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On

Resource Recovery from By-products

DESKU ENVIS RP, UNIVERSITY OF KALYANI, NADIA, WEST BENGAL

Email: desku-env@nic.in, Phone: +91-33-25828750

Website: http://www.deskuenvis.nic.in

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EDITORIAL

Literally, resource recovery is the use and recycling of waste products to generate new valuable products. The principle objective of a meaningful resource recovery is to reduce the amount of waste generated and need for landfill space in one hand and optimization of new products created from these wastes on the other hand.

The present issue of newsletter is provided with two very pertinent topics on resource recovery. The theme of this newsletter is recycling of waste generated from biomass. The first article deals with biochar, produced from treating biological waste in a particular manner. The use of a very promising biological material known as 'Biochar', produced by thermal treatment, has been discussed. The synthesis and application of 'Biochar' was also discussed elaborately in the article. In the second article utilization of by-products from fish waste as potential resource was discussed in details. The article also highlighted the different types of fish by-products and their usage as bio-resource. Both the articles are important, because they point to ways that can lead to (1) less problem of housing and disposing of garbage, especially around human settlements, (2) less damage to the environment, and a possibility of recovery and (3) production of useful materials which is needed for human utilization or improvement of soil and water quality. We hope these articles generate interest among citizens, especially among young persons, for they must take necessary steps that we, sometimes, have failed to take. We hope this newsletter will be helpful in understanding the merits of environment friendly use of by-products as potential bio-resource, and ways to protect of our environment.

– Prof. Asoke Prasun Chattopadhyay
- Dr. Subhankar Kumar Sarkar

IN THIS ISSUE:

Biochar from Biomass Wastes: A Novel and Sustainable Material for Environmental Applications

Abhishek Kumar, Tanushree Bhattacharya, Sukalyan Chakraborty*

Dept. of Civil & Environmental Engineering

Birla Institute of Technology, Mesra.

* sukalyanchakraborty@bitmesra.ac.in

1. Introduction

Unprecedented growth of human population and changing lifestyle has led to generation of enormous quantities of waste, depletion of natural resources, environmental pollution and climate change, endangering the survivability of the planet (Kumar et al., 2021a). Solid waste disposal and management has been specifically a challenging task all over the world owing to the huge amount of waste generated and the complexity of their separation, disposal, and management. Biomass waste is a class of solid waste, which has immense potential to be utilized after its conversion into various materials by different techniques like combustion or thermal depolymerization for environmental remediation and management. Such a very promising material, known as biochar, is produced by thermal treatment of biomass waste. Biochar is a solid carbon-containing material synthesized via thermal treatment of biomass waste in a limited supply of oxygen. Biochar can be produced from a huge variety of biomass materials such as agricultural waste, kitchen waste, forest-based waste, industry-generated waste, poultry waste, cattle waste, etc. (Kumar and Bhattacharya, 2021, 2020). Several techniques have been employed for production of biochar such as torrefaction, gasification, pyrolysis, and hydrothermal/ flash carbonization. Among them, pyrolysis is the most widely utilised method primarily due to its simplicity, high yield of production, and cost-effectiveness.

Variation in production technique and the type of biomass utilised affects the properties of biochar. Apart from decrease in load of waste biomass (during biochar production), biochar application helps in augmenting soil fertility and plant productivity (which could enable food security management), mitigating climate change (via sequestering carbon and minimizing greenhouse gas emission), remediation of organic and inorganic contaminants (from soil and water) and producing bio-energy (bio-oil and bio-gas generation which also decreases pressure on fossil fuels) suggesting that biochar could play a key role in environmentally sustainable development (Kumar et al., 2020). Recently, biomass waste has been utilised for production of graphene which has been utilised for various applications in electronics and energy sector. Lately, biomass waste-derived carbon-rich materials could help in promoting and establishing circular economy.

2. Different types of biomass wastes

Biomass is a plant or animal-derived organic and renewable material that could be utilized for production of energy. Biomass includes a wide range of materials but the most important ones seeking attention are waste generated by agro-forestry, industry, and animal-based wastes. Examples are:- wood from forests, agro-residues (straw and stover), agro-industrial wastes (food processing, rice husk and sugarcane bagasse), kitchen-based wastes, municipal solid wastes, and animal wastes (from poultry, cattle, fishery etc.) (fig. 1).

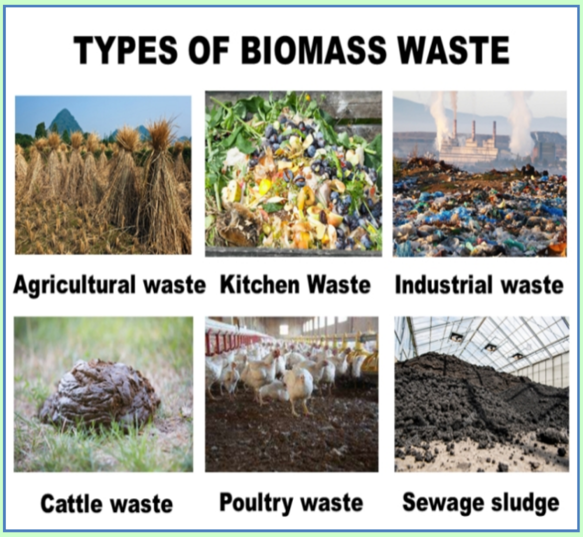

Fig.1: Types of biomass wastes

Agricultural residues include stubble, pulp, peel, husk, straw, leaves, stalk, stem, bagasse, shell, etc. which are produced in large quantities worldwide and remain under-utilized (mostly grazed by cattle, left to decompose, or burnt). Animal wastes includes animal and poultry manure which were previously used to enhance soil fertility but also led to bad odor and water pollution. Forestry residues include wastes originating from deforestation (for industries, road construction, and human settlements), plantations, paper manufacturing, wood processing (sawmill, plywood, or craft industries) etc. which could eventually be prone to wildfire, diseases and pest attack. Industrial wastes are inclusive of food industry waste (meat-based, fish processing,confectionery, etc.), solid wastes (fruit, vegetables, pulp, fiber, etc.), pulp and paper industry, etc. which are mostly dumped in landfills. Municipal solid wastes include household wastes (contain putrescible, paper and plastic) and sludge which are generally dumped on open fields or in large water bodies. Therefore, most of the biomass wastes either pollute our surroundings or remain under-utilized and conversion of these wastes to useful resources could be a boon to the society.

3. Disposal and waste management of biomass wastes

Waste disposal is a cause of concern as most of the biomass wastes are disposed off improperly and the problem is bound to augment with industrialization and population growth. Some of the methods of waste disposal (fig.2) include landfills (burial of waste on/in land, which is the most common waste disposal method), composting (bio-degradation of organic wastes into nutrient-rich compost to be used as soil fertility enhancer), incineration (combustion of biomass waste and conversion to steam, gas, heat, and ash), and recycling (transformation of biomass waste into new useful products). Improper disposal not only endangers human and ecosystem health, but there is a strong probability of contamination of soil (and water), pollution of air, and release of greenhouse gases (like methane and nitrous oxide) into atmosphere (which escalates global warming and climate change). Correspondingly, management of waste has become critical for the sustenance of planet. Waste management includes collecting, transporting, processing, recycling, and disposing the biomass waste safely (fig.3).

Fig. 2: Waste Disposal

Fig. 3: Waste management

4. Synthesis of biochar from biomass wastes

Biochar has emerged as a highly potent waste management strategy (with waste-to-energy conversion capability) in the recent past. Thermal treatment of biomass wastes in near absence of oxygen result in production of a stable, recalcitrant and carbon-neutral substance called biochar (IBI, 2015).

Farmers have been using biochar since ages to enhance soil fertility. Interestingly, Amerindian farmers used biochar in the form of *Terra preta* or "Amazonian dark earth" which is a mixture of faeces, manure, compost, plant and animal remains, and low temperature-fabricated charcoal (Forján et al., 2017). Several thermal treatment methods have been used to prepare biochar. The techniques include torrefaction, combustion, gasification, carbonization, and most widely pyrolysis technique for biochar production (fig.4). It is crucial to note that treatment method and fabrication conditions affect the physico-chemical properties of biochar preparation (Kumar and Bhattacharya, 2020).

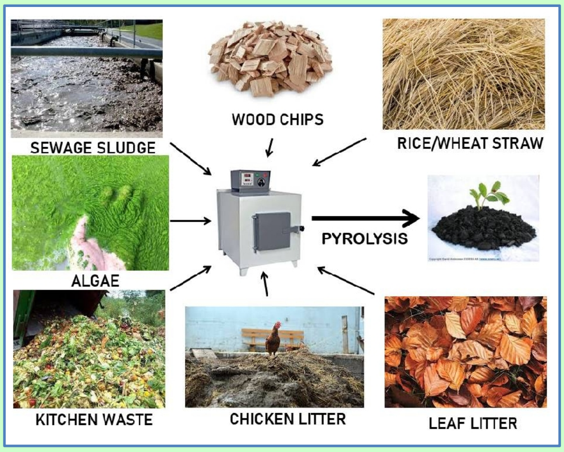

Fig. 4: Production of biochar from biomass wastes

Pyrolysis involves thermal treatment of biomass wastes at temperatures of 300°C-900°C in an oxygen-deprived furnace or kiln to obtain products of biochar, bio-oil, and syngas. Absence of oxygen enables biomass wastes to be heated above its thermal stability resulting in maximum amount of highly stable-biochar production during pyrolysis. Thermal treatment results in volatilisation of components and formation of oxygen-rich surface functional groups (such as hydroxyl, carboxyl, and carbonyl). Pyrolysis is affected by heating technique, treatment temperature, heating rate, vapour residence time, and pressure conditions. Pyrolysis could be classified as slow pyrolysis (biomass waste heated at temperatures of 400°C-500°C with moderate rate of temperature rise) and fast pyrolysis (biomass waste heated at temperatures of 800°C-1200°C with rapid rate of temperature rise). Further, slow steam pyrolysis and flash pyrolysis have also been utilised for production of biochar. Biomass wastes, such as crop residues, softwood chip, corn cobs, corn stover, sunflower oil cake, and vegetable waste, have been used for production of biochar via different types of pyrolysis.

5. Applications of biochar from biomass wastes

Biochar possesses crucial properties such as alkaline pH, high carbon content, large surface area, adequate porosity, abundant surface functional groups, remarkable water holding capacity, high nutrient content, and sufficient ash content. These properties make biochar a huge prospect for wide-ranging applications as listed below (fig. 5):

a) Waste management

Utilization of aforementioned waste biomass for production of biochar could aid in economical waste management by decreasing waste generation (Kumar and Bhattacharya, 2020). Moreover, this approach could make waste profitable. Further, biochar production would aid in decreasing the waste overload in landfills (eventually decreasing the number of landfill sites) and landfill-associated problems (release of toxins, leachate and greenhouse gases).

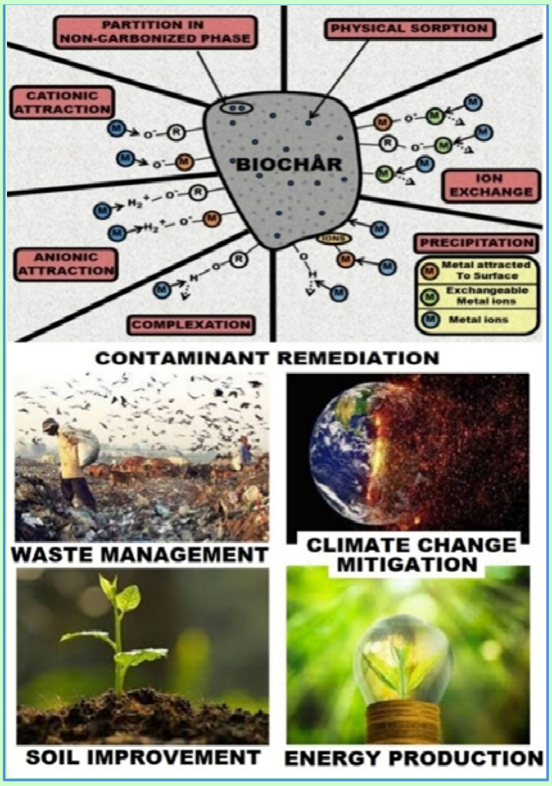

Fig. 5: Applications of biochar

b) Climate change mitigation

Biochar has immense potential to mitigate climate change. Biochar is an excellent medium for carbon sequestration (Woolf et al., 2018). Carbon content in biomass waste is converted into highly stable biochar during thermal treatment. Biochar could resist degradation in soil for as long as 1600 years. Apart from storing carbon, biochar can also sorb greenhouse gases, such as methane and nitrous oxides, on surface, thereby decreasing their concentrations from atmosphere. In other words, biochar acts as a sink for greenhouse gases. Interestingly, biochar could be amended to flooded soils for decreasing emission of greenhouse gases, even when paddy crops are grown on these soils. Biochar application also influences microbial activity resulting in suppression of methane emissions. Further, co-production of bio-oil and syngas during biochar preparation would assist in reduction of fossil fuel exploitation and the associated emission of greenhouse gases.

c) Soil improvement

High carbon content in biochar makes it a suitable soil conditioner by augmenting organic content which enhances water and nutrient retention capacity of soil (Karim et al., 2020). In fact, even 1% rise in soil organic matter (after amendment with biochar) could enable an acre of land in storing ~20,000 more gallons of water. Biochar addition enhances cation exchange capacity of soil which aids in reducing leaching of nutrients from soil. Further, alkaline pH of biochar enables it in neutralizing degraded acidic soils. Biochar could sorb sodium ions from saline soil thereby ameliorating saline/sodic soils. Moreover, large surface area of porous biochar escalates microbial population and microbial activity in soils which are crucial in improving the soil fertility and crop growth. Biochar can also be applied with fertilizers and/or compost to multiply the crop yield.

d) Energy production

Thermal treatment of biomass waste produces highly affordable bio-energy (biochar, bio-oil and syngas) in different amounts depending on treatment technique, treatment temperature, and feedstock (Kumar et al., 2020). While fast pyrolysis produces bio-oil in large quantities, gasification generates syngas in abundance. Further, gaseous emissions during thermal treatment could be recaptured and condensed into bio-oil. Bio-energy sources could be an adequate replacement of fossil fuels. Further, biochar-based materials or biochars themselves could act as excellent catalysts during production of biodiesel. Interestingly, biochar could also help in cost-effectively removing toxic gases, such as hydrogen sulphide, from biogas.

e) Contaminant remediation and pollution reduction

Biochar has shown promising results in decreasing organic and inorganic pollutants from soil and water primarily assisted by physisorption and chemisorption mechanisms including surface sorption, diffusion, complexation, precipitation, electrostatic attraction, hydrogen bonding, etc. (Kumar and Bhattacharya, 2021; Shaikh et al., 2021, 2018).

6. Circular economic approach

Recently, biomass waste-derived carbon-rich materials have been utilized in wide-ranging applications suggestive of its contribution towards circular economy, (Sherwood, 2020). Circular economy focuses on sustainable development and conservation of resources with key principles including-waste minimization, pollution reduction, re-utilization of waste materials, and regeneration of natural systems (Suárez-Eiroa et al., 2019). Circular economy possesses economic, environmental, and social benefits. Utilization of biomass wastes for production of biochar and graphene circumvents the take-make-waste model and enables re-employment of waste into the circular economy. Therefore, biomass wastes could prove to be critical components of circular economy.

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Resource from Fish By-products

Anusaya Mallick[1]*, Alok Chandra Samal[2] and Ashis K. Panigrahi[3]

[1]ENVIS RP on Environmental Biotechnology, University of Kalyani, West Bengal
[2]Department of Environmental Science, University of Kalyani, West Bengal, India
[3]Pro-Vice Cancellor, University of Burdwan, Burdwan, West Bengal, India
*E.mail: anusaya.cifa@gmail.com

1. Introduction

Fish is one of the protein rich foods and a major source for human since ancient times. It has social economic, nutritional and food security importance and it is the best source of omega-3 fatty acids. It also plays a lead role in the export earning of many Asian countries. In recent the increasing fish consumption leads to increase in fish processing resulted a large amount of fish by-product are also generated which contribute environmental pollution (fig.1). About one-third of the world catch of fish is not used for direct human consumption. Probably, more than 50% of the remaining material from the total fish capture is not used as food and involves almost 32million tonnes of waste (Kristinsson & Rasco, 2000). In fish processing enormous quantity of wastes (skin, head, viscera, scales, bones etc) are generated. Industrial fish processing for human consumption yields only 40% edible flesh and the remaining 60% is thrown away as waste. Today the most common understanding of by-products is all raw materials, edible or inedible, left during the production of the main products. During fish processing and filleting, 50–65% of the body is discarded which cause environmental pollution. More than 60% of these residues, including of the bone/frame (12–17%), viscera (4–12%), heads (18–60%), cut-offs (6%), skin (4–7%), and roe (2%) are considered as waste (Rawdkuen & Ketnawa, 2019). During preservation and processing, some materials of fish and prawn are discarded as waste also. Annual discard from the world fisheries were estimated to be 25% of total production, which is approximately 20million tones per year as 'waste' or by-products.

Fig. 1: By-products of fish processing industry *(Rawdkuen & Ketnawa, 2019).*

A byproduct is a secondary product derived from a manufacturing and filleting industries. All these are good sources of high quality protein, fat, minerals etc. These waste materials become an important source to produce fish byproducts, which in turn are used to produce different useful fish byproducts (fig.2).

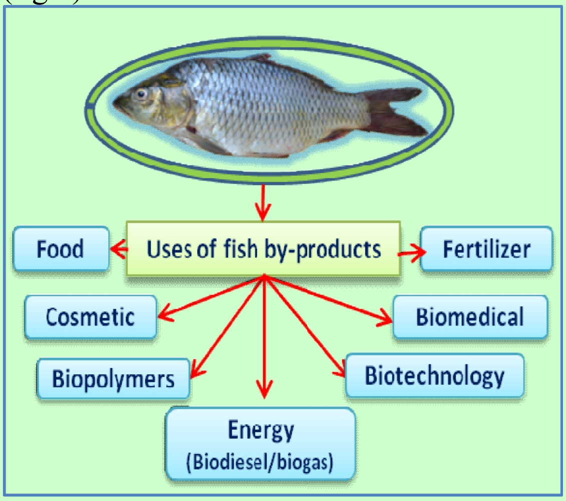

Fig. 2: Uses of fish by-products

An important waste reduction strategy for the industry is the recovery of marketable by-products from fish wastes. Fish byproducts are a nutritionally important source of proteins, fatty acids, and minerals, as their composition is similar to that of fish fillet and other food products used for consumption. Treated fish waste has found many applications among which the most important are animal feed, industrial uses such as gelatin, insulin, albumin, chitin and chitosan etc. Management of fish wastes has become a problem that affect the environment (Arvanitoyannis & Kassaveti, 2008). So these methods are used for a better fish-waste management which will also help to overcome environmental issues.

Worldwide there are several techniques for waste processing to produce speciality feed ingredients for aquaculture feeds, fertilizers for agriculture and home gardening, biogas, pharmaceuticals, industrial products, such as chitin and other specialized products, such as fish leather and pearl essence. There are a number of valueable products recycled from different fish byproducts (fig.3).

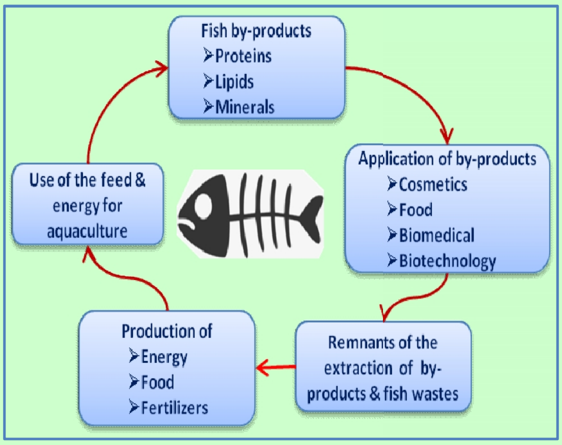

Fig. 3: - Recycling value of fish by-products

2.Value added Products of fish waste

The different value added products, i.e biopolymers (fig.4), food, medicine, cosmetics, biofuel etc. recovered from the fish wastes using various technologies are as follows:

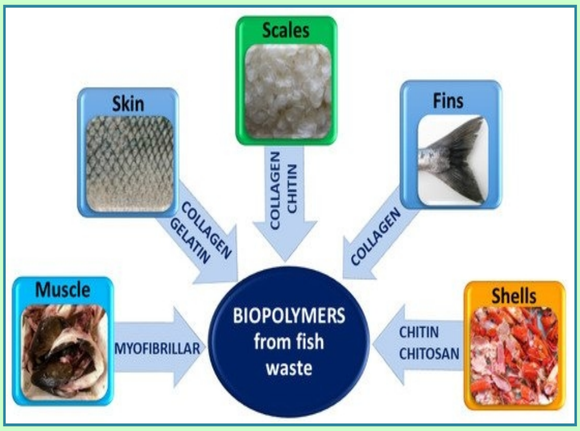

Fig. 4:- Biopolymers with potential food packaging application derived from fish industry waste *(Lionetto & Esposito Corcione, 2021).*

a) As human food

Malnutrition can be prevented by consumption of nutrientrich fish by-products. Fish by-products provide high levels of essential micronutrients, such as vitamins A, D, B, particularly B12, as well as minerals such as calcium, phosphorous, iron, zinc, selenium, and iodine. In addition to micronutrients, by products contain high quality proteins and lipids with long-chain omega-3 fatty acids (FAO 2016).

b) As feed ingredient for animal feed

Fishery by products such as viscera, head, fins and skin of fish are rich source of protein, minerals and vitamins, these can be used as a supplement in animal feed (fig.5). These are also used to fulfill the deficiency of protein in animals, these byproducts can be used in the form of fish meal, fish oil, and protein hydrolysates and fish silage. Fish protein is mostly used as a feed ingredient for poultry and swine. Protein hydrolysates provide high amount of nitrogen and fish oil provide triglycerides of fatty acids and phospholipids in the animal feed industry.

Fig. 5: -Fish viscera waste

c) Fish oil

Fish oil has been used in food from time immemorial. Some species of fish are good sources of liver oil such as shark, cod etc. They contain very high amounts of oil. Now the world aquaculture has also created a market for fish oil in fish feed (Opstveldt et al., 1990).

d) Gelatin

Gelatin is a high source of lysine and methionin, which is deficient in cereal. Gelatin can be extracted from the skin and bones of fish, which are suitable for the extraction of gelatin. So some industry use gelatin for pharmaceutical products and food products preparation.

e) Insulin

Insulin is a hormone used for correcting the condition called diabetes mellitus in humans. Fish insulin is more stable as it is not subject to decomposition by protein splitting enzymes of pancreas.

f) Albumin

Fish albumin is a product similar to egg albumin in physical and chemical properties. It can be processed out of proteinaceous residue from fish scrap or fish waste. It is used in food and pharmaceutical products. Albumin is an additive in ice cream, soup powder, puddings, confectionery, bakery products, mayonnaise, custard powder etc.

g) Chitin

Chitin is largest source from the shrimp shell and head waste. Chitin is produced from the shell waste by deproteinisation and demineralization. Chitin has several industrial and medicinal uses.

h) Protein

Fish flesh on an average contains 15-20 per cent protein. Fish protein concentrate (FPC) is a stable protein concentrate prepared from whole fish or other aquatic animals or parts thereof. It is used for human nutrition.

i) Fish calcium

Fish bones and scales are excellent source of calcium, which has better nutritional qualities Whole small fish or fish bone/scale can be used for calcium separation. The filleting frames of carps and other fishes can be used for extraction of calcium.

j) Chitosan

Chitosan is colourless and light in weight which gives viscous solution when dissolved in dilute organic acids such as formic acid, acetic acid etc. It is used in food industries, pharmaceutical applications, chemical industries, dental and surgical uses as a haemostatic agent, wound healing etc.

k) Collagen-Chitosan Membrane for Plastic Surgery and Dentistry

Collagen- chitosan membrane from the collagen of fish air bladder and chitosan from prawn shell prepared by Dr. M. K. Mukundan and his associates in the Biochemistry and Nutrition Division and was very well received by the medicos, as the trials done at the Calicut Medical College in Kerala. It finds extensive use in dental surgery also as a material for guided tissue regeneration. Dental surgery at present uses costly imported teflon membrane.

Upon contact with blood, chitosan induces coagulation. This property has led to the use of chitosan in bandages and dressings. Chitosan also has antimicrobial properties, and it is hoped that wounds bandaged with dressings containing chitosan will exhibit reduced infection rates.

l) Isinglass

Isinglass is prepared from fish maws (dried air bladder) (fig.6). It is mainly used for the clarification of wines, beer and vinegar. etc. Isinglass is also available in powder form.

Fig. 6: -Fish air bladder

m) Fish glue

Fish gelatin and fish glue are more or less same and can be prepared from fish skin and fish head (fig.7). It is the by-products of desalted fish skins. It is used in the gluing of wood, papers, cardboard and leather.

Fig.7:-Fish head

n) Food industry/cosmetics

Researchers have shown that a number of useful compounds can be isolated from seafood waste including enzymes, gelatin and proteins that have antimicrobial and antitumor capabilities. Chitosan, produced from shrimp and crab shell, has shown a wide range of applications from the cosmetic to pharmaceutical industries. (Arvanitoyannis & Kassaveti, 2008).

o) Shark leather

Skins of shark can be processed into fine leather suitable for manufacture of fancy items. The main component of skin is collagen. Shark skin has a protective coating of a calcareous deposit known as shagreen. Removal of shagreen is necessary as it makes the leather rough.

p) Biodegradable Polymers from Shrimp Shells

British and Egyptian scientists treated the shrimp shells and turned into a material known as chitosan, a biodegradable polymer that could be used for making shopping bags. Use of a degradable biopolymer made of prawn shells for carrier bags would lead to lower carbon emissions and reduce food and packaging waste (fig.8).

Fig. 8:- Shrimp shells

q) Fertilizer from fish by-products

Worldwide solid waste is an important and emerging environmental problem (Adamcová et al., 2016). Fish fertilizer is made from whole fish and carcass products, including bones, scales and skin (fig.9). Rather than let unusable fish products go to waste, these items are converted into nutrients for the garden. This product is then processed to remove oils and fish meal, which are used for other industries.

r) Biodiesel / biogas

The production of the biodiesel starts with the pressing of the fish waste Biodiesel from fish residue/waste could also promote more efficient utilization of aquatic living resources and generate additional income for fishers' and fish farmers' communities. These fish farms could provide income from the production and export of fish fillets and produce relatively cost-free local energy. It could therefore have a positive impact on food security and energy security.

Fig. 9:- Fish scale & skin

s) Natural pigments

Carotenoids are responsible for the colour of many important fish and shellfish products. Most expensive seafood, such as shrimp, lobster, crab, crayfish, trout, salmon, redfish, red snapper and tuna, have orange-red integument and/or flesh containing carotenoid pigments (Haard, 1992; Arvanitoyannis & Kassaveti, 2008). Shrimp waste is one of the most important natural sources of carotenoids (Shahidi et al., 1998).

3. Conclusion

The problem of fish processing wastes has increased day by day through increasing demand of the world fish consumption. The huge quantity of fish byproducts becoming a global concern which is affected by several biological, technological as well as socio-economic factors. One fourth of the total production of the fisheries discarded as wastes having a significant environmental concern. So management of fish wastes represents a challenging topic, since this suggests a possible way to solve environmental impacts of fishery discards. Applying various technologies the fish wastes can be utilized as a source of feeds for farmed fish, and promoting future aquaculture growth in a sustainable way. The valuable utilization of fishery wastes and by-products without discarding it allows the potential abatement of wastes and solve environmental problems. Fishery wastes and by.-products are an important source of a number of high-added valuable products, however possible risks related to the presence of contaminants must be considered before their utilization. Further scientific research can contribute to the sustainable exploitation of such fish byproduct resources, suggesting the most suitable methodologies and strategies for the valorization of these high added value products.

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FORTHCOMING EVENTS

Events	Date	Place & Correspondence
2021 International Agriculture Innovation Conference	3rd to 4th September 2021	TOKYO, JAPAN https://iaic2021.iaas.org.sg/
2021 Asia Environment and Resource Engineering Conference (AERE 2021)	14-16th October 2021	Singapore http://www.aere.net/
18th World Congress on Recycling & E-waste Management	20-21th October, 2021	Zurich, Switzerland https://recycling.insightconferences.com/
Waste Management and Valorisation for a Sustainable Future	26-28th October, 2021	Seoul, South Korea https://conferences.nature.com/event/3d762144-0d84-4f87-be38-f6f901f6cae7/summary
World Conference on Agro-Ecology and Crop Science	19-20th October, 2021	Manila, Philippines https://cropscience.agriconferences.com/
2021 8th International Conference on Biomedical and Bioinformatics Engineering (ICBBE 2021)	12th to 15th November 2021	Kyoto, Japan http://www.icbbe.com/

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