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SUSTAINABLE MANAGEMENT OF AQUACULTURE SOLID WASTE

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Abstract:
The aquaculture industry has become more and more significant as a source of protein for the growing population. With the increase in world population, demand for aquaculture is excessive and is expected to reach 62% of the total global production by 2030. Intense aquaculture produces fish waste, which has unfavorable consequences for the ecosystem if left untreated. With the increasing interest in the circular economy, utilization of discarded or underused aquaculture solid waste can become a sustainable approach for the conclusion of a circular bio-economy, with the generation of substance with excessively high added value .utilization and energy recovery from fish waste has become areas of interest for the global financial system.
Keywords: *Aquaculture, Fish Processing Waste, Chitin, Bio-Oil, And Circular Bio-Economy.*

Introduction:

Fish and seafood are primary sources of meals and nutrients and are part of a healthy, balanced food plan. The fishing sector provides earnings and livelihoods for millions of humans around the globe. A new world record in global fish consumption of 20 kg per capita, was attained in the year 2014 [1], but the rapid increase in fish production is associated with farm-bred instead of wild-caught fishes. The aquaculture waste produced is very heterogeneous in its quality and form depending on the locations and species [2]. Many factors influence the quantity and quality of the waste, consisting of fish length, season, rearing strategies, husbandry, catching, and production strategies. More than 50% of the residuals from the entire fish are unutilized as nourishment and involve close to 32 million heaps of waste [3].

Aquaculture is one of the fastest-developing industries for meal production globally, and its products make up a major supply of protein for human consumption in keeping with BoueletNtsama et al., (2018), aquaculture can be defined as 'the farming of aquatic organisms, inclusive of fish, mollusks, crustaceans, and aquatic vegetation, in selected or managed environments.' Because of the increased requirement for fish merchandise, aquaculture production is growing in terms of its share of total fish production to ensure delivery. In 2018, Aquaculture was envisioned to represent 46% of the entire fish production, with 52% of this cost for human consumption (Food and Agriculture Organization, 2018), and capture manufacturing was expected to rise every year (Freitas, et al., 2020; Ottinger, et al., 2016), attaining 62% by 2030 (Kibenge, 2016). This call for action is supported by the growth of the global populace and the decrease in capture manufacturing (Rahman et al., 2019). Even though the industry is growing to fulfill modern-day demand, it has introduced damage to the environment, leading to decreased land availability, water pollutants, eutrophication, poisonous chemical substances, and

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threats to the food chain (Troell et al., 2017). This kind of tradition also plays a key role in defining fish waste and deciding on the most effective technique to convert it into a usable product [9]. Huge fish farms produce good-sized quantities of particulate organic waste and soluble-inorganic excretory waste [10]. The disposal of aquaculture fish waste consists of fish offal, which includes heads, scale, tail, skin, lungs, bones, fins, and viscera. Fish waste is thought to be the primary source of biofuel in the near future. The growing production of waste and the necessity of applying renewable power assets pressure governments to enforce waste control applications. Further, the waste control area is obligated to reduce landfilling for residual disposal. Fish waste might be a crucial source of environmental infection, upsetting the need for specialized strategies for reworking fish disposal into a usable product. To date, there is restricted information from journal publications about the aquaculture industry, particularly regarding its demand and supply throughout the globe. The regulated environmental act governing the problems concerning contaminants is of high concern because of the applications of antibiotics, hormones, and vitamins for growth enhancement and their fate; first-rate practices adopted within the aquaculture industry; and the presently available remedy technologies for the aquaculture lifestyle. Therefore, this review paper seeks to close the above-mentioned gaps.

Sustainable Management of Aquaculture Solid Waste:

Fish waste control is a specialty of the era; it involves the treatment, specification, controlling, prevention, coping with, reuse, and ultimate residual disposition of fish waste. Aquaculture solid waste especially consists of aquaculture sludge (AS) and fish processing waste (FPW). In the aquaculture system, Aquaculture sludge continually comprises of residual feeds and fish feces, which are further divided into suspended solids and settled solids, and their yield is directly influenced by the aquaculture mode, feed dose, and feed coefficient, many directives have been initiated under the strategies of European Union, These directives discuss the control of aquaculture waste and the environmental influences of aquaculture industry [11]. Utilization and energy recovery from fish waste have become areas of interest for the global financial system. Specialized strategies and techniques were evolved to collect bio-methane, biodiesel, and bio-fertilizer from fish biomass. The production of Fish processing waste is inevitable given that about 70% of Fish needs to be processed before they are being offered or eaten. Fish processing Waste is mainly made from fish head, scale, viscera, fins, tail, and backbones, whose total production roughly consists of 20%–80% of the total fish weight, depending on processing techniques and fish species (Ivanovs, et al.2018). In line with a document through the United International Locations Meals and Agriculture Business Enterprise (FAO 2019), about nine million tons of FPW is discarded yearly. Furthermore, large portions of farmed fish died especially because of parasites and due to various diseases in a few nations (Solli, et al. 2014), which are also been categorized as FPW. for instance, there had been greater than 50 million dead salmon in Norwegian fish farms in 2015(solli,et al.,2015) these low price fish processing waste and useless fish contained ample nutrients which can be recycled and utilized as value-added products .but maximum FPW is typically discarded as waste will accelerate environmental pollution (susarani,2018). the development of the utilization of byproducts requires the implantation of guidelines for fishery regulation. aquaculture and associated industries produce waste, which is suspected to pose a big threat to the ecosystem. To mitigate pollutants, appropriate technology must be used. The conversion of those wastes and the simultaneous restoration of great substances before disposal come to

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be the principle intentions for fishery control [12]. In this review, we will deal with fish processing waste in aquaculture. In this context, the recent increased attention to alternative uses of fish by-products plays a vital role in economic growth and sustainable development. Since they are a rich source of value-added compounds such as enzymes, bioactive peptides, and biopolymers, and have many applications in various fields, several studies have analyzed their potential applications have been reported.

Collagen: Aquaculture waste processing is a promising source of collagen, which reduces the cost of manufacturing and has a positive effect on the environment. Collagen from fish waste processing is generally received by the strategies stated and defined below:

- Acid and alkali extraction
- Acid and enzyme extraction
- Extrusion cooking

Fish processing waste genuinely has the ability to be a good source of collagen. It is characterized by its high physicochemical functionalities and is utilized in various fields [13]. Similarly, Nibea japonica swim bladders [14], yellowfin tuna (Thunnus albacares) pores and skin [15], Scomber japonicus bone and skin [16], and shark cartilage [17], additionally confirmed antioxidant properties. Collagen from fish waste may also be utilized in the food industry as a meal additive and packaging [18]. Fish collagen has been used as a yogurt additive [19], collagen affects the proteolysis of milk proteins and conferred angiotensin I-changing enzyme (ACE) inhibitory properties; ACE has a key role in the law of blood stress in mammals and in the development of cardiovascular sickness; consequently, it represents a crucial target within the treatment of excessive blood pressure [20]. Collagen from Mustelus mustelus mixed with chitosan have been used to make a protective film to maintain nutraceutical products. Further, this film has antioxidant activities and will act as an anti-UV barrier [21]

Table 1. Collagen/gelatin from fish waste and their possible applications.

Compound	Byproduct	Source	Application	Activity/Conc.	Reference
Collagen	Skin	Tilapia Cartilage	tissue engineering	2% weight/volume	[22]
Collagen/ Polycaprolactone	Scale	Oreochromis sp. Cartilage	tissue engineering	12% weight/volume	[23]
Collagen/ polyvinyl alcohol	Not specified	Oreochromis sp.	Human periodontal ligament fibroblasts (HPDLFs), gingival fibroblasts(HGFs)	not specified	[24]

Chitosan:

Chitin is a polysaccharide that incorporates N-acetyl-D-glucosamine units. Chitin is present in the cellular walls of fungi, the exoskeletons of crabs, lobsters, shrimps, bugs, and the inner shells of cephalopods [25]. There has been excessive interest in chitosan, a deacetylated by-product of chitin. Chitosan has many biological properties, which include anti-cancer, antioxidant, and immune-enhancing properties, and for that reason can be implemented in diverse ways [26]. Kumari, et al., obtained and characterized chitin and chitosan from the scales of Labeo rohita by means of X-ray diffraction, elemental analysis, and Fourier-transformed infrared spectroscopy (FTIR). In addition to the research of Kumari and co-authors, other researchers have also investigated the capability of the L. rohita species, although they have focused more on the purification of chitosan, taking into consideration a

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compound with greater versatility of application. After a technique including deproteinization and demineralization, the yield of chitin was found to be 22.36%, while for chitosan, a final yield of 7.72% was achieved [29]. Muslim et al., strongly encouraged the possible advent of chitosan in different fields. These parameters make chitosan a suitable practical material that would be utilized in meals, biomedicine, cosmetics, and pharmaceutical applications. The most popular techniques for using chitosan are binding, thickening, gelling, and stabilizing. The studies out up to now are limited to evaluate the possible use of fish scales as a likely source for chitin and chitosan extraction. However, the promising outcomes strongly endorsed the exploitation and enhancement of this waste, whose production takes on growing connotations each year.

Table2.Chitin/Chitosan from fish waste and their possible applications.

Compound	Byproduct	Source	Application	Reference
Chitin, Chitosan	Scales	Labeo rohita	Not Specified	[30]
Chitin	Scales	*Cyprinus carpio I.*	Not Specified	[31]
Chitosan	Scales	*Anabas testudineus*	Coagulation-Flocculation Treatment for iron removal	[32]

Bio-oil/biodiesel:

The fish processing industry generates large quantities of fish oil. This valuable byproduct can be used as a renewable power source. Many studies have been completed on the use of fish oil as gasoline due to its high hydrogen and lower carbon content. It has decreased kinematic viscosity and a high flash point [33]. Bio-oil has suitable properties as a gasoline for diesel engines. As compared to standard diesel gas, it has a better heating Value and is better quality than methyl-esterified vegetable oil waste. Industrial fish processing operations generate a vast quantity of wastes, which include long-chain fatty acids, that may be applied in various markets [34] it can be effectively utilized in food, feed, industrial, and nutraceutical applications. The reason for the increasing interest in fish oil is that it consists of two vital PUFAs referred to as EPA and DHA, otherwise known as omega-3 fatty acids. The two main PUFA applications are feed, meal supplements, and biofuel production. The aquaculture area is an important marketplace and requires oils with low degrees of oxidation, low levels of contaminants, and better quality. The nutraceutical marketplace requires oils low in oxidation and contaminants but also with high levels of omega-3 fatty acids [35]. The omega-3 fatty acids are very widely recognized to have beneficial bioactivities together with the prevention of atherosclerosis, and arrhythmias, reduced blood strain, advantages to diabetic patients, safety against manic-depressive contamination, reduced signs in asthma patients, protection in opposition to chronic obstructive pulmonary diseases, alleviating the symptoms of cystic fibrosis, enhancing survival of most cancer patients, and reducing cardiovascular disease, [36, 37–39, 40–43].

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Table 3. Oil from fish waste and their possible applications.

Compound	Byproduct	Source	Application	Activity	Reference
Oil	Viscera	*LabeoRohita, Catla catla*	Supplement in animal feeding	Reduction in cholesterol (9.2 to 16.6%) and in triglyceride (1.5 to 3.1%)	[44]
Cod Liver Oil	Liver	*Cod fish*	Supplement in Bacterial Growth Media	14.8 U/mL (lipase production)	[45]
Omega -3, -6, -7, -9, fatty acids	Head, tissues	*Salmo Salar*	Antimicrobial	MIC: 25 and 12.5 (%v/v)	[46]

Protein Hydrolysate: Protein hydrolysis is an approach to breaking proteins into peptides and free amino acids. Recovery of protein has become an essential target for enzyme technologies due to the developing production and extensive use of protein-based material in the food industry. The main reason for producing protein hydrolysates is to enhance nutritional and biological costs and to produce high-priced merchandise. To acquire hydrolysates from aquaculture commercial waste, the technique is as follows: isolation or pre-remedies, hydrolysis, and protein recovery. In every technique, unique parameters must be fulfilled. Hydrolysates and purified peptides have been tested for bioactivities beneficial for the prevention and treatment of several human diseases. Numerous authors have said that amino acid type, function, and hydrophobicity have been considered to play relevant roles in peptide bioactivities [47]. The most common bioactivities are antimicrobial, antihypertensive, antioxidant, and neuroprotective activity [48]. Regarding antimicrobial activities, peptides from fish hydrolysates were especially active towards Gram-negative bacteria, along with Aeromonas hydrophila, Klebsiella pneumoniae, Salmonella enterica, and Salmonella typhi, and Gram-positive bacteria, such as Streptococcus iniae, Micrococcus luteus, S. aureus, and Bacillus cereus as suggested by Theodore and associates [49]. low-MW peptides have typically higher ORAC values at the same time as high-MW peptides have better FRAP and DPPH radical scavenging activities. However, it's tough to compare bioactivities between different peptides analyzed with various techniques due to the fact that radical scavenging activity isn't usually reported with the same unit. Recently, Vázquez, et al., [50], with the purpose to valorize farmed fish processing wastes, studied fish protein hydrolysates received through alcalase hydrolysis from turbot S. maximus head, viscera, trimming, and scale. Antioxidant and antihypertensive possible activity were analyzed and outcomes confirmed that visceral hydrolysates, containing peptides above a thousand Da and below 200 Da, were the most active, with scavenging activity of 65.15% (DPPH), 12.28 µg BHT/mL (ABTS) 8.03 µg Trolox/mL (Crocin), and 81.91% of ACE inhibitory activity. Several studies mentioned the antioxidant activity of hydrolysates of collagen and its derivatives obtained from different fish byproducts, including Gadous macrocephalous skin [51], shark cartilage [52], and yellowfin tuna (T. albacares) skin; particularly low-weight peptides (< 3 kDa) confirmed higher radical scavenging [53]. Collagen polypeptide from tilapia skin (MW< 3000Da) had protective results against injuries to the liver and kidneys of mice prompted via d-galactose by lowering oxidative stress [54].

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Table 4. Hydrolysates from fish waste and their possible applications.

Compound	Byproduct	Source	Application	Activity/Concn.	Reference
SJGAP	Skin	Skipjack tuna (Katsuwonus pelamis)	Antimicrobial	MECs 3, 26, 4.8, 25, 2.7, 9, 16 µg/mL against B. subtilis, M. luteus, S. iniae, A. hydrophila, E. coli, V. parahaemolytics, C. albicans	[55]
YFGAP	Skin	Yellow fish tuna (Thunnus albacares)	Antimicrobial	MECs 1.2, 6.5, 17, 8, 3, 3.2 µg/mL against B. subtilis, M. luteus, S. iniae, A. hydrophila, E.coli, V parahaemolytics	[56]
Hydrolysates with MW ≤1000 Da	Bone	Yellowtail	Antihypertensive Antioxidant,	1.5 mg/mL (ACE inhib.), ~35 mg/mL (DPPH)	[57]

Natural pigments:

Fish and aquaculture products have a diverse range of colors, which influences customers' selection to buy them. One of the most important sources of herbal carotenoids are shrimp and prawns. The increasing production of these types of seafood generates large portions of processed commercial waste. The yellow, orange, and crimson color of the shell, skin, and exoskeleton of sea creatures is a result of carotenoids, one of the most generally recognized herbal pigments. Carotenoids are responsible for the coloration of many crucial fish and shellfish products. maximum luxurious seafood, such as shrimp, lobster, crab, crayfish, trout, salmon, redfish, crimson snapper, and tuna, have orange-pink integument and/or flesh containing carotenoid pigments (Haard,1992) [58]. The grading or pricing of shrimp, salmon, rockfish, and snapper is immediately associated with the intensity of pink hue (Sacton, 1986) [59]. Shrimp waste is one of the most crucial herbal sources of carotenoids (Shahidi. et al., 1998). Shrimp waste, such as head and frame carapace, is used for carotenoid extraction with diverse natural solvents [methanol, ethyl methyl ketone, isopropyl alcohol (IPA), ethyl acetate, ethanol, petroleum ether, and hexane] and solvent mixtures (acetone and hexane, IPA and hexane) at numerous extraction conditions (percentage of hexane in the solvent mixture of IPA and hexane, the ratio of solvent to waste, and wide variety of extractions) (Sachindra, et al., 2001).

Table 5. Natural Pigments from fish waste and their possible applications

Compound	Byproduct	Source	Application	Activity	Reference
Astaxanthin	Head, shell, and tail	Shrimps&prawns	Food coloring agents, cosmetics	Scavenging activity against hydrogen peroxide	[62]
Carotenoids	Shells/carapace	Salmon	Antioxidant	Higher antioxidant activity of Microencapsulated astaxanthin from *Phaffia rhodozyma.*	[63]
Astaxanthin	Shells	Shrimp	Antimicrobial	Activity against *Escherichia coli, Bacillus, Staphylococcus,* and *Pseudomonas.*	[64]

Conclusions:

In the future, the aquaculture industry will supply more fishes with much less expenses. This indicates a powerful utilization of sources, growing profits, and sustainability practices on the one hand, and then again inputs disposal of, pollutants, and waste discount. Specific varieties of aquaculture waste could be dealt through numerous strategies. Moreover, the risky biomass is recycled and transformed into usable resources, electricity, or gas. Waste, which usually consists of fish viscera, has the largest capability to attain protein hydrolysate. A few of the most outstanding current uses of aquaculture waste are pigment, chitosan, and collagen isolation for cosmetics, meals, biomedical, and pharmaceutical enterprises. Recovery and obtaining the useful compounds from fish processing waste need extra inputs and outputs from the diverse activities concerned with processing waste.

.Aquaculture has advanced unexpectedly in its manufacturing to meet international desires because the human population and intake increase annually. With the increasing trend in manufacturing, a considerable amount of waste has been generated, and proper remedy and waste management want to be brought about so as to take care of environmental and mental influences and human well-being. Regulations and legislation have to be set up to ensure that aquaculture operations comply with standards and desirable exercises before waste is discharged into the surroundings. Modern technologies applied to lifestyle structures are capable of taking away waste in a safe manner; however, they nonetheless need to be optimized. These technologies may, in addition, be stepped forward with extra studies to locate more efficient solutions for zero-waste discharge.

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