LUMEN ET VIRTUS
ISSN: 2177-2789

FISH PRODUCTION AND THE POTENTIAL OF TILAPIA PRODUCTION IN BRAZIL AND IN THE WORLD: A SYSTEMATIC REVIEW OF ITS USE AS ENERGY AND FOOD

https://doi.org/10.56238/levv15n41-075

Submitted on: 09/22/2024 **Publication date:** 10/22/2024

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ABSTRACT
The need for new sources of renewable energy is something that is widely studied today. In several countries, the search for new sources of raw materials for biodiesel production is being evaluated and used. Among these sources is the use of animal fat waste. In this context, the use of fish waste is being evaluated and applied as an intensive source in the production of biodiesel. However, the development of technologies that can make the extraction of these fats feasible is still a determining factor in the full use of these wastes. The present study presents a review of the production of Nile tilapia, cultivated in captivity, as well as its use in the production of and application in the biodiesel production chain. This

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work, as it is a review of the potential use of tailings, used a systematic evaluation of the capitation of studies, market evaluations, government agencies, which made it possible to obtain data on the production and generation of waste. To this end, searches were carried out on journal platforms and websites that involve the fish production chain. Thus, the verification of this new source of biomass in energy generation becomes feasible for the development of new technologies that can add value to the tailings and reduce the environmental impacts caused by fish farming. The study points out that there is a significant opportunity in the use of fish waste for the production of renewable fuels, specifically, those that have a high lipid content, and it is possible to use it for the production of biodiesel.

Keywords: Literature review. Tilapia. Waste. Economic potential.

INTRODUCTION

According to Mota (2011), the growing concern about global warming has encouraged great discussions about the need to find new sources of renewable energy. The twentieth century can be characterized as the century most dependent on oil, since the energy demand is increasing for this product (Mota *et al*., 2009). Today's society has become accustomed to fossil fuel derivatives, becoming dependent on this non-renewable product. Products derived from organic matter comprise a large percentage of all processed products on the market. Petroleum products have been widely used since the middle of the last century, replacing wood, metals and even concrete, starting what we call petrochemicals.

The increase in the world's population is leading to the growing demand for new energy sources. The scientific and technological environment, together with the industrial environment, has sought new technological sources to meet the energy needs that grow every day. In this context, the use of alternative renewable energies has been shown to be an option to diversify the energy matrix, thus attributing greater local sustainability and preservation of reserves (Parente, 2003).

Due to the high levels of emission of polluting gases released by the combustion of diesel oil into the atmosphere, increasing the average temperature of the Earth's surface, and especially the greenhouse effect, there is great interest in seeking fuels that can partially or totally replace diesel oil (Filho *et al*., 2009).

In a strategic view of rising oil prices, together with the instability of the producers' supply and price policy, the risks of nuclear energy production (Suzuki, 2011; Morton, 2012, Nakamura and Kikuchi, 2011), renewable energy has emerged as a less impactful alternative to the global energy problem.

The use of fuels of vegetable or animal origin in diesel cycle engines is quite attractive. In this aspect, biodiesel has some advantages over fuels derived from organic matter (petroleum), such as: being free of sulfur and aromatic compounds, having a high cetane number, being oxygenated, having a higher flash point, having a non-toxic character and being biodegradable. However, it is the renewable character that makes it more interesting as a fuel, mainly due to the abundant existence of raw material (Ferrari *et. al.,* 2005; Knothe *et al*., 2006).

Therefore, research in the area of biomass reuse contributes to the search for a solution for the strands that covers environmental impacts, social development, raw material for biodiesel production and study of its economic viability. In this way, the study carried out will seek to fill another gap with regard to the reuse of fish and the introduction of new technologies.

From what has been exposed, so far, the objective of this work is to seek to present a complete study of the extraction of oil from Nile Tilapia tailings. For this, it will be necessary to study methodologies that make it possible to increase the production capacity of oils extracted from these tailings. Thus, the main focus of the work is the grouping of data that can develop a pilot system for extracting oil from Nile Tilapia viscera. After describing the system's capacity, production scales, expenses and implementation methodology, quantify the expenses and profitability that will make the project economically and ecologically accessible to small producers of fish in captivity.

METHODOLOGY

The present work, as it is a review of the potential use of tailings, used a systematic evaluation of the capitation of studies, market evaluations, government agencies, which would enable the obtaining of data on the production and generation of waste. To this end, searches were carried out on journal platforms and websites that involve the fish production chain.

DEVELOPMENT

It is estimated that in the year 2024 the world population will have already exceeded 8 billion people. Depending on the individual's profile (age, body weight, intensity of physical activity, etc.), daily protein consumption can vary from 0.8 to 1.3 g/kg/day (Grace et al., 2021). Considering an average protein consumption value of 1 g/kg/day and individuals with an average weight of 60 kg, we have a worldwide daily demand of 4.8x108 kg of protein per day (or 480 thousand tons of protein per day). Based on the fact that lean meat has about 22% protein in its composition, the demand for protein is very high, and protein enters the diet of each and every individual.

In this context of a very high protein demand, the consumption of aquatic foods has grown in recent years, mainly due to the need for a healthy animal protein source (Moura *et al*., 2016). This information is corroborated by the *Food and Agriculture Organization* (FAO), which states that between 1970 and 2015 fish production increased by about four times, reaching 168.8 million tons (FAO, 2015). One of the factors responsible for the sharp increase in fish production in Brazil was the creation of the Ministry of Fisheries and Aquaculture in 2009. Thus, fish farming corresponds to 81% of the total production of fish, mainly due to the support of government agencies and improvement of the technology of the production chain (Mota *et al*., 2018)

Lopes *et al*. (2015) show that the increase in the consumption of protein from fisheries reached 15% of all protein consumed in the world. This data is explained by the awareness that proteins of aquatic origin are indispensable for a balanced diet and an improvement of water infrastructure for fish farming. Leading to an annual increase in production of 3.2% (which exceeds the population growth of 1.6%). Thus, fishing activity as a source of protein is a promising resource.

Despite the exponential growth in fish production, fishing has not been able to meet the international demand for food in recent years (David *et al.,* 2021). This activity tends to increase in the coming years, since the high and growing demand is a reality, bringing to the agenda discussions about the sustainability of the activity and the environmental impacts that can be entailed.

Mota (2018) warns that, with the growing demand for protein of animal origin, extractive production and control in captivity have become the most commonly used form of production to ensure the need for food sources. Therefore, the production of fish in captivity continues to grow on all continents in general, being the main way to obtain fish (Valaddão *et al*., 2018). This trend is ratified by the increase in fish consumption, with the annual average consumption increasing from 9.9 kg in 1960 to 19.2 kg in 2012 (FAO, 2014).

This fact raises the alarm of the environmental impacts involved with the practice of the activity and how sustainability is threatened in the short and long term, since resources are allocated to the cultivation of animals. Depending on the type of fish that is being cultivated, if there is no adequate management technique, there may be contamination of water bodies, eutrophication (due to the release of excess nutrients), reduction of biodiversity, contamination with the entrails of animals, etc.

This discussion is directed to the type of management of the agricultural production system for the rational use of resources and proper disposal of waste. Lopes *et al*. (2012) in his work states that it is possible to achieve satisfactory results such as generating a source of income, employment, supply and poverty reduction through aquaculture in the semi-arid Northeast. In other words, the way in which the activity is carried out has to be studied more thoroughly, seeking economic and environmental balance.

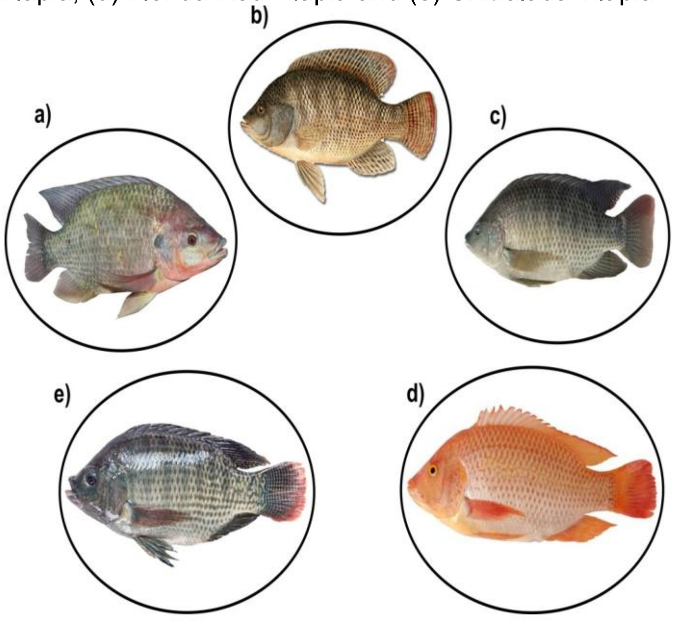
Fortunately, the scientific community has been joining efforts to implement methods that will mitigate environmental damage without compromising fish production. In this regard, the work of Alexander *et al*. (2016) that through the IMTA (*Integrated Multi-trophic*

Aquaculture) method managed to maximize the positive aspects and at the same time reduce the negatives and thus promote a more sustainable aquaculture of fish production.

In view of what has been presented, we have two distinct scenarios. The need for an economically viable alternative that will produce protein of animal origin in quantities and qualities compatible with the market and a form of sustainable management in order to minimize the environmental and social impact. In this context, Nile tilapia (*Oreochromis niloticus*) emerges as a promising alternative. Myers *et al*. (1997) came to the conclusion that climate change and alterations in the aquatic environment were responsible for the precipitous drop in fish production. Therefore, the choice of a culture resistant to environmental inclement weather is of paramount importance, and it is in this context that Nile tilapia is presented.

Some sources indicate that tilapia was introduced in the country with the objective of containing the proliferation of aquatic macrophyte algae and others to populate dams in the northeast region by the DNOCS (National Department of Works Against Droughts) in 1971 (Figueiredo Junior; Valente Júnior, 2008). The main types of tilapia introduced in Brazil were Rendalli Tilapia, Zanzibar Tilapia, Nile Tilapia, Florida Red Tilapia and Chitralada Tilapia (Mota 2018), described in Figure 01.

Figure 01 – Main types of tilapia introduced in the country prepared by Mota (2018) - (a) Rendalli Tilapia, (b) Zanzibar Tilapia, (c) Nile Tilapia, (d) Florida Red Tilapia and (e) Chitralada Tilapia.



Barros-Castilho, et al. (2020) affirm the economic viability of tilapia culture. These researchers found satisfactory economic indicators (Net Present Value (NPV) and Updated Net Present Value (NPV)) for tilapia farming for scenario A (fish weighing 700 g with a value of 1.34 $/kg) and for scenario B (fish weighing 1100 g with a value of 1.46 $/kg) for cultivation areas of 1, 2, 3, 4 and 5 hectares. On the other hand, tilapia cultivation is also indicated and promoted by state and federal governments, which bring as an alternative to improve poverty rates and levels of food security in regions marked by low development rates and adverse environmental conditions (Sampaio; Batista, 2004). These promising characteristics (in the economic and social sphere) make Nile tilapia the second most cultivated fish in the world, with emphasis also on its nutritional value, resistance to diseases, and adverse environments (FAO, 2020).

In 2017, Brazil produced about 283.25 million tons of tilapia, being among the four largest international producers (China, Indonesia and Egypt) (PEIXEBR, cahú). This is mainly due to 5.5 million hectares of fresh water (reservoirs) and a coastline of 8,500 km (with a total of 12% of the planet's fresh water) (IBGE, 2011), that is, an enormous water availability for the cultivation of fish *in natura* and in captivity. In order to serve the 3 main market niches (fresh fish, salted fish and salted fish fillet) and simultaneously give adequate disposal to the tailings (mainly offal) that proves to be a challenge (Barone *et al*., 2016). Appropriate forms of reuse and disposal of waste (viscera, carcass, head, skins, bones, etc.) from fish processing must always be taken into account. Considering that depending on the species of fish, these residues can vary between 50-70% by weight in relation to fresh fish (Bezerra et al., 2014). Yahyaee et. al. (2013) state that 2/3, by mass, of all fish is discarded as waste. Waste that can, through the appropriate recovery process, become products with high added value. This value reached 250 million tons per year, a value that tends to increase.

Today, the main techniques for reusing fish waste are for the production of fish meal, fish oil, fish silage, biodiesel and use in biodigesters (Mota, 2018). Highlighting the production of biofuels due to the high lipid content contained in fish viscera. Andersen and Weinback, *et al*. (2010) bring the alternative of using fish animal fat as a promising input for the production of biodiesel, suggesting that the production of biofuels from fish farming waste is a potential alternative to achieve sufficient production to reach the 5.75% of mixture required by the European Union in petroleum fuel.

With regard to the expansion of biofuels from the implementation of public policies to promote production, technological and market development at the national level, it is worth emphasizing the National Program for the Production and Use of Biodiesel (PNPB). This program seeks incentives to attract the private sector to the sustainable production of biodiesel, thus creating a growing market through social inclusion and regional and technological integration (Sampaio; Bonacelli, 2018). This program created in 2005 implemented the "Social Fuel Seal", this resource brings tax incentives to companies that purchase raw materials and products from companies that fit a certain profile. In this way, renewable technologies are fostered aiming at the energy transition from conventional energies, usually from fossil sources, to a renewable matrix. The oil crisis of the 70s, where the price of a barrel of oil increased four times in a short period of time, shows the need for investments in non-renewable energies so as not to suffer from the seasonality of fossil fuel prices in the market.

Directing the study to the production of biodiesel from fish waste, those that can be found triglycerides in fatty oils in sufficient quantities such as meat, head, fin, skin, viscera and cause, Prasanna *et al*. (2023) outlined this process into: *i)* treatment with solvents to transform fish waste into fish waste oil, *ii)* methanol, catalyst (acid or basic), temperature and time to transform fish oil into biodiesel through the transesterification reaction and finally *iii)* washing, filtration and drying to adapt the biodiesel to the patterns of use.

The costs of extracting and refining the inputs for the production of biodiesel correspond to 70-80%. Due to these very high costs, Zhang *et al*. (2020) suggested carrying out an *in situ* transesterification of fish processing waste. In other words, there is the possibility of using biomass in its raw state, or only dehydrated, for the production of biodiesel, eliminating a costly step in the process. Another benefit pointed out by the authors is that in *situ* transesterification produces waste that can be used as animal feed, further reducing production costs. Grass carp inputs were used to perform in *situ* transesterification. Despite a challenging input quality (high concentration of free fatty acids, solid impurs and pigments) a satisfactory biodiesel quality was achieved.

Biodiesel is a type of fuel that has characteristics that are close to petroleum diesel. The conventional biodiesel production route consists of consecutive alcoholises that transform the triglycerides present in the feedstock (vegetable oil or animal fat) into fatty acids and alkyl esters (i.e., biodiesel and glycerol) (Guldhe *et al*., 2015). Today, the main route for the manufacture of biodiesel on an industrial scale has been the basic catalysis using Sodium Hydroxide (NaOH), mainly due to the higher conversion rate of triglycerides into methyl esters and much lower reaction time (between 4 and 10 hours of reaction) (Singh; Kumar, 2018). Although there is a need for reaction control to inhibit the saponification reaction and contamination with catalyst.

The great appeal that makes biodiesel so important (in the social, ecological and economic sphere) is the possibility of being produced from diverse and varied sources and being able to be mixed with diesel (in any proportion) or be used pure. Considering that 70% of biodiesel is produced from soybean oil, this fact shows how urgent it is to diversify production to other inputs (Coppola *et al*., 2021). In view of what has been previously exposed, the potential for fish production (with emphasis on Nile tilapia) and the use of fish entrails for the production of aviation fuel as a sustainable alternative for this waste are discussed in the following sections. In this way, an effort is made to close the production chain both for the production of protein from fish and for the appropriate destination for waste for the production of fuels.

POTENTIAL OF FISH PRODUCTION

National production in 2022 reached 860,355 tons, an increase of 2.3% compared to 2021, this increase is mainly due to the improvement of the production chain (despite high input costs). Figure 02 shows this trend since 2014 (since when these data began to be cataloged), where tilapia corresponds to almost 64% of this share, with some states standing out in production (PeixeBR, 2023). These data indicate the strength that the activity plays in the country. Part of this success is explained by the possibility of cultivation in the most diverse ecosystems, such as the Amazon basin and the semi-arid Northeast, and drinking water reservoirs, in which the exotic Nile tilapia has adapted very well (Lopes, 2018). Table 01 shows the production of tilapia in Brazil by state in 2022.

Figure 02 – Fish production in Brazil between 2014 and 2022 (PeixeBR, 2023)

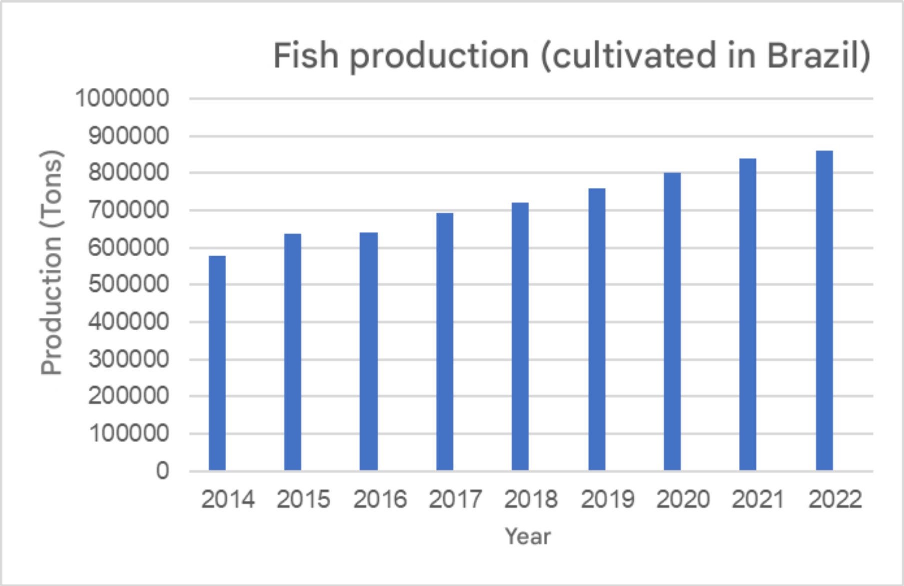
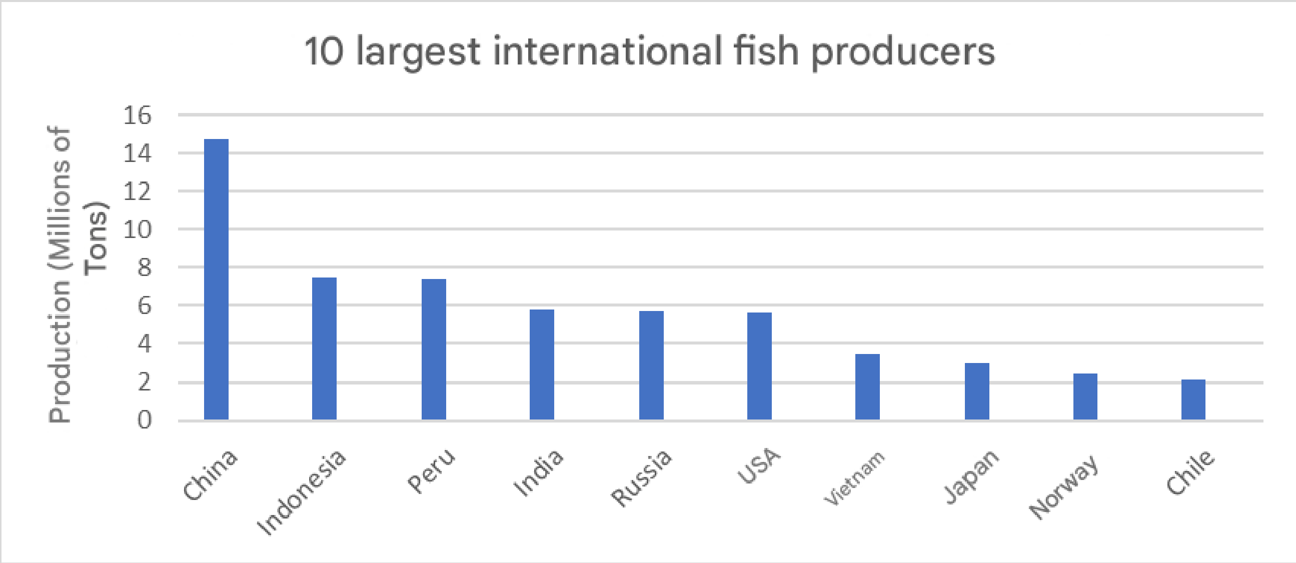


Table 01 – Tilapia production in Brazil by state in 2022

STATE	TILAPIA PRODUCTION (TON)
Acre	60,0
Amazonas	0
Alagoas	9.850,00
Amapá	80,00
Bahia	29.670,00
Ceará	6.800,00
Distrito Federal	1.850,00
Espírito Santo	17.000,00
Goiás	21.500,00
Maranhão	5.200,00
Minas Gerais	51.700,00
Mato Grosso do Sul	32.200,00
Mato Grosso	4.100,00
Pará	800,00
Paraíba	3.100,00
Pernambuco	31.900,00
Paraná	187.800,00
Piauí	9.800,00
Roraima	0,0
Rondônia	0,0
Rio Grande do Norte	2.800,00
Rio de Janeiro	3.100,0-
Rio grande do Sul	9.000,00
Sergipe	1.200,00
São Paulo	77.300,00
Santa Catarina	42.500,00
Tocantins	750,00
TOTAL	**550.060,00**

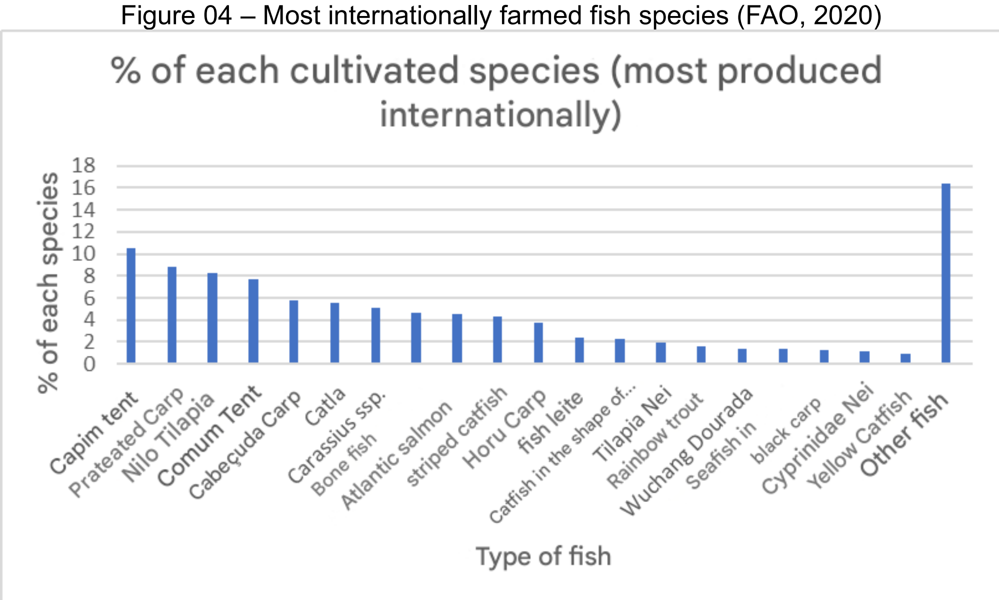
The data cataloged by PeixeBR (2023) shows that of the 860,355 tons of fish produced in 2022, almost 64% are tilapia. Pointing out that this crop has great strength in the national scenario (and corresponds to a large part of exports) and the State of Paraná corresponds to almost 34% of the entire market. Despite the data exposed that show that Brazil had a sharp growth, the country is far from having international prominence for fish production (not even participating in the top 10 largest producers). Occupying the simple 13th place internationally in the ranking of largest producers. Data extracted from the 2020 FAO (*Food and Agriculture Organization on the United Nations*) report show the production data (in millions of tons) of the 10 largest producers for the year 2018 (Figure 03).

Figure 03 – Production data (in million tons of fish) for the world's 10 largest producers for the year 2018 (FAO, 2020)



Despite the sharp increase between 2014 and 2022 and having a huge availability of available area, Brazil is far from entering the *ranking* of countries that produce the most fish in the world. In view of the analysis of Figure 03 Table 2, it is coherent to know what makes China so far ahead of all other countries, the main factors are: length of coastline and abundant resources, investment in aquaculture, technology and innovation, high global demand and favorable government policies. Having already been presented an overview of national production and the countries that are in the top 10 as largest producers, it is worth specifying which are the fish cultures with the greatest representation at an international level. These data are cataloged by FAO, 2020 for the year 2018, described in Figure 04.

Figure 04 – Most internationally farmed fish species (FAO, 2020)



At the international level (unlike the national case, in which tilapia is by far the most cultivated species) the cultivation of carp stands out. It is mainly due to the value of this product in the international market, despite being a relatively demanding species for the quality of the water used (FAO, 2014).

POTENTIAL FOR WASTE REUSE

As pointed out in the previous topic, China alone produces a value above 14 million tons of fish per year and that on average 50% of this value in mass generates waste (dark parts, scales, head, bones, viscera, carcasses, etc.). In other words, China alone produces 7 million tons of waste per year. Martins *et al*. (2011) reveals how costly the process of waste disposal and/or processing is for producers, showing that waste removal corresponds to 83% of costs, internal handling represents 44% of costs, storage in refrigeration chambers 64% and transport and disposal (generally public landfills) correspond to 44% by mass of the waste produced in the activity.

This frightening, potentially polluting value shows the need to foster technologies that promote an adequate destination for waste in addition to the production of inputs with added value for the production chain. In other words, it seeks to add value to fish waste in addition to reducing the social and environmental impacts produced by them.

One of the wastes that are produced in abundance is the effluents from fishing practices, Bunting (2006) in his work focuses on the need for a rational reuse of wastewater from aquaculture involving policy makers in the spheres of health, agriculture, urban planning and the environment. This work is essential to safeguard livelihoods and mitigate risks to health and environmental conservation.

The environmental damage resulting from the activity begins at the implementation stage, mainly due to the preparation of the soil to receive the breeding captivity, degradation of fauna and flora. This brought an alert to the public authorities of the need to establish guidelines for a sustainable practice of the activity. In this work, the General Policy of the European Union (European Commission, 2013) is highlighted, having as its basic objective guidelines for the social and economic future of European fisheries. Bringing the need to make the best possible use of the biomass resources obtained in the fishing activity. To achieve this goal, processes of valorization of fish by-products were presented as key to meet this policy required by the European Union. To this end, the international scientific community has been developing technologies for the reuse of waste for the production of a variety of products such as chitin, chitosan, collagen, gelatin, fatty acids, taurine, protein, antifreeze, enzymes, fish oil meal, biofuels, etc.) (Lopes et al., 2015).

In view of the variety of products from the processing of fish waste, we highlight the production of biodiesel from fish oil. Oil from fish is composed of a variety of fatty acids (saturated, mono and polyunsaturated) (Maia Junior; Sales, 2013), making this input an excellent candidate to serve as a reagent for the production of biodiesel from the transesterification reaction, mainly due to its high lipid content (Andersen and Weinback, *et al*., (2010)).

Jaiswal *et al*. 2024 present the fishing and processing industry for biodiesel production as a new opportunity to boost the local economy and reduce the harmful effects of fossil fuels (mainly by reducing the emission of carbon dioxide and nitrogenous compounds). In order to increase the generation of jobs and income in fishing communities and use biodiesel locally for the locomotion of vessels and in the fish processing industry.

There is a significant opportunity in using fish waste for the production of renewable fuels. More specifically, those that have a high lipid content, and it is possible to use them for the production of biodiesel. This fuel can be used directly by local producers or sold blended, in any proportion, with petroleum diesel. Leading to the conclusion that there is an opportunity to implement an important agricultural industry (Papargyriou *et al*., 2019). These authors produced biodiesel from cod liver oil using the basic route and catalyst of 6Ca/Al, and were able to achieve results in accordance with the current legislation of the European Union, for use in countries with cold climates.

Another appeal for the use of oils of animal origin in contrast to oils of vegetable origin is that those of animal origin have a longer carbon chain length. In other words, biodiesel from this raw material can cause an improvement in diesel engine performance and a reduction in pollutant emissions (Yahyaee *et al*., 2012).

One of the key steps for the production of biodiesel from fish entrails is the oil extraction process, which goes through the transesterification reaction for the production of biodiesel and glycerol. The main challenge of this stage is to maintain the characteristic of the oil, avoiding decomposition and thus the degradation of the quality of the raw material. Where the methods of oil extraction are divided into physical, chemical, and biological (Jaiswal, 2024). Mota (2018) in his work outlined the main route of oil production from fish viscera, namely, in sequence, we have cooking of the raw material, followed by the sifting stages in which we obtain crude oil. Once the crude oil is degummed, we have the neutralization stage (pH correction) followed by a washing stage. Subsequently, dehumidification is carried out followed by a filtration stage until the filtered oil is obtained.

Yahyaee *et al*. (2012) present biodiesel produced from oil from fish processing as a precious renewable energy source. These researchers claim that 50% by mass of all processed fish is waste and that of this figure between 40-65% is bio-oil. Considering that each liter of fish oil produces 0.9 L of biodiesel, we have that the potential of the technology is enormous. These authors were able to produce biodiesel with good characteristics for use in internal combustion machines and highlighted the decrease in the emission of pollutants.

Here the work of Garcia-Moreno *et al*. (2014) that studied the process of optimizing the production of biodiesel from fish oil. Optimizing important operating parameters in the transesterification process namely temperature, methanol mole fraction and reaction time. In this way, obtaining biodiesel with excellent characteristics for use.

The literature emphasizes the potential of using fish waste as a renewable source for biodiesel production, promising to be an efficient fuel and an excellent substitute for petroleum diesel (Qureshi *et al*., 2019). Jaiswal *et al*., (2024) emphasize that the waste produced by the fish industry has the potential to produce a range of products such as animal feed, nutrient production, cosmetics, biomaterials, fertilizers, biogas, and biodiesel. However, these authors emphasize that the enormous amount of free fatty acids indicates a potential for the production of biodiesel to help in waste management. Being one of the best ways to transform waste into valuable products. On the other hand, the feasibility of the process depends on many factors, the main ones being the efficiency of fish oil extraction, biodiesel production yield and quality of the oil produced.

Fossil fuels provided more than 80% of total energy between the years 2013 and 2035 and are the main components for power generation in extremely polluting industries, including the automotive, transportation, chemical, and other materials industries (Varaprasad *et al*., 2022). Heidari-Maleni *et al*. (2024) present biodiesel as an alternative to reduce the consumption of fossil fuels and thus reduce the emission of nitrogen oxides, ammonia and other pollutants, which contribute to atmospheric pollution and other environmental issues (greenhouse effect, acid rain, etc.). These authors went further, through a Life Cycle Analysis (LCA) in order to evaluate the environmental sustainability of products and processes evaluated in the process of producing biodiesel from fish oil. Revealing several important and advantageous aspects for the production of biodiesel from fish oil (as opposed to petroleum diesel), such as acidification, potential emission of greenhouse gases, photochemical oxidation, eutrophication of water bodies, abiotic depletion of fossil fuels and depreciation of abiotic elements.

The increase in emissions of air pollutants (mainly carbon dioxide, HCx and NOx) and the depletion, or difficulty of exploiting fossil fuels, has caused a series of concerns at the international level. Therefore, the use of biofuels in search of climate sustainability is an important point to be addressed. Another appeal for the use of biodiesel versus petroleum diesel is that the carbon dioxide (CO_2) released by the burning of biodiesel is constantly recycled by the plants. In other words, an efficient way to avoid the release of CO_2 released by the combustion of fuels in internal combustion engines is the use of renewable biofuels with biodiesel (Bergthorson; Thomson, 2015). Katrirvelu *et al*. (2017) states that the efficiency of biodiesel engines is slightly lower than petroleum diesel. However, HC, CO and soot emissions are lower than those of petroleum diesel and biodiesel is an eligible fuel for several government incentive plans that can lead to steep savings when blended with petroleum diesel.

One of the biggest challenges in the production of biodiesel from oil extracted from fish entrails is the high acidity. Kara *et al*. (2018) state that a concentration of free fatty acids higher than 0.5% causes a series of setbacks, namely, soap formation (saponification reaction), inhibits the separation between biodiesel and glycerol and decreases the yield of the final products. To overcome this problem, the authors indicate a pre-treatment stage of acid esterification followed by a basic transesterification, thus producing biofuels that meet the standards required by the main regulatory agencies.

To get an idea of the potential of this technology for the production of biodiesel (which can be used pure or mixed with petroleum diesel in any proportion), we will estimate it with the following information;

- National annual fish production is 860,355 tons, with Nile tilapia accounting for 64% of this total (PeixeBR, 2023);
- 7.97% by mass consists of viscera in the Nile Tilapia species (Anbel, 2011);
- The average yield of the oil extraction process from fish entrails is 50.3 ± 3.3% and the yield for the production of biodiesel by the ethyl and methyl routes are respectively 89.5 ± 0.32% and 96.9 ± 0.17% (Dias, 2009);
- Biodiesel density (900 kg/m3);
- National annual diesel demand of 66 billion liters for the year 2023 (source: https://forbes.com.br/forbesagro/2024/03/brasil-importa-menos-diesel-com-mais-biodiesel-e-maior-producao-local-diz-stonex/#:~:text=Em%20contrapartida%2C%20a%20StoneX%20estima,a%20máxima%20do%20ano%20passado.)
- From the study of the diesel life cycle, it is found that there is a reduction in net CO_2 emissions by 78.45% with the use of biodiesel. In other words, 0.578 tons of CO_2 per m3 of biodiesel used are not emitted into the atmosphere (Coronado, *et al*., 2008)

From these data, it can be seen that the production capacity of biodiesel from Nile tilapia viscera alone is around 276965481.6 L or 276.96 million liters. In other words, the production of biodiesel from viscera corresponds to 0.4% of the total production of diesel from petroleum. This corresponds to a non-emission of 144077.4 tons of CO2 into the atmosphere. In addition to biodiesel from fish entrails, it stands out for having excellent lubricating characteristics and very low levels of NOx emissions (Christensen and Bimbo (1996) and Wang *et al*. (2008)). In addition to having already been proven through quality tests in terms of combustion in ethyl biodiesel obtained from fish oil that it is an efficient substitute for petroleum diesel in any proportion (Sakthivel *et al*., (2014))

These data show the potential that the production of biodiesel has for the production chain, being an alternative, so that it can gradually be an additive to petroleum diesel, becoming less and less hostage to vegetable oil sources. This alternative comes in response to the high costs of disposing of waste from fish processing (which is most often done without any sanitary control) and the need for the most diversified sources possible (vegetable oil and animal fat) for the production of biodiesel (Mota, 2011). In this way, avoiding problems with high input prices that have marked seasonality. Therefore, a source of income is generated from an environmental liability. This alternative has its feasibility corroborated by MOTA (2018) who attested to the economic viability of the fish oil extraction unit followed by the biodiesel production unit.

CONCLUSION

The present work, in its priority development, proposes to carry out a survey of the production of fish, especially tilapia, and from the surveys, to quantify, qualify, the potential of these residues for the production of biofuels, for the study of biodiesel. It was observed that there is the potential for production, conversion of waste in the aquaculture industry is extremely high. However, there is a need for several factors that make it possible to exploit this potential. Among them, water is the primary factor for confirming production efficiency. In this way, with the vast potential of water resources in the country, Brazil, with a production of 860,355 tons in 2022, is one of the nations with the greatest capacity to produce on a global scale. Therefore, from this production, the generation of waste will provide the generation of new products, for the case under study biodiesel, which may make a new production chain viable.

ACKNOWLEDGMENT

The authors thank the National Council of Science and Technology (CNPq), which the resources for this project were obtained in the call for fuels for the future.

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