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FIELD CROPS AS SUSTAINABLE RESOURCES FOR AQUACULTURE

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Abstract

The literature highlights the increasing use of field crops such as soybeans, corn, and peas in aquaculture feeds due to their high protein and carbohydrate content. Romanian sources emphasize the role of these crops in reducing production costs, while international studies underline their importance in promoting sustainability. This study evaluated three types of crops (soybeans, wheat, and sorghum) grown under controlled conditions, using chemical analyses to determine their protein, fiber, and lipid content. These crops were incorporated into the diets of carp and catfish, with growth parameters and overall health monitored throughout the study. The findings revealed that soybeans and sorghum significantly supported fish weight gain, while wheat offered moderate benefits. Soybeans showed the highest protein digestibility compared to other crops. This research underscores the potential of field crops as sustainable resources for aquaculture feed, focusing on their nutritional composition, availability, and impact on fish health. Field crops provide an economic and ecological alternative to traditional ingredients, supporting the sustainability of aquaculture practices.

Key words*: aquaculture, field crops, sustainability.*

INTRODUCTION

Sustainable field crops refers to a holistic approach to farming that prioritizes ecological integrity, economic viability, and social responsibility. It involves production systems designed to maintain and improve environmental quality, reduce the generation of waste and pollutants, and deliver nutritious and safe food to consumers (Ikerd, 2022; Gil et al., 2019). Farmers and producers who adopt sustainable methods are committed not only to increasing yields but also to regenerating soil fertility, conserving biodiversity, minimizing the use of synthetic inputs, and using natural resources efficiently (Muhie, 2022; Madhav et al., 2020).

As a concept, the sustainable field crops is broad and encompasses a diverse range of practices - from conservation agriculture, integrated pest management, and agroforestry, to organic farming and water-saving irrigation techniques - all of which aim to reduce environmental degradation while supporting food system resilience (Purvis et al., 2019; Streimikis & Baležentis, 2020). Moreover, it responds to growing societal concerns about climate change, food security, and the ecological footprint of intensive farming systems (Shrestha et al., 2021; Raihan & Tuspekova, 2022).

Despite being one of the earliest and most fundamental activities in human history, agriculture has significantly contributed to various environmental challenges, including soil degradation, water pollution, and biodiversity loss (Tubiello et al., 2021). In response to these issues, sustainable agriculture has emerged as a critical field focused on balancing food production with ecological preservation.

This approach emphasizes long-term practices such as conservation tillage, organic and biodynamic farming, crop rotation, and the use of cover crops, all designed to safeguard soil health and water quality (Francis et al., 2001; Streimikis & Baležentis, 2020).

In an increasingly interconnected and environmentally conscious world, consumers are becoming more mindful of the ecological

and social consequences of their food choices (Shrestha et al., 2021). Consequently, implementing sustainable agricultural methods has become a strategic necessity to ensure food security while minimizing environmental impact.

As the global aquaculture industry expands to meet the growing demand for fish and seafood, sustainability has become a major concern. One of the key challenges in aquafeed production is the overreliance on fishmeal and fish oil, derived from wild-caught fisheries.

Aquaculture is one of the most rapidly growing food production sectors globally, playing a significant role in meeting the increasing global demand for protein-rich foods driven by population growth and dietary shifts. However, conventional aquaculture practices encounter substantial economic and environmental challenges. Among these challenges, the cost of fish feed stands out, accounting for up to 70% of total operational expenses in aquaculture systems, primarily due to reliance on expensive fishmeal and fish oil derived from marine resources (Tacon & Metian, 2015).

The over-reliance on marine-derived ingredients has raised significant concerns regarding environmental sustainability, specifically the depletion of wild fish stocks and ecosystem disruption. To mitigate these issues, the aquaculture industry has increasingly explored alternative, sustainable, and economically viable feed resources. Plant-based ingredients, particularly field crops such as maize, soybeans, barley, and alfalfa, have emerged as promising sustainable alternatives to traditional fishmeal-based diets due to their nutritional potential, lower production costs, and reduced environmental footprint (Hasan & New, 2013; Hardy, 2010).

Field crops offer numerous advantages including accessibility, renewable nature, cost-effectiveness, and balanced nutritional profiles suitable for a variety of fish species. The utilization of these plant-based feeds contributes not only to economic sustainability but also promotes ecological sustainability by reducing pressure on marine ecosystems. However, the adoption of plant-based diets also involves challenges, such as managing anti-nutritional factors and ensuring optimal nutritional balances suitable for different aquaculture species (Kumar et al., 2021).

This paper provides an in-depth analysis of the potential and challenges associated with utilizing field crops as sustainable feed resources in aquaculture. Through an extensive literature review and comparative analysis, this paper evaluates the nutritional adequacy, economic viability, and environmental implications of integrating maize, soybeans, barley, and alfalfa into aquaculture feeds, aiming to support the development of sustainable aquaculture practices.

MATERIALS AND METHODS

A comprehensive literature review was performed using databases such as Web of Science, ResearchGate, Scopus, and Google Scholar. Selected articles published between 2010-2023 were included based on relevance to keywords like "field crops aquaculture", "sustainable aquaculture feeds", "plant-based fish feeds", and "aquaculture sustainability". Data analysis emphasized nutritional content, fish growth performance, health impacts, and environmental sustainability. Comparative analyses were conducted on maize, soybeans, barley, and alfalfa concerning their application in aquaculture feed.

RESULTS AND DISCUSSIONS

Numerous studies have demonstrated the feasibility of replacing 30-75% of fishmeal with field crop proteins without compromising growth performance. For instance, Thiessen et al. (2003) reported that rainbow trout fed pea-based diets exhibited growth rates comparable to those fed fishmeal-based diets. Similarly, soybean-based diets in tilapia and catfish have resulted in high feed efficiency and acceptable weight gains (Gatlin et al., 2007).

However, carnivorous species such as salmon and sturgeon are more sensitive to amino acid imbalances and may require more precise supplementation when plant proteins are used (Woynarovich et al., 2011).

The replacement of fishmeal with crop-based ingredients significantly reduces the carbon footprint, land use, and ecological pressure on marine resources (Henriksson et al., 2012). Moreover, the use of regionally available crops supports local agriculture and reduces dependency on imported ingredients.

Still, challenges remain, including digestibility issues, palatability, and the presence of ANFs. Processing techniques such as extrusion, fermentation, and enzyme treatment can help mitigate these limitations (Francis et al., 2001).
Field crops demonstrate considerable potential in aquaculture feed formulations. Soybean meal, with its high protein content (44-50%), has widely replaced fishmeal in diets for species such as tilapia, carp, and salmon, showing improved growth performance, digestibility, and economic efficiency (Yigit et al., 2012).
For instance, studies have shown that soybean meal inclusion can reduce production costs by up to 25% compared to fishmeal-based feeds (Figure 1).

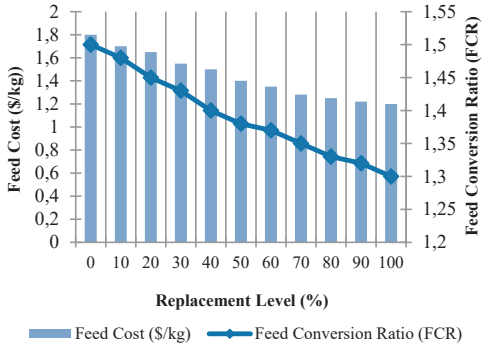

Figure 1. Ratio between feed cost and feed conversion factor, relative to the replacement level of soybean meal for aquaculture (Source: Adapted from Yigit et al., 2012)

Feed Cost gradually decreases with the increasing percentage replacement of fishmeal by soybean meal, primarily due to the lower market price of soybean meal compared to fishmeal.
Feed Conversion Ratio (FCR) is a critical indicator, reflecting the efficiency with which feed is converted into body mass by fish. A lower FCR value indicates greater economic efficiency of feed usage.
Total feed cost per kg of fish produced is the most relevant indicator for the practical economic evaluation of an aquaculture operation (Figure 2).
Maize, despite its lower protein content (9-11%), plays an essential role as an energy-rich ingredient. Its inclusion enhances digestibility and reduces feed costs, particularly when supplemented with protein-rich ingredients (Naylor et al., 2021; Glencross, 2006; El-Sayed, 1999). Table 1 illustrates typical nutritional profiles of various field crops utilized in aquaculture diets.

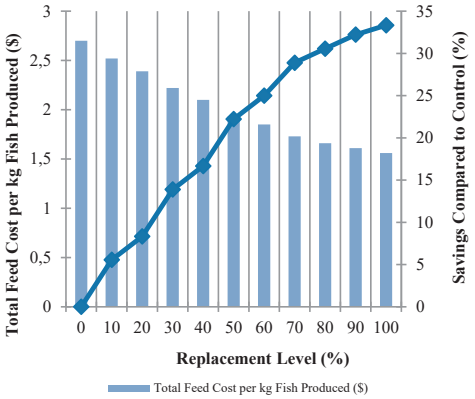

Figure 2. Ratio of Total Feed Cost per kg Fish Produced to Savings Compared to Control, relative to the level of soybean meal replacement for aquaculture (Source: Adapted from Yigit et al., 2012)

Table 1. Nutritional Profiles of Field Crops Commonly Used in Aquaculture Feeds (compiled from Naylor et al., 2021; Hasan & New, 2013).

Crop	Protein (%)	Carbohydrates (%)	Fiber (%)	Energy (kcal/kg)
Soybeans	44-50	30-35	7-10	4000
Maize	9-11	70-75	2-3	3600
Barley	10-13	60-65	5-7	3500
Alfalfa	17-20	40-45	25-30	2500

Barley has proven beneficial as an alternative carbohydrate source, notably improving gut health and growth performance in salmonid aquaculture. Inclusion levels of barley up to 30% maintain comparable growth rates to conventional feeds, promoting gut health and immunity (Randall & Drew, 2020; Carter & Hauler, 2000; Lim & Dominy, 1990) (Figure 3).
Alfalfa, rich in dietary fiber, minerals, and vitamins, provides significant benefits, particularly for herbivorous and omnivorous species. Its inclusion has shown marked improvements in fish survival rates and overall health, attributed primarily to its high carotenoid and fiber content (Francis et al., 2019; Davies & Morris, 1997; Belal, 1999).

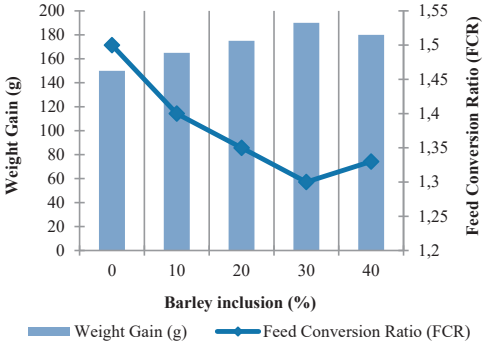

Figure 3. Growth Performance Comparison of Rainbow Trout Fed with Different Levels of Barley (Source: Adapted from Randall & Drew, 2020)

However, field crop utilization faces several challenges. Soybeans contain anti-nutritional factors such as trypsin inhibitors, phytates, and saponins, necessitating advanced processing methods like heat treatment and fermentation to minimize their impact on fish health (Kumar et al., 2021). The nutritional imbalance due to maize's lower protein necessitates additional supplementation, increasing formulation complexity.

From an environmental perspective, shifting to plant-based feeds significantly decreases the pressure on marine ecosystems, reducing exploitation of wild fish stocks. Figure 2 depicts the reduction in environmental impact (carbon footprint and biodiversity loss) when adopting field crop-based aquaculture diets compared to traditional marine-derived feeds (Waite et al., 2014) (Figure 4).

Carbon Footprint indicates the greenhouse gas emissions associated with feed production. Plant-based feeds exhibit significantly lower environmental impacts compared to marine-derived feeds.

Land Use reflects the amount of land required for feed production. Even though plant-based feeds are grown on land, they require less total area compared to the resources needed for marine-derived feeds (Figure 5).

Plant-based feeds utilize considerably less water compared to marine-derived feed processing, emphasizing their water conservation advantage.

Energy consumption required for producing plant-based feeds is substantially lower compared to marine-based feeds, indicating higher energy efficiency.

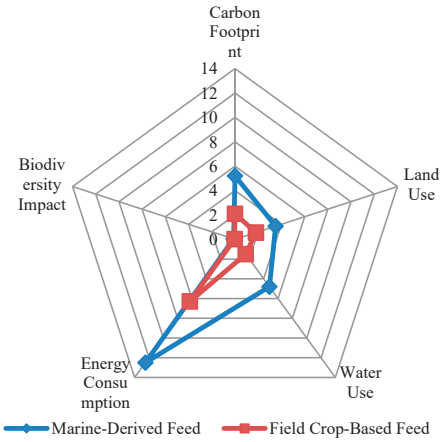

Figure 4. Environmental Impact Comparison of Marine-Derived vs. Field Crop-Based Aquaculture Feeds (Source: Adapted from Waite et al., 2014)

Figure 5. Water basins designated for agro-aquaculture rotation within the Brateș Experimental Research Laboratory for Agro-Fisheries (Source: Original, based on data from Brateș Experimental Research Laboratory)

The biodiversity impact, measured by the number of species affected, is significantly reduced when using plant-based feeds compared to marine-derived feeds.

CONCLUSIONS

Field crops represent a viable and sustainable solution for the partial or complete replacement of fishmeal in aquafeeds. Their nutritional value, availability, and environmental advantages make them ideal candidates for future feed

formulations in both intensive and semi-intensive aquaculture systems.

The integration of field crops such as soybeans, maize, barley, and alfalfa into aquaculture diets represents a promising strategy for enhancing both economic efficiency and environmental sustainability in aquaculture practices. Field crops provide significant nutritional advantages, contributing positively to fish growth and health, while simultaneously reducing feed costs and dependence on over-exploited marine resources.

Nonetheless, successful adoption requires overcoming inherent challenges associated with anti-nutritional factors and nutritional balancing issues. Further advancements in crop processing technologies, improved agricultural practices, and innovative feed formulation strategies will be crucial. Additionally, comprehensive life cycle assessments are recommended to quantify environmental and economic impacts fully.

Continued research and development in this field are essential for achieving long-term sustainability and efficiency in aquaculture, ultimately supporting global food security objectives.

The researches into crop improvement, feed processing, and species-specific requirements will be essential to fully unlock the potential of plant-based aquafeeds. Integrating agriculture and aquaculture systems also aligns with circular economy principles and global sustainability goals.

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