling animal and plant cells to produce complete compounds for making them naturally resistant to pests, diseases and better yield and productivity. High amount of iron (Haem-iron) present in liquid fish hydrolysate is essential for increasing and stabilizing chlorophyll production.

Liquid fish hydrolysate contain chilated minerals which are easily absorbed into cell membranes and result in increased metabolism. Negative charges on the proteins are responsible for attracting positive minerals, thus this setting up phenomenon is known as "chelation". Organic compounds bind to metallic ions to form a stable, water soluble complex minerals in food, feed and fertilizer. Liquid fish fertilizer helps in phosphate fixation. Food, feed and fertilizer containing high concentration of aluminium, copper, iron combine with phosphates and prevent cells from utilizing either phosphates or minerals. Chelation prevents fixation and makes both mineral and phosphates available for fish, animal and crop productivity.

Fish hydrolysate as feed additive are added in trace amounts to the diet or feed ingredients to promote its nutritional characteristics, anti-oxidant and mold inhibition. Facilitates feed ingestion (feeding stimulant) and food colourant.

High value elements in prawn waste hydrolysate (Shelfifert)

The amount of prawn processing waste can be upto 65% of initial shrimp weight and it constitutes an environmental problem in disposal. The Chitin content percentage (C%) of prawn waste dry basis varies from 14 to 30%. The percentage of weight or protein and mineral salts can be upto 40% and 35% respectively (Sachindra *et al*., 2005) [7].

Shrimp processing waste is an important source of bioactive molecules, which is a natural source of carotenoids, particularly that of astaxanthine and its esters. Use of strong acid and alkali in bioconversion of fish and prawn waste is ecologically aggressive and a source of pollution. The process also renders the protein component useless for making feed material.

Spontaneous fermentation of fish waste with molassess inherent Enzymes and Microbes

Spontaneous fermentation with previously performed inoculums, sugar (molasses) and yeast ensures rapid acidification for converting fishery waste into industrial products. Molasses assist in fermentation process, ensures rapid acidification and inhibits unwanted microorganism, as well as is relatively in expensive and acceptable to animals (Arbia *et al*., 2013) [8]. Fish intestine, gills, muscle, fat and other miscellaneous fish waste contain mixed cultures of beneficial and naturally occurring microorganism used as inoculants to soil, water plant eco-system for increasing the microbial diversity of soil and for soil quality, soil health for enhancing growth, yield and quality of crops, fodder, food animals finally the welfare of the human being in a ecofiendly and sustaianable manner.

Chitin and Chitosan

Chitin and Chitosan in deacetylated form are applied in water treatment, dietary supplement and agriculture (2hao *et al*, 2010). Bioconversion of shrimp shell and head waste for bio-fungicide production (Wang *et al*., 2011) [13]. Purified chitinase inhibited fungal hyphal extension. Liquid waste from chitin production process could be a feed stock for anti-fungal material.

Shrimp shell hydrolysates are a excellent sources of Chito-ligo saccharides. The mixture of chitoligo saccharides have high antioxidant activity and have anti-tumor activity. There is a growing interest to convert chitin and chitosan into their oligomers that have better functional properties and improved absorption through human and animal digestive tract. Enzymatic hydrolysis is more preferable for the preparation of oligomers, since this method results greater yield of Oligomers with higher degree of polymerization.

Chitin and Chitinase in Therapeutics

Chitinase play an important role in regulating shrimp molting immunity and stress response, chitinase plays important physiological roles in crustaceans, including degradation of chitinous cuticle and digestion of chitin containing food and defence against viral pathogen.

High expression level of chi-4s were detected in hepato-pancreas which are the main tissue involved in the immune response, and the major site for synthesis of immune defence molecules involved in eliminating pathogen or particular waste in crustaceans. (Zhou *et al*., 2017) [18].

Fish scales under cold hydrolysis produce hydroxyl apatite which can be converted into scaffolds used in various dental and orthopedic surgical applications and drug delivery. Application of fermentation technique in utilization of prawn shell waste in production of chitin glucosamine, carboxy methyl Chitin (Sini *et al*., 2005; Santosh and Mathew, 2009) [29].

Chitin and its derivatives have potential application in agriculture for various use such as in germination and growth providers and germination, self-protection against pathogenic organisms in plants and suppress them in soil to induce chitinase activity in encapsules of fertilizer. They induce chitinase activity and proteinase inhibitor synthesis for antivirus activity and antibacterial activity of chitosan against Aeromonas hydrophila (Tah and Swailam (2002).

Chintin and chitosan showed suppression of swelling and lysis of hyphce. Chitinase produced by Bacillus Cereus with shrimp and crab shell powder have good antifungal properties.

A sea of Antioxidative Properties

Chintin and chitosan peptides have antioxidative and anticarcinogenic properties. Shrimp shell waste are rich source of phenolic compounds which play an important role in antioxidative, antimicrobial, anti-inflammatory and vasodilaliry properties. Bio-control of opportunistic, fungal human/animal pathogens.

Shrimp shell hydrolysate are rich in compounds with amino groups to enhance its antioxidant properties. It is expected that this bioactive material rich liquor have beneficial biological functions owing to inherent protein, chitin hydrolysis, astaxanthine, anti-fungal agent and other bio-active material produced during fermentation (Wang *et al*., 2005).

Fish processing waste as Bioremediation agent

Chitin and Chitosan derivatives have shown good potential for removal of various aquatic pollutants. Treatment of water and waste water utilizing Chitin and Chitosan derivative have shown good potential for removal of various aquatic pollutants. Chitin and Chitosan derivatives are used for removal of metal cat ions, metal an ions, radio neuclides, dyes, phenol substituted protein an ions and miscellaneous pollutants (Bhatnagar and Silanpaa, 2009).

Nutriceuticals and flarouring agent

Leucine is an essential amino acid detected in shrimp head hydrolysates are good for animal feeding. Glutamic acid and Aspartic acid, Alanine and Glycine are known to be flavor enhancer in shrimp heap hudrolysates (Randriama hatody *et al*., 2011) [10].

Prawn waste Recycled Products as fish feed

The development of aquculture hampered by inadequate supply of feed stuff particularly fish meal which is scarce and expensive.

Lime treatment of shrimp head waste produced a highly digestible animal feed (Coward-kelly *et al*., 2006) [11]. Fish waste and shrimp head silage have been reported to be dietary source for Nile tilapia (Srour, 2009) [12].

Shrimp shell hydrolysate are rich in compounds with amino groups to enhance in antioxidant properties in powdered and extruded animal and fish feed. It is expected that this bioactive material rich liquor (Planktofert and Shelfie fort) have beneficial biological function and product keeping quality owing to inherent protein, chitin hydrolysis astaxanthin, antifungal agent and other bioactive material product during fermentation (Wang *et al*., 2011) [13].

Fish hydrolysate generally show a beneficial effect on growth performance and feed utilization at low inclusion levels. The performance is postulated to be due to the balance of free amino acids, peptides and proteins to digestion, absorption and utilization. Satidi *et al*., 1995 confirmed that amino acid profile of protein hydrolysate are generally similar to the raw material except for the sensitive amino acids, such as methionine and tryptophan. Fish byproduct contain the same valuable protein as the fish muscle. Recovery and alteration of protein may be possible to produce a broad spectrum of food, feed and fertilizer ingredient for wide range of application (Rustad *et al*., 2011) [6, 16].

Fish and Prawn hydrolysate for plankton production in aquaculture ponds

Organic fertilizers like cow dung, poultry manure, oil cakes are often used to promote desirable phytoplankton and zooplankton in aquaculture ponds. Basal application of cow dung 10,000 kg/ha in grow out ponds and 1,000 kg/ha in nursery ponds for aquatic macrophyte production (Olah *et al*., 1986) [31].

Cattle manure and poultry droppings upon addition to fish ponds start decomposition and reduction of dissolved oxygen in fish ponds and responsible for mass mortality of aquatic organisms, produces unpleasant smell and causes mortality of fish and aquatic organism (Begum *et al*., 2012) [30].

The highest chlorophyll II and Plankton composition (Phytoplankton and zooplankton) was observed in 0.25m/L fish hydrolysate treatment and lowest value was revoked the control. Fish hydrolysate as successive organic fertilizer at above concentration as successful organic manure is an ecofriendly product for aquaculturepractices. The dose has been calculated total 20L/Acre m water body in four split doses with 15 day interval for aquaculture practices (Sahu *et al*., 2016) [21, 34, 41, 42].

Around 3 groups of phytoplankton belonging to Chlorophyceal (9), Bacillariophyceal (8) Cyanophyceal (7) and zooplankton (7) were abundantly identified. Fish hydrolysate (planktofert) treatment0.25ml/L enhances the phytoplankton and zooplankton productionin aquaculture ponds for fish food production so it has been recommended for application in aquaculture ponds as organic fertilizer for zooplankton, phytoplankton and fish food organism production.

Fish hydrolysate (planktofert) at 0.25 ml/L application to pond water increased Chlorophyll II concentration ranging 0.37 to 2.67 g/L and a gradual incease was noticed between 0.28 days (Sipabua-Tavares *et al*., 2001).

The underutilized fish processing waste cost effectively transformed into fish hydrolysate using a natural fermentation process. Their value has been increased by using them as bio-organic manure, liquid organic fertilizer, feed additive and supplement and as a feed binder during feed technology. The nutritive content is reported to be nitrogen(2.95), phosphorus(1.98%), potassium(0.65%), Sulphur(1.52%), Boron(10.4 ppm), Calcium (2.24%), Magnesium(1.75%) (Sahu *et al*., 2014) [20].

Plankton and fish food organisms require both macronutrients and micronutrients for growth and optimum production. Fish hydrolysate (Planktofert) is a liquid organic fertilizer contains all the required nutrients in a natural proportions. Micronutrients, macronutrients in optimum fertilization rate is cost effective ecofriendly and utilized in a pond ecosystem without any harmful effect on water quality and fish growth (Boyd, 1979; Sahu *et al*., 2016) [33, 21, 34, 41, 42].

A significant amount of Haem-iron present in fish hydrolysate is an essential element for growth of phytoplankton and primary productivity in aquaculture ponds in both freshwater and marine ecosystem (Naito *et al*., 2006) [36].

Fish hydrolysate contain both macro and micronutrients in a balanced form. It contain copper, magnesium, iron and zinc as micronutrients and N:P:K::1.5:0.5:0.4 as macronutrients (Davies *et al*., 2006; Sahu *et al*., 2014) [37, 20].

Can fish hydrolysate replace fish meal

Fish meal is the major ingredient and primary source of protein in most poultry and fish diets. However, increase cost of fishmeal in market and unavailability of quality fish meal, are forcing the farmers and animal feed entrepreneurs to replace the fish meal with other animal and plant sources like soybeanbone meal, blood meal or other marine products (Soren Sen *et al*., 2009) [38]. However such alternate ingredients are often devoid or contain very low concentration of taurine compared to fish meal (El-Sayed, 2013) [39]. It has been reported that taurine play an important role in production and reproduction behavior of animal, fish and birds (Gaylord *et al*., 2014) [40].

Fish hydrolysate (Bind-add$^+$) belongs to binder and additive of protein origin and carbodydrate source. Fish hydrolysate contain well balanced protein, fatty acids, amino acids, macro and micro nutrients (Sahu *et al*., 2017) [14, 22].

Molasses based fish hydrolysate have been developed into a binder cum additive for extrusion processing. Bind-add has been replaced from the total amount of water required for extrusion cooking. Extruded pellets (Ciflysate forte) have desired streangth, resistant to mechanical strength during transportation, texture and strength to facilitate high feed utilization, less dust and broken particles. The floating pellets so developed desired water stability, bulk density to control sinking velocity and buoyancy. The binder cum additive developed have served multiple purposes as nutrient rich, plasticizer and binder (Sahu *et al*., 2017) [14, 22].

Taurine content in fish hydrolysate makes it indispensible. The role of taurine in fish embryonic and larval development. Dietary taurine supplementation increases buoyancy, fertilization and hatching rate of brood fish. FH (Bind-add+) supplement makes it an ideal feed for the brood fish rearing. FH is ecofriendly and advantageous from environmental and economic point of view.

Pigments, Xanthine and Carotenoids:

Prawn processing by products contains some value added nutrients for the aquaculture and feed industry such as carotenoid pigments commonly astaxanthine and n-3 poly unsaturated fatty acids. Shrimp carotenoid increase the resistance of common carp fingerlings to ammonia induced stresses. Carotenoids would find use as pigment source in feed for ornamental fish, salmon and prawn culture. Invitoo antioxidant activity of liquor from fermented shrimp biowaste reveals the antioxidant activity (Babu *et al*., 2008). Carotenoids are prone to degradation by acids, mild treatment may have beneficial effect on stability of carotenoids.

Fish waste bio-refinery products: Its application in organic agriculture and aquaculture

Bio-refinery of fish waste material can be converted into bio-fuels, bio-chemicals, animal and fish food, human food, neutraceuticals and organic fertilizer. Hydrolysate production through cold, natural fermentation is low cost, simplicity at operation, reduced cost of material less energy and labour consumption process. Fish hydrolysate application generally shows beneficial effect on growth performance and feed utilization at low inclusion levels. The excellent performance of the pond is due to balance of free amino acids, peptides, protein micro and macronutrients, minerals, trace minerals in digestion, absorption and utilization.

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