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Exploring the Capability of Fish Waste-Derived Oil as a Sustainable Biofuel Option

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Abstract

The rapidly increasing global energy demand, along with the rapid depletion of non-renewable fossil fuels, needs a coordinated effort to investigate alternate and sustainable energy sources. Biofuels generated from diverse biological sources, such as biodiesel, bio-ethanol, bio-butanol and bio-hydrogen, have emerged as similarly fascinating alternatives in this environment. Among them, the exploitation of biological wastes, notably from fish, gives a compelling alternative. Despite substantial studies on biodiesel production from plant, algal and microbial sources, there is an enormous gap in understanding regarding the effective conversion of fish waste into biodiesel. This analysis assesses the sustainability of fish waste-derived oil as a biofuel source, highlighting the requirement for efficient biodiesel manufacturing processes. Despite its environmental as well as economic benefits, inadequate knowledge and limited attempts to convert fish waste to biodiesel restrict advancement in this sector. In compliance with PRISMA principles, a systematic review was performed. After an extensive search was conducted using the databases of PubMed, Web of Science and Google Scholar, 200 pertinent studies were found. Once the inclusion criteria were applied, 15 papers were chosen for examination. Unrealized potential for meeting waste management and energy demands is revealed by the investigation of oil produced from fish waste as a biofuel alternative. The Physicochemical parameters that affect fish oil production for biodiesel waste are discovered, providing information regarding essential components for effective conversions. The results encourage further investigations into fish waste as a useful resource for the manufacture of bio-fuels and they are by international initiatives to create environmentally friendly along with renewable energy alternatives.

Keywords: Fish Waste, Renewable Fish Oil, Biofuel Option, Chemical Parameters

INTRODUCTION

Biofuels could be produced from waste oil, animal dung, or food crops. An essential component of coastal towns that are isolated and rural is the seafood processing sector. (1) The bones, trims, heads, entire fish and skin are included in the effluents and they are combined with wastewater before that is disposed. The waste is either dumped into the maritime environment, dewatered and land filled or composted, or sent to a fishmeal factory (2). A growing number of people are interested in using fish by-products to make edible fish oil to meet the market demand for omega-3-enhanced goods, they can have a low-value use (fuel oil/biodiesel) (3). Fuel for vehicles that are derived from sustainable resources, like fats from vegetables or animals, is called biodiesel and it has benefits over petroleum diesel (4). It possesses natural lubricating qualities, limited sulfur content, raised flash points, increased biodegradability, lesser toxicity and fewer emissions (5). Despite their widespread use, alkaline catalysts have lower yields and they are more susceptible to contaminants such as water and free fatty acids, which can cause soap production (6). Although they have disadvantages including reduced reaction speeds and sensitivity to water, acid catalysts provide a solution for Free Fatty Acids (FFA) problems (7). A better option that minimizes by-products during purification and it is resistant to changes in oil composition is biocatalysts, especially enzymatic catalysis (8). Thermomyces lanuginosus (TLL) coupled with other lipases

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perform particularly well despite problems with inhibition and enzyme cost (9). The expensive food oils used in traditional biodiesel manufacturing raise both financial and environmental issues. In search of alternatives, the study investigates the use of enzymatic catalysis to turn fish oil into biodiesel, a by-product of the fish business (10). Achieving success with this strategy resolves environmental problems related to the disposal of fish waste.

The study (11) examined the efficacy, emissions and combustion properties of mixing n-butanol with biofuel made from Sterculia foetida at two distinct ratios (5% and 10%). The chemical composition includes a cyclopropane ring, which makes up more than 70% of sterculic acid. Biodiesel was produced from Sterculia foetida kernel oil using the base-catalyzed transesterification procedure. The article (12) employed green calcium oxide nanomaterials made from Boerhavia procumbens aqueous leaf extract to generate biodiesel from the unique, inedible seed oil of Monotheca buxifolia. The study (13) introduced environmentally beneficial substitutes for fossil fuels, fish oils are explored in this article since they share characteristics with petroleum fuels. The research (14) presented an initial examination of an environmentally friendly approach for producing bio-fuel from fishing waste. The article (15) used a mix of response surface approach and composite central design to increase the efficiency of enzymatic biodiesel manufacturing utilizing oil generated from fish waste. The Research (16) focused on optimal conditions found through optimization using the immobilized Thermomyces lanuginosus lipase, which served as the biocatalyst in this investigation. The study (17) described experimental biodiesel production of 75.3% was obtained with these parameters in a 24-hour response time. The final fuel had an acidity level that was higher than expected (0.8 ± 0.27 mg KOH/g), exceeding predetermined limitations. The article (18) used acid value, the process of producing enzymatic biodiesel through optimization showed encouraging results, surpassing industry standards in multiple important aspects.

METHOD OF SEARCH

Fishery Waste-Derived Oil as a Sustainable Biofuel Alternative was explored using PRISMA criteria. To find fish waste-derived oil as a sustainable biofuel option, we searched PubMed, Web of Science and Google Scholar. The analysis is interesting in that it leaves out reviews, fluid percussion and controlled cortical impact. Since fish wastes are high in fatty acid esters, they are the greatest source for producing biodiesel. Fifty PubMed, fifty Web of Science and one hundred Google Scholar results were produced by these searches. Figure (1) presents 15 pertinent articles following the integration of these lists and the removal of unnecessary references.

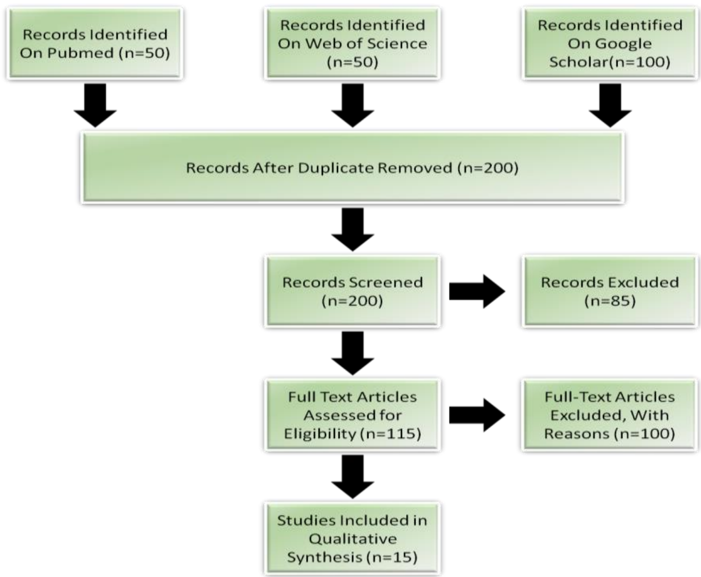

Figure (1). Flowchart of Methods(Source: Author)

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The Process of Making Biodiesel from Wasted Fish

Animal, plant, algae fats and oils were the main sources of biodiesel production in the past. But because of their high fatty acid ester concentration, fish and their by-products fish waste components dumped along coasts are sorted using traditional selection processes into skin, internal organs, viscera, tails, fins and trimmings. Solvents used in fish oil extraction procedures and pre-treatment (19). The initial attempts to make biodiesel directly from waste fish oil were not viable from a business standpoint. By using hot distilled water as a solvent to extract free fatty acids, researchers improved the quality of oil from fish. Crude oil was taken out of fish excrement using techniques like squeezing, grinding, solvent extraction and creative devices. Fish oil extraction was done using a variety of solvents, such as hexane, boiling water and mechanical expellers. In addition, phosphoric acid was used in the tests to degum waste fish oil together with solvents including n-hexane and hexane (20). They were proven in scientific discovery to be better sources of biodiesel. Waste products from fish, including fat and oil content are influenced by various factors, including age, sex, health and nutritional status. Different parts of fish, including the meat, bones, head, fin, skin, intestines and tail, contribute differently to fish oil, which is high in long-chain polyunsaturated fatty acids like omega-3 (EPA and DHA) (21). The procedure for removing fish waste fats and oils to create biodiesel is covered in this section and it is shown in Figure (2).

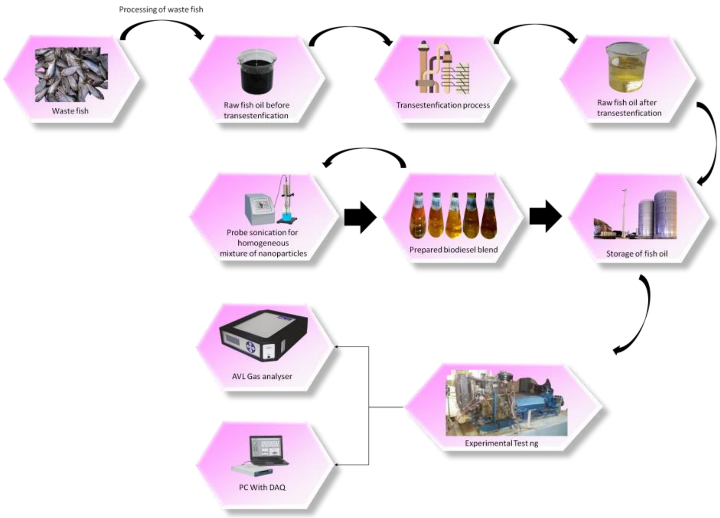

Figure (2). Diagram showing how fish waste is used to produce biodiesel (Source: Author)

To determine the purity of the biodiesel produced, it is necessary to comprehend the properties of fish oil that have been investigated and the different types of fatty acids. One common technique that combines etherification and transesterification is called transesterification. Producing biodiesel from trash requires the ideal extraction of fish oil with a methanol-to-water ratio (22). Yield levels are influenced by several factors during transesterification, such as the alcohol-to-oil ratio, catalyst type, temperature and reaction time. The transesterification methods and solvents used in the manufacture of biodiesel are shown in Table (1). Gas chromatography and engine testing are essential methods for determining the chemical composition of biodiesel and determining its capacity. Different techniques are used worldwide to generate biodiesel other than the conventional wet and dry rendering procedures (23).

Table (1). Fish waste biodiesel extraction using various transesterification techniques (Source: Author)

S. No	Reference	Method	Yield	Important Catalysts and Solvents
1	(33)	Enzymatic transesterification	25% Biodiesel in 24 hours	Lipase from Thermomyceslanuginosus

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				and methanol
2	(32)	Thermally-induced transesterification	efficient in the production of biodiesel	Methanol and Clay
3	(31)	Lipase-catalyzed transesterification	Novozym 435 had the highest yield of FAEE	Novozym 430 combined with ethanol
4	(30)	Esterification and transesterification	FAME yield is high	Sulfuric acid, sodium hydroxide and methanol together
5	(29)	Esterification and transesterification	This process yielded biodiesel with success	Ethanol, $\frac{SO^{42-}}{SnO^2} - ZrO^2$.
6	(28)	Esterification and transesterification	The biodiesel that was produced met industry standards worldwide	FFAs esterification with H_2SO_4 catalyst. using methanol for transformation and KOH as a kind of catalyst
7	(27)	Transesterification	High-purity biodiesel was generated	Crab waste was utilized in the preparation of methanol and CaO solid base catalysts.
8	(26)	Both esterification and transesterification	Biodiesel was produced from acidified salmon oil through a two-step procedure	In catalytic form, methanol and 1% H_2SO_4. As a catalyst, methanol and KOH
9	(25)	Transesterification	Compared to leftover frying oil, different biodiesel was observed	Methanol combined with NaOH
10	(24)	Transesterification and Combination using ultrasound	There was an improvement in the manufacturing of biodiesel	Heterogeneous catalysts like KOH/γ-Al_2O_3 and methanol with ultrasonic mixing
11	(23)	Transesterification	The biodiesel produced was assessed by ASTM guidelines	Phosphoric acid, sulfuric acid and methanol
12	(22)	Esterifying the FFA using an acid-catalyzed pre-treatment and alkaline transesterification	Two steps were used to create the biodiesel	Molasses with sulfuric acid. Catalyst: NaOH
13	(21)	transesterification catalyzed by a base with co-solvent assistance	In this method, the amount produced was maximized	Methanol, hexane and potassium hydroxide
14	(20)	Enzymatic transesterification	Engine efficiency was enhanced by the biodiesel that was obtained	It uses methanol as a catalyst to create lipase
15	(19)	Transesterification	Produced biodiesel complies with ASTM regulations	Methanol and KOH as catalyst

Because different fish species have different compositions, it is important to screen those regarding fats and oils (24). Prominent species including albacore, salmon and ahi, among others, are important. The energy sector can be made more sustainable by producing biodiesel from fish waste, such as Sardinella longiceps and Oreochromis aureus (25).

Production of Biodiesel from Diverse Fish Wastes

In light of the growing need for sustainable energy, biodiesel is a unique renewable fuel that produces less emission during combustion and holds great potential as a replacement for finite fossil fuels (26). Because fish waste is abundant around coastlines and in aquaculture, using it to produce biodiesel is advantageous. Because selected fish waste can be turned into biodiesel, an environmentally friendly and commercially feasible technology, traditional diesel production methods are expensive as well as inadequate. Fish oil compositions and fatty acid compositions have been studied, the fish waste and biodiesel generation from different fish species. Addressing the various uses for fish waste, including abandoned marine components and by-products from canning companies, for large-scale biodiesel generation, researchers have used a variety of procedures, including pyrolysis, transesterification and enzymatic processes (27). Generating biodiesel from a variety of fish wastes are shown in Table (2). These findings signal a major advancement in the direction of cleaner energy by demonstrating the adaptability of fish waste as a viable resource for the efficient and sustainable manufacture of biodiesel.

Table (2). Methods for Producing fish oil to Biodiesel (Source: Author)

S. No	Procedure for Manufacturing Biodiesel	Results	Citations
1	Fish waste oil is converted into defined biodiesel by an enzymatic method	After a 24-hour response period, a yield of 74.2% biodiesel was achieved	(33)
2	Using clay and heat transesterification, fish waste is transformed into biodiesel	More biodiesel was obtained	(32)
3	Utilizing immobilized lipases, waste fish oil is converted into biodiesel	A high FAEE yield was achieved	(31)
4	Using etherification and transesterification techniques, fish waste produced biodiesel.	Optimal biodiesel production was noticed	(30)
5	Fish waste produces biodiesel and oil rich in omega-3 fatty acids	The process of producing biodiesel using FAEE's saturated content worked well	(29)
6	Elevated free fatty acid content biodiesel derived from fish oil	International standards are met by the biodiesel produced through esterification and transesterification	(28)
7	Excellent biodiesel was created using a feedstock sourced from crab waste and a CaO catalyst.	High-quality biodiesel was prepared.	(27)
8	Fish waste is transesterified and then characterized to produce biodiesel.	As tested by ASTM, the biodiesel is produced in compliance	(26)
9	Sardine oil was converted into biodiesel by enzymatic transesterification, which improved engine performance.	Blending sardine biodiesel with diesel improved engine efficiency	(25)

10	Exploring co-solvent impact on Cyprinus carpio oil transesterification.	The greatest yield was achieved using co-solvent-assisted base-catalyzed transesterification	(24)
11	A two-step process was used to turn waste fish oil into biodiesel	Improved production of biodiesel was observed	(23)
12	Methanolysis of fish waste using acid catalysts produced biodiesel.	This technique allowed for the optimization of biodiesel	(22)
13	Utilizing catalyst and ultrasonic mixing, biodiesel is produced from catfish fat	The fat of tra catfish was used to produce biodiesel	(21)
14	Tested engine performance; biodiesel derived from discarded marine fish	Fish oil was used to produce a different type of biodiesel than leftover cooking oil	(20)
15	A two-step procedure is used to make biodiesel from fish oil	A maximum biodiesel production of 99% was achieved	(19)

The Impact of Physico-Chemical Elements on Fish Waste Biodiesel Production

One of the most promising feedstocks for biodiesel is fish waste, along with vegetable oils, especially soybean oil. Its potential is dependent on various parameters, such as the kind of waste, how well fatty acids are extracted and the amount of oil present (28). Fish growth in the first stage and fish oil extraction in the second are the two steps involved in the manufacturing of biodiesel shown in Figure (3). The key to setting up the right circumstances for extracting the oil from fish and producing biodiesel is choosing the right solvent, executing the pyrolysis along with transesterification processes and analyzing the molecular structure of fish waste. Efficient manufacture of biodiesel requires careful consideration of catalysts, solvent concentration and type of fish waste (29). The ability to separate and process fats from fish waste under precisely controlled circumstances is essentially what makes biodiesel production successful.

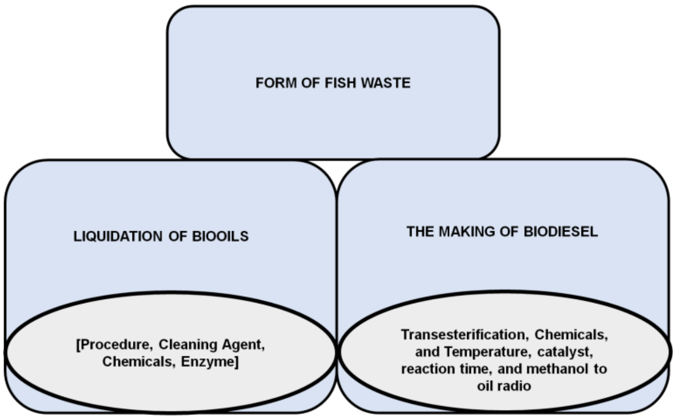

Figure (3). The essential components of fish waste biodiesel manufacturing (Source: Author)

The impact of temperature on the esterification process

To achieve etherification, several reaction periods (2, 3 and 4 hours) and temperatures (50, 60 and 70 degrees Celsius) were applied (30). A set reaction period of 60 minutes was observed throughout the esterification stage,

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along with the usage of a H_2SO_4 catalyst and a constant extra proportion of reactants with petroleum to methanol ratio of 1:5 throughout the experiment. A continuous $NaOH$ catalyst was used during transesterification and 600 rpm of stirring was used. Figure (4) illustrates how temperature affects biodiesel conversion during acid esterification.

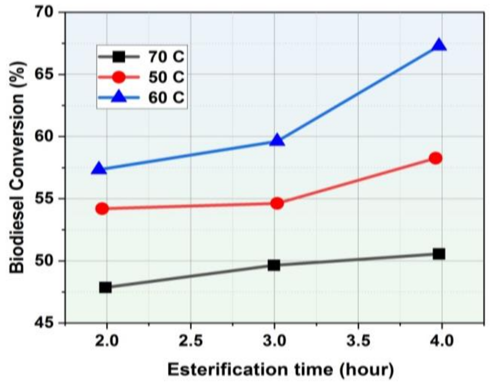

Figure (4). Temperature and duration of esterification have an impact on the conversion of biomass to fuel (Source: Author)

Longer esterification times of two, three and four hours caused a higher conversion of biodiesel, which peaked at sixty degrees Celsius (31). At 50°C, there were lower conversions than at 60°C (51.94%, 52.61% and 55.84%). Similar to 60°C, conversions were seen to be lower at 70°C (46.05%, 48.64% and 50.10%), which was attributed to increased temperature-induced methanol evaporation. The temperature at which conversion was most effective was 60°C, avoiding both too-high and too-low reaction rates.

The impact of acid promoter type

In the first esterification phase, the following conditions were kept constant: methanol ratio at 6:1, 2% H_2SO_4 catalyst, 60°C and 60 minutes (32). This was done to evaluate the effect of alkaline catalysts on transesterification. Next, NaOH, KOH and K_2CO_3 were used for transesterification at 60°C and 600 rpm of stirring. Figure (5) shows how different alkali catalysts affect the transesterification process's ability to convert biodiesel.

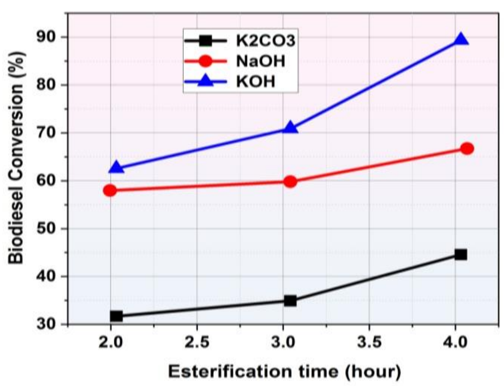

Figure (5). Impact of kind of alkaline catalyst on the conversion efficiency of biodiesel (Source: Author)

KOH produced the significant results, producing 62.34%, 71.48% and 88.98% at 2, 3 and 4 hours. The lowest conversion rates were seen in NaOH (56.87%, 57.41% and 65.08%) and the lowest in K_2CO_3 (28.10%, 31.66%

and 43.48%). In Methanolysis, KOH performed better than NaOH and achieved 96% conversion in 100 minutes at 65°C. KOH is preferred for reduced soap byproducts. Soap formation was reduced and transesterification was improved with a four-hour esterification (33). Lower biodiesel yields can result from side reactions caused by alkaline catalysts during transesterification. Esterification and transesterification of rubber seed oil effectively reduce free fatty acid content to produce biodiesel with less than 3% FFA.

CONCLUSION

In conclusion, the exploration of sustainable alternatives is required due to the global energy demand that is growing and the depletion of fossil fuel reserves. This work assesses the feasibility of producing biodiesel from oil obtained from fish waste and looks at the physico-chemical parameters that affect production. Limited efforts obstruct progress in this field, despite anticipated benefits. By using a systematic review guided by PRISMA to identify knowledge gaps, the study highlights the significance of creating effective techniques for producing biodiesel from fish waste. There are several methods for transesterifying fish waste to create biodiesel, but KOH is the most effective. These findings highlight the underutilized potential of fish waste as a sustainable resource, bolstering global efforts to manage trash and develop environmentally acceptable sources of renewable energy.

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