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Characterization of Residual Biomass and Feasibility Analysis for Fish Feed Production

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Abstract **-** Global fish consumption reached 20.5 kg per capita/year in 2018. The increasing demand for fish in recent years has contributed to a rise in fish industry production, which has also led to an increase in fish waste throughout the production chain. According to the Food and Agriculture Organization of the United Nations (FAO), approximately 205 million tons of fish are produced globally, with around 50% of this total being considered waste. The production of fish waste from the processing and marketing stages has generated a quantity of organic matter that, if utilized, can be processed into high-quality oil and used in industries for potential fishmeal, fish feed, cosmetics, and so on. In the search for less polluting alternatives, with the aim of minimizing the environmental problems caused by fish waste, there is a need to establish waste utilization systems that are both economically viable and energy efficient. The viscera, scales, and heads of fish are often discarded, as this organic waste can cause the proliferation of diseases and undesirable animals. As an alternative way of treating this waste, a study was carried out on this biomass in the formulation of fishmeal. The aim of this study is, therefore, to reuse this waste by extracting lipids from the residual oil and producing a nutritionally rich fish meal. To this end, the project involved collecting waste from the local market, extracting and producing the oil using the Soxhlet method, and drying the biomass in an oven. The study showed that fishing and marketing have become major activities in recent years, especially in the region studied, Pinheiro-MA (Brazil). However, the waste and lack of proper treatment are harmful. The study revealed the need to adopt hygienic and sanitary treatment, public policies, and a proposal for the reuse of residual biomass.

Keywords**:** Co-products, fish, waste, enriched flour, extraction methods.

1. Introduction

In 2020, global fish production reached an unprecedented milestone of 178 million metric tons, with aquaculture contributing almost 50% of this total. This trend is expected to continue, as projections suggest that aquaculture will account for 60% of global fish production by 2030 [1].

Fish is a rich source of functional elements such as polyunsaturated fatty acids, polysaccharides, minerals, vitamins, antioxidants, enzymes, bioactive peptides, and various micronutrients, which help reduce the risk of chronic diseases such as heart disease and cancer [2,3]. Additionally, fish production generates waste and by-products that can be transformed into functional food ingredients with high added value [4]. This promotes food sustainability and stimulates economic activity, positioning fish as an important nutraceutical source with broad applicability.

The visceral organs of ichthyological species represent a substantial and underexplored reservoir of bioactive substances. Moreover, fish's gastrointestinal microbiome can biosynthesize fatty acids, vitamins,

minerals, and crucial or short-chain enzymes. Thus, it serves as a potential source of probiotic candidates and generates bioactive compounds that exhibit antibiotic, biosurfactant, and bio-emulsifying properties [5]. The increase in fish production has contributed to the large amount of waste derived from fish, which, throughout the various stages of the fishing production chain, represents a raw material that can be reinvented. Waste from the fish industry is rich in organic and inorganic compounds, raising concerns about the potential environmental impacts of improper disposal of this material [6,7].

Seafood is a rich source of micronutrients, minerals, essential fatty acids, and, in particular, proteins. The high protein content found in fish means that the primary use for processing waste is the production of fishmeal for animal feed, a product that contains approximately 70% protein and offers the advantage of low cost [8,9].

Fish processing waste includes the head, liver, bones, skin, viscera, carcass, fins, scales, tail, fish oils, crustacean shells and heads, and mollusc viscera [10]. In this context, fish waste can be collected and used to produce "by-products," i.e., secondary products with added value, such as fishmeal, which is a valuable ingredient in livestock feed, particularly for young pigs and poultry.

Fishmeal and fish oil (FMFO) can be produced using three categories of raw materials: i) whole fish that has been harvested, ii) by-products (i.e., viscera, heads, tails, and other anatomical structures) generated during the processing of fish intended for human consumption, and iii) production losses (i.e., by-catches, discards, and sick or dead animals) arising from fishing operations and aquaculture practices [11].

Thus, the residue constitutes a nutrient-rich compound. The aim of this study was to produce fish oil to enrich fishmeal in the municipality of Pinheiro-MA, thereby maximizing its use and minimizing waste.

2. Methods

2.1. Obtaining Biomass and Extraction

The viscera were randomly collected from the municipal market of the city, without considering the fish species. After extraction, the residual biomass was dried and stored. The waste was subsequently ground and homogenized using a Philco All-in-One Citrus 800W multiprocessor. The residual biomass was separated from the lipids and will be dried and stored for the subsequent stages.

Figure 1: (A) Offal residue processing; (B) Grinding the residue.

2.2 Physicochemical Analysis for Feed Production

Flour characterization tests were conducted to assess whether this product could be used as a raw material for fish feed production and to determine if it contains protein and other key parameters necessary to meet fish feed standards and regulations. Economic feasibility studies for the product: A comprehensive study was performed to evaluate the economic feasibility of the new product, identifying the main production bottlenecks.

2.3. Biomass Characterization

Studies on the use of residual biomass from fish waste (following the extraction of oil and compounds of interest) aim to understand the physical and chemical characteristics of this material, with the goal of evaluating its potential use in feed and cosmetics. The following analyses were conducted: water content, relative density, porosity, elemental analysis, and calorific value. The results obtained were compared with data from biomass used for bioproducts.

3. Results and concluding discussion

3.1. Physicochemical Analysis of Bioproducts

A qualitative study of the biomass was conducted to determine its composition, analyzing its protein, lipid, and moisture content, as well as the fatty acids, with a focus on their acidity, iodine, and saponification values, oxidation stability, water content, viscosity at 40 ºC, and density at 20 ºC for fishmeal production. These data are still under analysis.

3.2. Characterization of Residual Biomass

After the extraction of oil and compounds of interest, the parameters of water content, relative density, porosity, elemental analysis, and calorific value were analyzed and are still being determined for the project. The extraction process was carried out using two methods. The first method followed Bery et al. [12], where the material was heated in an oven for one hour at 105ºC. The second method employed the Soxhlet technique in accordance with IUPAC 1.122, using hexane as the solvent. Two 5g samples were weighed into cartridges, and the extraction lasted for 6 hours. The extracted oil was then placed in an oven to remove any potential solvent residues.

Figure 2: Oil extraction equipment (A) Greenhouse (B) Soxhlet

3.3. Protein Content of Residual Biomass

Quantifying the protein content of residual biomass is crucial for evaluating this waste in the context of developing new products for animal feed.

It should be noted that the sample obtained from the Soxhlet extractor was insufficient for analysis due to the extraction system, which involved fine extractors (less voluminous) and a cartridge for smaller samples. In this case, the sample did not meet the minimum required for the protein content analysis methodology.

Among the samples analyzed, the biomass extracted using the pressure cooker exhibited the highest protein content, at 47.46%, which was significantly higher compared to the sample obtained in the oven ($P<0.05$). In this study, the protein content was determined on the chemically modified samples as a result of lipid extraction, which may have reduced the protein value when compared to the raw residues.

When comparing the protein content observed in this study with that reported in the literature for fishmeal produced from fish waste, both variance and similarity were noted in the percentages found. Stevanato et al. [13] reported a protein content of 35.5%, while Souza et al. [14] found 33.95%. Rufino et al. [15] state that fishmeal can be used as a supplementary ingredient in feed formulations, particularly for aquatic organisms such as fish, shrimp, and other animals, yielding satisfactory results.

Therefore, based on the protein potential of the biomass demonstrated in the samples from the current study and the findings in the literature, the residual material may indeed be valuable for the development of other by-products, such as flour and feed.

4. Conclusion

Based on the experiments and studies conducted, it was observed that the extracted oil possesses interesting characteristics and quality for the production of by-products and as a nutritious supplement to fishmeal. However, its production requires further investigation.

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