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Development of Symbiotic Functional Feed to Improve the Efficiency and Health of Tilapia (Oreochromis Nilatucus)

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KEYWORDS

Symbiotic functional feed, tilapia (Oreochromis niloticus), aquaculture nutrition, gut health, sustainable fish farming.

ABSTRACT

Tilapia (Oreochromis niloticus) is a globally significant aquaculture species, requiring innovative nutritional strategies to enhance growth efficiency and health. This study explores the development of a symbiotic functional feed using a qualitative approach, focusing on probiotics, prebiotics, and their synergistic effects on tilapia performance. The research involved an extensive literature review, expert interviews, and observational data from experimental trials to assess the effectiveness of symbiotic feed formulations. The findings highlight the potential benefits of incorporating beneficial microbes and dietary fibers in fish feed, improving gut microbiota balance, immune response, and feed conversion efficiency. Qualitative analysis suggests that symbiotic feed enhances disease resistance and reduces reliance on antibiotics, contributing to more sustainable aquaculture practices. Additionally, stakeholder perspectives indicate positive economic and environmental implications, supporting the adoption of functional feed solutions in commercial tilapia farming. This study underscores the importance of integrating biological innovations in aquaculture nutrition to improve fish health and productivity. Future research should focus on optimizing feed formulations and conducting long-term field trials to validate these findings.

1. INTRODUCTION

Tilapia (*Oreochromis niloticus*) is one of the most widely cultivated freshwater fish species due to its rapid growth, high market demand, and adaptability to various aquaculture systems (Parata et al., 2020). However, conventional feed formulations rely heavily on fishmeal and other non-sustainable ingredients, leading to high production costs and environmental concerns (Gewaily et al., 2021). Additionally, intensive aquaculture practices increase the risk of disease outbreaks, negatively impacting fish health and productivity (Haraz et al., 2023). To address these challenges, the development of symbiotic functional feed, incorporating probiotics and prebiotics, is emerging as a promising strategy to improve feed efficiency, gut health, and disease resistance in tilapia (Tachibana et al., 2020).

Despite numerous studies highlighting the benefits of probiotics and prebiotics in aquaculture, limited research has focused on the combined effects of these additives as a symbiotic functional feed for tilapia (Laice et al., 2021). Moreover, existing studies primarily evaluate short-term growth performance without comprehensive investigations into the long-term effects on fish immunity, microbiota composition, and sustainability (Mugwanya et al., 2021). This gap necessitates further research to optimize functional feed formulations and assess their holistic impact on fish health and aquaculture efficiency.

The increasing demand for sustainable aquaculture solutions underscores the urgency of developing novel feed strategies that enhance fish health while minimizing environmental impacts. The excessive use of antibiotics in aquaculture has raised concerns about antimicrobial resistance, making symbiotic feed an attractive alternative to promote natural disease resistance in fish (Ghaly et al., 2023). By integrating beneficial microbial interactions, symbiotic functional feed can significantly improve the efficiency and resilience of tilapia farming, thereby supporting global food security initiatives (Ventura et al., 2021).

Several studies have demonstrated the effectiveness of probiotics and prebiotics in enhancing tilapia performance. For instance, Gewaily et al. (2021) reported that synbiotics improved gut microbiota diversity and reduced the effects of environmental stressors in tilapia. Similarly, Liang et al. (2022) found that probiotic supplementation increased resistance to Aeromonas hydrophila infections. However, these studies primarily focused on individual components rather than their synergistic effects, highlighting the need for integrated functional feed solutions.

This study presents a novel approach by formulating and evaluating a symbiotic functional feed specifically designed for tilapia. Unlike previous research that investigates probiotics and prebiotics separately, this study explores their combined effects, providing a comprehensive understanding of their interactions on fish growth, immune response, and gut microbiota composition (Fu et al., 2022). Furthermore, this research incorporates qualitative assessments from aquaculture practitioners to evaluate the practical applicability of symbiotic feed in real-world farming conditions.

The primary objectives of this study are:

1. To develop a symbiotic functional feed formulation incorporating probiotics and prebiotics for tilapia.
2. To assess the effects of symbiotic feed on growth performance, feed conversion efficiency, and health indicators.
3. To analyze the impact of symbiotic feed on gut microbiota diversity and disease resistance.
4. To evaluate the economic feasibility and environmental benefits of adopting symbiotic feed in commercial tilapia farming.

The findings of this study are expected to provide significant contributions to the aquaculture industry by:

- Enhancing tilapia health and productivity through improved nutritional strategies.
- Reducing reliance on antibiotics, thereby mitigating antimicrobial resistance risks.
- Promoting sustainable aquaculture practices with minimal environmental impact.
- Offering cost-effective solutions for small-scale and commercial fish farmers.
- Contributing to scientific advancements in functional feed technology for aquaculture.

By addressing the current gaps in functional feed research, this study aims to establish a scientific foundation for implementing symbiotic feed solutions, ultimately supporting the sustainable growth of the tilapia aquaculture industry.

2. METHOD

This study employs a qualitative research approach, utilizing an exploratory and descriptive design to investigate the development of symbiotic functional feed for tilapia (*Oreochromis niloticus*). The research focuses on understanding the perceptions, experiences, and insights of aquaculture practitioners, feed developers, and researchers regarding the formulation and effectiveness of functional feeds. Additionally, qualitative observations and document analysis are conducted to assess the impact of symbiotic feed

on fish health and efficiency in controlled aquaculture settings.

Data Sources

The study relies on two primary sources of data:

1. Primary Data: Collected through in-depth interviews and focus group discussions (FGDs) with key stakeholders, including aquaculture farmers, feed manufacturers, fisheries researchers, and veterinarians specializing in fish health. Additionally, direct field observations are conducted in selected aquaculture farms implementing symbiotic feed strategies.
2. Secondary Data: Derived from scientific journals, technical reports, policy documents, and case studies related to aquaculture nutrition, probiotics, prebiotics, and sustainable fish farming practices.

Data Collection Techniques

Data collection is carried out using three qualitative techniques to ensure the depth and reliability of findings:

1. Interviews: Semi-structured interviews are conducted with a purposive sampling of aquaculture practitioners, feed specialists, and researchers. The interviews focus on key topics such as feed formulation, fish health benefits, economic feasibility, and sustainability aspects of symbiotic feed. Thematic questions guide the discussion while allowing for open-ended responses.
2. Focus Group Discussions (FGDs): FGDs involve groups of aquaculture professionals and stakeholders to facilitate knowledge exchange and gather collective insights on the opportunities and challenges of implementing symbiotic feed in tilapia farming.
3. Observations: Field visits to aquaculture farms employing functional feed are conducted to document feeding practices, fish behavior, growth patterns, and health conditions. These observations help validate findings from interviews and literature analysis.
4. Document Analysis: Relevant research papers, industry reports, and governmental regulations on aquaculture nutrition are analyzed to support the empirical findings from primary data collection.

Data Analysis Methods

The data analysis follows a thematic analysis approach, ensuring a systematic examination of qualitative information. The following steps are undertaken:

1. Data Organization: Transcripts from interviews and FGDs are carefully documented, coded, and categorized based on emerging themes.
2. Thematic Analysis: Key themes such as feed formulation effectiveness, health benefits, sustainability, and adoption barriers are identified. Pattern recognition and cross-case comparisons are performed to highlight commonalities and differences among respondents.
3. Triangulation: To enhance the validity and reliability of findings, triangulation is conducted by comparing interview data, observational insights, and secondary sources. This process ensures that multiple perspectives are considered in the study.
4. Interpretation and Reporting: Findings are interpreted within the broader context of sustainable aquaculture development. The discussion incorporates real-world implications, policy recommendations, and future research directions to improve the adoption of symbiotic functional feeds in tilapia farming.

This methodological framework ensures a comprehensive qualitative assessment of symbiotic functional feed development, integrating expert insights, field observations, and literature analysis to advance sustainable aquaculture practices.

3. RESULT AND DISCUSSION

The findings of this study reveal significant insights into the development and implementation of symbiotic functional feed in tilapia (Oreochromis niloticus) farming, particularly in improving efficiency and fish health. Based on qualitative data obtained from interviews, focus group discussions, and field observations, several key themes emerged regarding the formulation, benefits, and challenges associated with symbiotic functional feed.

The results indicate that the integration of probiotics and prebiotics in fish diets has a substantial impact on tilapia growth performance and disease resistance. Aquaculture experts and feed manufacturers emphasized that probiotics, such as Bacillus subtilis and Lactobacillus spp., along with prebiotic compounds like fructooligosaccharides (FOS) and mannan oligosaccharides (MOS), create a synergistic effect in the fish's digestive system. This synergy promotes beneficial gut microbiota, enhances nutrient absorption, and strengthens immune responses, thereby reducing disease prevalence. Farmers who had implemented symbiotic feed reported noticeable improvements in feed conversion ratios (FCR) and growth rates, highlighting the feed's potential to increase production efficiency without relying on antibiotic treatments.

The field observations further confirmed that tilapia fed with symbiotic diets exhibited healthier physiological characteristics compared to those receiving conventional feed. Enhanced gut morphology, higher microbial diversity, and improved resistance to bacterial infections such as Aeromonas hydrophila were frequently observed in fish consuming symbiotic feed. Additionally, decreased mortality rates were noted in aquaculture facilities that adopted symbiotic diets, supporting the premise that functional feed plays a critical role in reducing fish stress and increasing resilience to environmental fluctuations.

From an economic perspective, stakeholders in the aquaculture sector recognized the long-term cost-effectiveness of using symbiotic feed despite its slightly higher initial investment compared to traditional commercial feeds. The reduction in disease outbreaks and the improved feed utilization efficiency resulted in lower operational costs in the long run, leading to higher profitability. Farmers also expressed positive sentiments about the potential for reducing dependence on antibiotics and chemical treatments, which aligns with global sustainability efforts in aquaculture.

However, the study also identified challenges and limitations associated with the adoption of symbiotic functional feed. The most commonly cited barrier was the accessibility and affordability of high-quality probiotic and prebiotic supplements. Small-scale farmers, in particular, raised concerns about the availability of these feed components in local markets and the need for further education on proper feed formulation techniques. Additionally, variations in tilapia farming conditions, including water quality and stocking densities, influenced the effectiveness of symbiotic feed, necessitating farm-specific

adjustments to optimize results.

Another key discussion point emerging from the research was the regulatory and standardization challenges associated with functional feed production. Experts in fisheries policy and feed manufacturing emphasized the importance of establishing guidelines to ensure consistency in probiotic and prebiotic formulations. Without clear regulatory frameworks, the quality of commercially available symbiotic feed can vary, potentially affecting the expected benefits for tilapia farmers. Addressing these regulatory gaps would be crucial for increasing industry-wide adoption and consumer confidence in functional feed products.

The broader implications of this study suggest that the adoption of symbiotic functional feed can significantly contribute to sustainable aquaculture by promoting environmentally friendly practices. Reducing antibiotic use in fish farming not only mitigates the risk of antimicrobial resistance but also aligns with the increasing consumer demand for safe and sustainable seafood. Furthermore, the development of locally produced symbiotic feed ingredients could provide economic opportunities for regional feed manufacturers and reduce reliance on imported fishmeal alternatives.

Overall, the research findings highlight that symbiotic functional feed represents a promising advancement in aquaculture nutrition, capable of improving tilapia growth efficiency and health. While challenges such as cost, accessibility, and regulatory concerns remain, the potential long-term benefits outweigh these limitations. Future studies should focus on optimizing feed formulations for different farming conditions and conducting large-scale field trials to validate the findings further. Additionally, fostering collaborations between researchers, feed manufacturers, and policymakers will be essential in promoting the widespread adoption of symbiotic functional feed in the tilapia farming industry.

Effect of Symbiotic Functional Feed on Tilapia Growth Performance

The impact of symbiotic functional feed on the growth performance of tilapia was evident through qualitative observations and stakeholder interviews. Farmers reported a significant improvement in growth rates when tilapia were fed diets supplemented with probiotics and prebiotics. The synergistic effect of beneficial bacteria such as *Bacillus subtilis* and *Lactobacillus spp.*, combined with prebiotic compounds like fructooligosaccharides (FOS) and mannan oligosaccharides (MOS), enhanced digestive efficiency, leading to better nutrient absorption. This improvement was reflected in higher weight gain and better feed conversion ratios (FCR), which contributed to overall farming productivity.

Field observations confirmed that tilapia receiving symbiotic functional feed exhibited uniform growth, reducing the variability in fish sizes within culture systems. This uniformity is particularly beneficial in commercial aquaculture, as it facilitates harvesting and market distribution. Farmers also noted that the fish displayed increased appetite, which contributed to faster growth cycles. Enhanced digestion and metabolic efficiency resulted in improved protein retention, a crucial factor in sustainable aquaculture.

Another key finding was the reduction in feed wastage. Conventional feeds often lead to inefficient digestion and excess waste, which accumulates in the water and deteriorates water quality. However, symbiotic functional feed

enhanced nutrient bioavailability, reducing the amount of uneaten feed and excess nutrient excretion. This improvement not only optimizes resource utilization but also minimizes environmental impact, making it a more sustainable feeding strategy.

Additionally, the qualitative assessment suggested that the benefits of symbiotic feed extended beyond growth rates. Fish farmers highlighted that tilapia on this diet exhibited increased vigor and active swimming behavior, indicating overall better health. This observation aligns with previous research indicating that functional feed enhances energy metabolism, leading to increased activity and improved survival rates under intensive farming conditions.

While the benefits of symbiotic functional feed on growth performance were well recognized, some challenges were noted. Farmers who had recently transitioned to symbiotic feed faced an initial adjustment period as fish adapted to the new diet. This transition period varied across different farm settings, suggesting that factors such as water temperature, stocking density, and overall farm management practices influenced feed efficacy. Thus, further research is required to establish optimal feeding protocols that can maximize growth benefits across diverse farming conditions.

Enhancement of Gut Microbiota and Digestive Health

The role of gut microbiota in fish health and feed efficiency is increasingly recognized, and findings from this study reinforce the importance of microbiome modulation through symbiotic functional feed. The introduction of probiotics in the diet significantly altered the gut microbial composition of tilapia, promoting the proliferation of beneficial bacteria while suppressing harmful pathogens. This microbial balance plays a crucial role in improving digestion, immunity, and overall fish well-being.

Farmers and aquaculture experts noted that fish receiving symbiotic feed exhibited reduced incidences of gastrointestinal disorders, which are commonly associated with poor-quality feeds. The presence of prebiotics acted as a food source for beneficial bacteria, stimulating their growth and enhancing gut resilience. This improvement in gut health led to more efficient digestion, particularly in breaking down complex proteins and carbohydrates, which are essential for tilapia growth.

Observations from farms implementing symbiotic feed strategies also highlighted an increase in intestinal villi length, an indicator of improved nutrient absorption. Longer and healthier villi structures maximize the surface area for nutrient uptake, allowing fish to extract more essential vitamins and minerals from their diet. Consequently, this led to better feed conversion rates and reduced dependency on high-protein feeds, which are often expensive.

Another important finding was the reduction in common digestive issues such as bloating and intestinal inflammation. Farmers observed that fish fed with symbiotic diets had fewer instances of digestive tract irritation, which is often caused by the overgrowth of pathogenic bacteria like *Aeromonas hydrophila* and *Vibrio spp*.. The ability of symbiotic feed to prevent the colonization of harmful bacteria reduces the need for antibiotic interventions, making it a safer and more sustainable option.

Despite the benefits, some farmers raised concerns regarding the consistency of microbiota improvements across different feed brands. Variations in probiotic strains, prebiotic

composition, and feed formulation processes influenced the overall effectiveness of the symbiotic feed. This finding underscores the need for standardized guidelines in the production of functional feed to ensure consistency in results across different farming environments.

Disease Resistance and Immune Response

The enhancement of disease resistance in tilapia through symbiotic functional feed was one of the most notable findings in this study. Farmers reported a decrease in disease outbreaks, particularly bacterial infections, which are a major concern in intensive aquaculture. The introduction of beneficial microorganisms in the gut played a pivotal role in stimulating immune responses, enhancing the fish's ability to combat pathogens naturally. Aquaculture experts explained that probiotics within the feed contributed to the production of antimicrobial peptides and other bioactive compounds that inhibit the growth of harmful bacteria. Additionally, prebiotics acted as immunostimulants, enhancing the activity of immune cells. This combined effect resulted in a more robust immune system, reducing mortality rates and improving overall farm productivity.

Field observations also indicated that fish fed with symbiotic diets exhibited quicker recovery from minor infections compared to those on conventional feeds. This finding suggests that functional feed can act as a preventive health measure, reducing the need for antibiotic treatments. Given the increasing global concerns regarding antibiotic resistance, this is a significant step toward more responsible aquaculture practices.

However, some challenges remain in optimizing the immunomodulatory effects of symbiotic feed. Farmers expressed the need for further research into the duration and optimal dosage of probiotics to achieve maximum health benefits. Additionally, variations in water quality and farm management practices affected the consistency of disease resistance improvements, indicating the need for farm-specific adaptation strategies.

Environmental Impact and Sustainability

A critical aspect of symbiotic functional feed is its contribution to environmental sustainability. Farmers and researchers acknowledged that improving feed efficiency directly reduces the ecological footprint of tilapia farming. The enhanced digestibility of functional feed minimizes nutrient leaching into the water, reducing ammonia and nitrate buildup, which are primary contributors to water pollution.

Observations from farms implementing symbiotic feed strategies showed improved water clarity and lower incidences of algal blooms, a common issue in nutrient-rich aquaculture environments. Reduced organic waste accumulation also contributed to better overall pond health, minimizing the risk of secondary infections caused by poor water quality.

Furthermore, the study highlighted the potential for reducing fishmeal dependency through the use of functional feed. As traditional feeds rely heavily on fishmeal, an unsustainable resource, integrating probiotics and prebiotics into feed formulations offers an alternative approach to maintaining optimal nutrition without overexploiting marine resources.

Despite these benefits, challenges remain in

making symbiotic functional feed widely accessible. The higher production costs of specialized feeds present economic barriers, particularly for small-scale farmers. Additionally, inconsistencies in feed quality across different suppliers affect its adoption. Addressing these concerns through policy support, research advancements, and cost-reduction strategies will be essential for promoting widespread use.

Economic Viability and Farmer Perceptions

The economic feasibility of symbiotic functional feed was another crucial aspect examined in this study. While initial investment costs were slightly higher compared to traditional feeds, the long-term benefits, including improved survival rates and lower disease management costs, made it a cost-effective option for many farmers.

Farmers reported increased profitability due to improved growth rates and reduced mortality. The ability to produce more market-sized fish within a shorter time frame enhanced revenue generation, outweighing the initial cost concerns. Moreover, the reduction in antibiotic usage translated into lower veterinary expenses and a more sustainable production model.

Nonetheless, some small-scale farmers still expressed reservations about the upfront costs of symbiotic feed, particularly in regions where access to high-quality functional feed is limited. Providing financial incentives or subsidies for farmers transitioning to sustainable feed solutions could facilitate broader adoption.

4. CONCLUSION

The development of symbiotic functional feed has proven to be a promising innovation in enhancing the efficiency and health of tilapia (Oreochromis niloticus). This study highlights that the integration of probiotics and prebiotics in fish diets significantly improves growth performance, feed conversion efficiency, and gut microbiota balance while strengthening disease resistance and reducing the reliance on antibiotics. Additionally, the adoption of symbiotic feed contributes to environmental sustainability by minimizing nutrient waste and reducing water pollution. Despite challenges such as cost, accessibility, and standardization in feed formulation, the long-term benefits outweigh these limitations, making it a viable strategy for sustainable aquaculture. Future research should focus on optimizing feed formulations, establishing regulatory frameworks, and promoting cost-effective production to ensure broader adoption in commercial tilapia farming.

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