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An overview of fish visceral waste pollution and its eco-friendly management practices

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Abstract
The fisheries division occupies a very important place in the socio-economic expansion of our country. It has been documented as a dominant profits and service generator as it stimulates enlargement of a number of subsidiary industries and is also a source of low-priced and healthy food besides being a foreign trade earner. However, there is an increase in fish production as a consequence of a rise in demand for fishery products. This means that the volumes of fish processing by-products and fish wastes have also increased. These fishery wastes are highly perishable, owing chiefly to the action of microorganisms that find the wastes to be an excellent growth medium. The discarding of fish waste creates environmental problems as well as disposal problems. Therefore, there is a necessity to find ecologically acceptable means for reutilization of these wastes. Various scientific research have been found that a large quantity of bioactive substances can be extracted and purified from fish waste such as bioactive peptides, oligosaccharides, fatty acids, enzymes, water-soluble minerals and biopolymers. Now fish waste fertilizer is new trend to boost the crop yield.

Keywords: Fish visceral waste, fish protease, fertilizer, chitin and fish meal

Introduction

Aquaculture has been a fast-growing industry due to significant increases in demand for fish and seafood throughout the planet. It is growing sooner than the other segment of the animal culture industry (Gang *et al*., 2005) [1]. India is the second largest fish producer in the world with a total production of 13.7 million metric tonnes in 2018-19 of which 65 per cent was from inland sector (The Economics Times, 2019) [2].

In the recent years, fish consumption per person has doubled on a worldwide basis due to its nutritive values and omega 3 fatty acid contents and hence the fishery waste on land has also increased.

Processing discards from fisheries account for nearly 70-85% of the total weight of the catch and these are generally dumped into land or hauled into the ocean (Bhaskar & Mahendrakar, 2007) [3]. As a result, every year a considerable amount of total catch is discarded as processing leftovers and this includes trimmings, fins, frames, heads, skin and viscera. Even if a little portion of the by-products are utilized, the core mass is neglected to waste forming both disposal and pollution problems (Norziah *et al*., 2009) [4].

India brings about 2 million metric tonnes of by-products owing to fish processing operations. The fish left over is measured as insignificant trash and is normally throw out without revival of any valuable product (Nurdiyana & Mazlina, 2009) [5]. The untreated portions of the waste have a greater biological oxygen demand and if not disposed correctly, can create environmental evils.

Undesirable environmental issues linked with seafood processing waste discharges include, aggregation of the waste deposits and full fish parts in close proximity to shore locations, production of poisonous hydrogen sulfide gas, harmful circumstances caused by odours, bacteria and waste decomposition (U.S. Environmental Protection Agency Report, 2010) [6].

Fig 1: Fish visceral wastes - dumped in fish markets

The wastage may go up to 80% or higher when there are massive kills in aquaculture or when only roe (eggs) are harvested from fishes. The common practice of disposing the residues of the seafood industry into natural open bodies of water and landfills has heightened environmental concerns. Most of the objections to off-shore dumping of waste are based on odour problems, floating debris and visible surface slick, attractants of undesirable predator species, increased turbidity and dissolved oxygen depression of bodies of water.

Thus, the main focus of this review is to summarize the fish waste pollutions and the effective utilization by means of various eco friendly operations.

Utilization of Fish and Fish Waste

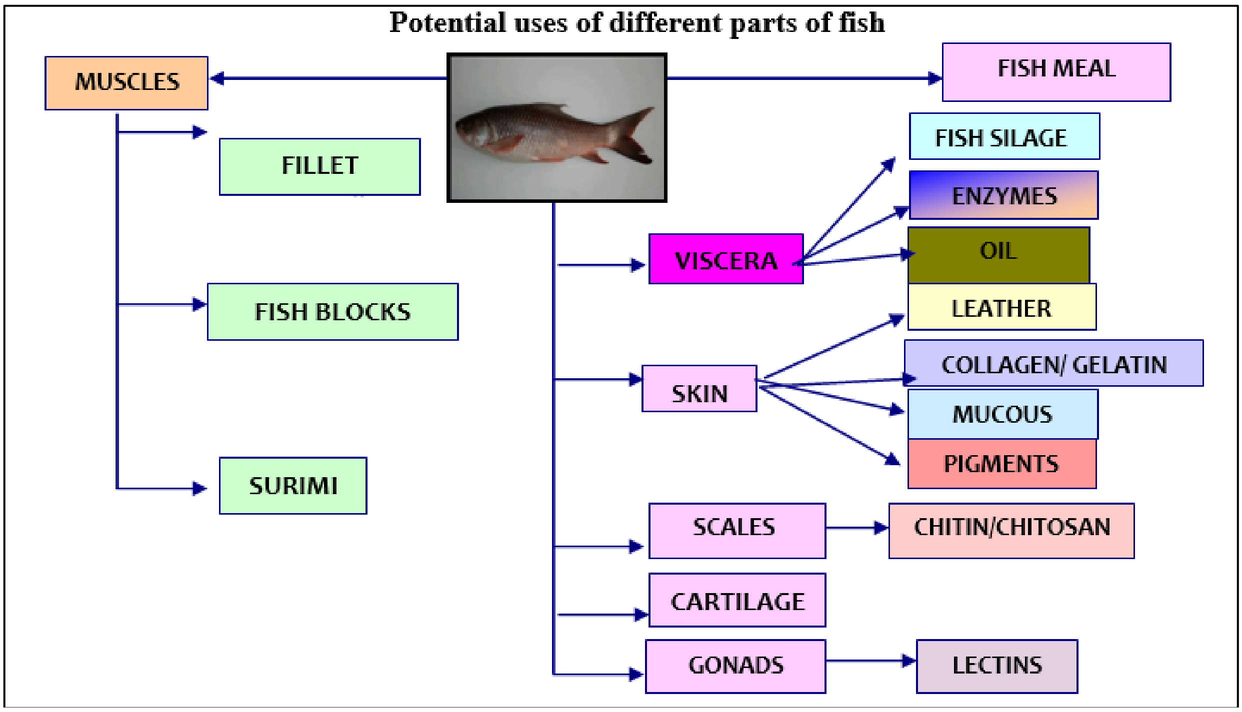
Fishes are ectothermic animals and have many morphological and physiological adaptations representing different food habits and characteristics of the digestive tracts. It is reflected in the digestive enzyme activities and their properties (Souza *et al*., 2007) [7].

Fish catches are used mainly for human consumption. Other minor uses include meal production, bait and miscellaneous purposes. Fish for human food represents around 78%, both in developed and developing countries, leaving about 21% for non-food uses (Vannuccini, 2004) [8]. Therefore, fish and its derived by-products are considered important from the nutritional point of view, the average world fish consumption being 16 kg/person/year. This is especially true for some areas where the fish consumption per capita is relatively high.

In processing, massive volumes of left over including heads, scales and viscera are produced and rejected (Bougatef *et al*., 2007) [9]. Fish waste is a good source of protein, but a huge amount of the waste is still being discarded without much effort to recover its protein (Kristinsson & Rasco, 2000; Bhaskar & Mahendrakar, 2007) [10, 3]. Besides that, the discarding of fish waste creates environmental problems as well as disposal problems (Amiza *et al*., 2011) [11]. Conventional methods for reutilization of fish waste are ensilation, production of high-protein meals used in animal feeds, fermentation and composting. Yeasts and / or lactic acid bacteria were used to ferment fish wastes and to remove fish odours (Kim *et al*., 2010) [12, 57].

The most important environment-friendly and profitable option for utilization of fish waste for the recovery of marketable by-products and production of value-added products through bioconversion has been recently reviewed by Arvanitoyannis & Kassaveti, (2008) [13]. These include production of animal feed such as swine and poultry feed, monogastric animal feed supplements, aquaculture feed, fishmeal and fish silage, renewable energy in the form of biodiesel and biogas, composting for production of organic fertilizers, extraction of natural pigments, extraction of novel and industrial enzymes like proteases, cosmetics, pharmaceutical industries like collagen, fish protein hydrolysate, fish bone extracts, and polyunsaturated fatty acids. Other options for utilization of fish waste includes the production of short-chain organic fatty acids, substrates for microbial culture media, production of attractants for economically important flies of agricultural crops, chromium immobilization and use of fish scales as natural adsorbents and organic wastewater coagulant for sedimentation of small particles (Gumisiriza *et al*., 2009) [14].

Fish and parts of fish can have a variety of applications.



Source: Blanco *et al*., 2007

Fig 2: Shows the uses of different parts of fish.

Composition of Fish Waste

The solid fish waste consists of head, tail, skin, gut, fins and frames. These byproducts of the fish processing industry can be a great source of value added products such as proteins, amino acids, collagen, gelatin, oil, enzymes and so on. Also, palmitic acid and oleic acid are abundant in fish waste. The composition of fish waste is indicated in Table 1.

Table 1: Composition of fish waste

Nutrient	Fish waste
Crude protein (%)	57.92±5.26
Fat (%)	19.10±6.06
Crude fiber (%)	1.19±1.21
Ash (%)	21.79±3.52
Calcium (%)	5.80 ± 1.35
Phosphorus (%)	2.04 ± 0.64
Potassium (%)	0.68 ± 0.11
Sodium (%)	0.61 ± 0.08
Magnesium (%)	0.17 ± 0.004
Iron (ppm)	100.00 ± 42.00
Zinc (ppm)	62.00 ± 12.00
Manganese (ppm)	6.00 ± 7.00
Copper (ppm)	1.00 ± 1.00

***Source*:** Ghaly *et al*., 2013; Esteban *et al*., 2007 [16, 17].

Fish meal

One of the chief products, obtained from fish waste is Fish meal. It is dry product prepared from whole fish or fish filleting waste which are unacceptable for human consumption [15]. Fish meal is a concentrated nutritious feed supplement consisting of protein (70%), minerals (10%), fat (9%) and water (8%) (Gildberg, 2002) [18] cobalamine (Bl2), choline, niacine, pantothenic acid and riboflavin. Fish meal is rich in essential amino acids, which animal body cannot synthesis and this makes it an unrivalled constituent of feed stuff (Pagarkar *et al*., 2014) [19]. Fish meal is commonly used as a food for fish. Alterations in fish meal grade can impact the development and feed competence ratios of the organism's nourish (Sotolu, 2009) [20].

Enzymes from Marine animals

The world's oceans cover more than 70% of our planet's surface (Zhang and Kim, 2010) [50, 53]. The marine habitat is one of the natural ecosystems which contain variety of organisms. The sources of marine enzymes have been widely studied in microorganisms like bacteria, fungi and actinomycetes, several additional marine organisms such as fishes, prawns, crabs, snakes, plants and algae (Trincone, 2011; Debashish *et al*., 2005) [51, 52].

Marine enzymes were categorized as a unique class of biocatalysts since it is located inside the organisms and reside an environment characterized by high pressure, high salinity, low temperature and modest sunlight. These conditions are extremely altered from those of the terrestrial environment. On this basis, marine enzymes may have some physical, chemical and catalytic properties that could be of an advantage in several biotechnological processes (Zhang & Kim, 2010) [50, 53, 12, 57]. Thus marine enzymes are recommended for a number of industrial applications like pharmaceuticals, cosmetics, nutritional supplements, molecular probes, enzymes, food additives, fine chemicals and agrichemicals (Rasmussen and Morrissey, 2007) [54].

The practice of enzymes extracted from sea animals is applied in food technology is becoming a promising application for substitution of rennet in cheese manufacture, removal of the oxidized flavour from milk, ripening and fermentation of fish products and preparation of fish protein hydrolysates and concentrates (Rossano *et al*., 2011) [55].

In recent years, recovery and characterization of enzymes from fish and aquatic invertebrates has taken place and this has led to the emergence of some interesting new applications of those enzymes in food processing. On the other hand, extraction of enzymes from fish and shellfish processing wastes and their utilization in the food industry may contribute significantly to reducing local pollutions where it creates an aesthetic as well as an ethical problem in many places. From marine animals, enzymes like proteases, amylases, cholinesterases, protein kinases, green fluorescent protein and others have been isolated (Hayes, 2012) [56].

The possible advantages of enzymes from fish and aquatic invertebrates are no necessity to perform toxicological testing of the raw materials in order to demonstrate their safety because they are obtained from edible animal tissues (Kim *et al*., 2010) [12, 57].

Fish viscera

Viscera of fish include the digestive tissues, namely, stomach, pyloric caeca, intestines, liver, pancreas and so on and other organs like spleen and gonads.

Visceral wastes were used to obtain fish protein hydrolysate (FPH), fish silages and so on. Also, Fish viscera were reported to be used as a source of enzymes particularly proteolytic digestive enzymes or serine protease ((Prasertsan and Prachumratana, 2008) [44].

Fish protein hydrolysates are proteins chemically or enzymatically hydrolysed into peptides of varying sizes (Rustad, 2003) [27, 45]. The enzymatic hydrolysis *in vitro* is an effective approach for the recovery of bioactive peptides as well as for the improvement of the functional and nutritional properties of protein from under-utilized fish and fish by-products (Slizyte *et al.*, 2009) [46].

Fish protein hydrolysates and silages constitute a broadly accepted nitrogen source for rats, pets, aquaculture fish, bacteria and other commercially grown organisms and can be used as substitutes for other peptones for culture of lactic acid bacteria, permitting the production of biomass and bacteriocins with equal or superior qualities to those obtained with common commercial media (Vazquez *et al*., 2004; Martone *et al*., 2005) [47, 48].

Enzymes from fish waste

Various enzymes have been isolated and studied from fish visceral waste. The fishes and higher vertebrates utilize the same enzymes and hormones in the breakdown of proteins into amino acids. In fish, the precise levels of digestive enzyme activities are reliant on age, diet, season, and/or ambient temperature (Rathore *et al*., 2005; Debnath *et al*., 2007) [58, 59]. Fish viscera are really a good source of digestive enzymes, such as pepsin and the serine proteases, trypsin and chymotrypsin and serine proteases such as elastase and collagenase (Rossano *et al*., 2011) [55].

One of the main proteases detected in fish viscera, especially in the pyloric ceaca and intestine is trypsin, a member of a large family of serine proteases, isolated and characterized thoroughly based on their physiochemical and enzymatic properties from several species of fish, example, carp (*Cyprinus carpio*), tambaqui (*Colossoma macropomum*), true sardine (*Sardinops melanostictus*), arabesque greenling (*Pleuroprammus azonus*), Alaska pollock (*Theragra chalcogramma*) and Skipjack tuna (*Katsuwonus pelamis*)

(Cao *et al*., 2000; Bezerra *et al*., 2001; Kishimura *et al*., 2006; Kishimura *et al*., 2008 & Klomklao *et al*., 2009 [60, 61, 62, 63, 64, 65].

Nasri *et al.* (2011) studied the alkaline protease activities in the viscera of goby (*Zosterisessor ophiocephalus*), thornback ray (*Raja clavata*), and scorpionfish (*Scorpaena scrofa*).

Pepsins and pepsin-like enzymes have been isolated and characterized in several fish species such as Atlantic cod (*Gadus morhua)*, North Pacific blue fin tuna (*Thunnus thynuus orientalis*), capelin (*Mallotus villosus*), orange roughy (*Hoplostethus atlanticus*), polar cod (*Boreogadus saida*), salmon (*Oncorhynchus keta*), Monterey sardine (*Sardinops sagax caerulea*), sardine (*Sardinos melanostica*) and pectoral rattail (*Coryphaenoides pectoralis*) (Klomklao *et al*., 2007) [66].

Proteolytic enzymes have been detected and partially purified from the trout (*Salmo gairdnerii*) heads by Michail *et al*, (2006) [67].

Nayak *et al*, (2003) [68] reported the presence of lipase activity in the stomach and pyloric caeca, liver, intestine and red muscle of Rohu (*Labeo rohita*), oil sardine (*Sarinella longiceps*), mullet (*Laza subviridis*) and Indian mackerel (*Rastrelliger kanagurita*).

Recently Geethanjali & Subash, (2018) [69] isolated and purified the protease from the visceral organ wastes of *Labeo rohita*. The study was taken up with the view of utilizing the large amount of fish waste for the extraction of beneficial enzyme protease there by contributing the reduction of pollution caused by disposal of fish waste.

Fish oil

Fish oils can be extracted from the whole fish, skin or liver of fish. Composition of fish oil is different from that of other oils and is mainly composed of two types of fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These are polyunsaturated fatty acids classified as omega-3 fatty acids and predominantly found in many marine animals including cold-water fish species with a higher unsaturated fat content. Compared to saturated fats, polyunsaturated fatty acids in fish oil are readily digested for energy production and have been reported to have various bioactivities (Kim & Mendis, 2006) [21, 49]. During the last several decades, interest in the dietary effects of n-3 polyunsaturated fatty acids has increased because of their ability to lower serum triacylglycerols and cholesterol and convert them to eicosanoids, which are known to reduce thrombosis. In addition, these fatty acids play an important role in the prevention and possible treatment of coronary heart disease, hypertension, arthritis, and other inflammatory and autoimmune disorders, and DHA is particularly important in brain development (Pak, 2005) [22]. An additional lipid found in huge amount in shark liver oil is squalene. It is essential therapeutic bio-active oil and its function has been reported in the curing of diabetes, cancer and tuberculosis. Moreover, squalene found to contain antifungal and antioxidant properties (Archer, 2001) [23]. Fish liver oils were used for the therapeutic purposes in the treatment of vitamin A and D deficiencies. It is used in the manufacture of detergents, rubber, lubricants, printing inks, leather and cosmetics, stearic acid, glycerine, soap or candles, pharmaceuticals. It is also used in paints and varnishes (Pagarkar *et al*., 2014) [19].

Fish minces and restructured products

Muscle is the most frequently used part of the fish since it is the edible portion. During the processing of fish, only the fillets are retained while the bulk of the product up to 66% is discarded (Knuckey *et al*., 2004) [24]. In order to obtain this muscle, fish can be prepared before sale, by hand, or using mechanical filleters, and the resulting fillet can constitute the main product, leaving some parts like trimmings which can be used for different products such as fish mince and restructured products. Restructured fishery products are made from minced or chopped muscle, which is subjected to a gellification process. In order to improve the gelling properties, certain techniques and binding agents, such as transglutaminase are employed (Uresti *et al*., 2004) [25].

'Surimi' products are based on techniques used traditionally in Japan, and the resulting products have a variety of forms and textures, imitating the characteristics of natural products. Surimi is a paste formed by myofibrillar proteins obtained from mechanically deboned fish flesh washed with salt solutions to remove sarcoplasmic proteins and stabilized with the inclusion of cryoprotectants. It is an intermediate product used in a variety of foods such as the traditional Japanese kamaboko or different preparations of shellfish substitutes such as crab legs, crab meat, young eel and so on (Kang *et al*., 2007) [26].

Fish skin

Fish skin is a beneficial by-product of the fish-processing industry, produced during filleting which causes pollution. It has been used for making clothing, shoes, and trousers. Also bags, carrier bags and sacks are made from this material (Rustad, 2003) [27, 45]. Fish glue is formed by boiling the skin, bones and air bladder of fish (Sankpal & Naikwade, 2012) [28]. Fish skin waste might be used as a possible source to isolate collagen and gelatin ((Nalinanon *et al*., 2007) [29].

Collagen and gelatins

Collagen and gelatin are currently utilized in diverse fields including food, cosmetic, and biomedical industries. Collagen is structurally formed as a triple helix by three extended protein chains that wrap around each other. Collagen and gelatin are different sorts of an equalent macromolecule and gelatin is that the partially hydrolyzed sort of collagen. Skin and bones of fish are rich source of gelatin and collagen and several studies have been carried out to obtain collagens from the waste of fish like skin, bones, scales and fins of different fish species, and invertebrates (Senaratne *et al*., 2006) [30]. The yield of collagen obtained from these sources ranges from 36% to 54% (Nagai & Suzuki, 2000) [31].

The collagen and gelatin which are extracted from fish have much utilization. It can be applied as edible casings in meat processing industries, cosmetics as it has good moisturizing properties (Swatschek *et al*., 2002) [32] and biomedical materials or pharmaceutical applications which include production of wound dressings, vitreous implants or carriers for drug delivery. Some studies have also exhibit that collagen may possibly reveal high anti-radical activity (Morimura *et al*., 2002) [34].

In addition, fish gelatins are practiced as emulsifiers in food products (Surh *et al*., 2006) [35], since it could stabilize emulsions remaining moderately stable to droplet aggregation and creaming even after being subjected to changes in temperature, salt concentration and pH. Choi & Regenstein (2000) [36] found that fish gelatin has similar properties to pork gelatin but its lower melting point, compared with pork or beef, together with the fact that fish gelatin has a better release of aroma and gives a stronger flavour could offer new opportunities to product developers.

Pigments

Precious pigments have been discovered in some type of fish raw materials. Numerous researches have recorded the occurrence and recovery of pigments such as astaxanthin and its esters, β-carotene, lutein, astacene, canthaxanthin and zeaxanthin in crustacean waste. Carotenoids are a group of fat-soluble pigments, found in many plants, algae, microorganisms and animals and are responsible for the yellowish orange colour. Carotenoids have been extracted from various fish waste like the processing head and shell of *Penaeus indicus* (Sachindra *et al*., 2005) [37]. Carotenoids can also be extracted from fish eggs (Li *et al*., 2005) [38] and fish scales ((Stepnowski *et al*., 2004) [39]. These important pigments are acting as a cheaper alternatives for wide variety of industrial requirements such as coloration of some surimi-based products or aquaculture feed formulations. Furthermore, some pigments like astaxanthin are important in medical and biomedical applications due to their high antioxidative effects and due to the fact that they are precursors of vitamin A (Arvanitoyannis and Kassaveti, 2008) [13].

Chitin and Chitosan

Chitin and its derivative chitosan are natural polymers composed of randomly distributed β (1-4) - linked D-glucosamine and N-acetyl-D-glucosamine. Chitin is insoluble in aqueous media while chitosan is soluble in acidic conditions owing to the free protonable amino groups present within the D-glucosamine units (Aranaz *et al*., 2009) [40].

One of the chief constituents of fish scales and crustacean shell waste is chitin (Zaku *et al*., 2011) [41]. It has numerous applications in food, biomedicine, agriculture and others. Some of the specific usages of chitin and chitosan are drug delivery, tissue engineering, functional food, food preservative, biocatalyst immobilization, wastewater treatment, molecular imprinting and metal nano composites. Chitosan has a strong antimicrobial activity against a variety of microorganisms and its non-toxic, biocompatible and biodegradable properties make it adequate for application as a food ingredient and in medical applications. Chitooligosaccharides also exhibit a scavenging activity on hydroxyl and superoxide radicals, being dependent on their molecular weight (Tsai & Hwang, 2004; Park *et al*., 2003) [42, 43]. This property makes them not only potential additives for the inhibition of lipid oxidation in food but can also prevents certain pathological processes associated with free radical modification of cellular compounds, such as atherosclerosis, arthritis, diabetes, inflammatory disorders and neurological disorders such as Alzheimer's disease. Other applications of chitin and chitosans are their use as ingredients of toothpaste, shampoo, hand and body creams, for cell immobilization, and as materials for production of contact lenses (Aranaz *et al*., 2009) [40].

Lectins

Fish eggs from fish processing can be easily converted into special food (caviar) or fish bait. An unrevealed nutraceutical potential exists in fish eggs because they are rich sources of lectins. Lectins are widely found in reproductive cells, eggs and sperms, because of their role in fertilization. They are naturally occurring glycoproteins that can bind with carbohydrates to form stable complexes. Due to the ability of lectins to bind with carbohydrates, it may have a potential to be used as a better alternative for antibiotics to make pathogens incapable of causing diseases by making lectin-pathogen complexes (Kim and Mendis, 2006) [21, 49].

Fish waste as fertilizer

Fish waste is suitable for agricultural use owing to high contents of nutrients, such as N, P and Ca. A number of fertilizers were made from fish meal are currently commercially accessible and some are allowed for use in organic agriculture. Nowadays, fish effluents are used to irrigate cherry tomato plants. Composting initiatives using fish visceral waste have been accepted in different parts of the world in explore of unconventional and feasible techniques for transforming fish waste into useful agricultural products (Radziemska., *et al*., 2019) [70].

Biodiesel/Biogas

Biodiesal fuel, acquired from the oils and fats of vegetables and animals is a substitute for or an additive to diesel fuel derived from petroleum (Alcantara *et al*., 2000) [71].

Kato *et al*, (2004) [72] evaluated the ozone treated fish waste oil as a transportation fuel. The oil manufactured from fish waste was tested for its density, flash point, pour point, heating value, distillation test and sulphur content. The yield of he produced fuel was 95 – 96%, after filtration and primary and secondary treatments. The obtained oil was found to have suitable properties for use in diesel engines, such as almost identical higher hating value (10 700 kcal kg^{-1}) and density (15°C, 0.87g cm^{-3}) lower flash and pour points (37 & - 16°C) respectively. It was compared with commercial diesel fuel, no production of sulphur oxides lowered or no soot, poly aromatic acid and carbon di oxide emissions. These properties suggested that the obtained oil had better properties than methyl esterified vegetable oil waste and was suitable for diesel engines especially at low – temperature areas.

Conclusion

Increasing concern about environmental pollution and limiting biological resources has emphasized on the need for better utilization of by – products from fish processing. It generates large amounts of solid and liquid wastes, such as heads, tails, skin, bones and viscera. This processing waste is a huge problem for the fishery industry and its disposal has a major economic and environmental impact. The digestive tract or the viscera of the fish, which constitutes 5 to 8% of the fish weight, is usually wasted. Visceral organs have a nutritional value equivalent to that of whole fish and are being usually converted into feeds, fertilizers, silage and so on.

The protease enzyme from the fish visceral wastes were isolated and studied thereby reduction in the pollution of disposal of fish waste.

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