Nomico Journal
E-ISSN : 3046-6318
https://nawalaeducation.com/index.php/NJ/index
Vol.1.No.6 August 2024
DOI : https://doi.org/10.62872/jagdc251

Enhancing Technical Efficiency in Aquaculture: A Bibliometric Analysis and Literature Review

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Entered : August 07, 2024
Revised : August 21, 2024
Accepted: August 22, 2024
Published : August 25, 2024

ABSTRACT

Early 2024, fueled by rising demand, growing awareness of healthier animal protein, and technological advancements. With the global population expected to reach 9.7 billion by 2050, aquaculture, particularly freshwater fish farming, is pivotal in satisfying the increasing need for animal protein. As the third-largest aquaculture producer, Indonesia faces significant challenges in optimizing production, requiring advanced technology, farmer education, and environmentally sustainable practices. This study conducts a bibliometric analysis of the literature on technical efficiency in aquaculture, mapping out research trends, collaborations, and existing gaps. The findings highlight the critical role of technical efficiency in enhancing economic performance and promoting environmental sustainability. Factors such as farmer demographics, training, infrastructure, gender inclusion, and environmental adaptation are identified as key influencers of efficiency. The study emphasizes the necessity of a comprehensive understanding of technical efficiency across various regions and species, underscoring Indonesia's potential as a focal point for further research in this area. This knowledge is essential for improving practices and policies to meet future food security needs effectively.

Keywords: *Aquaculture, Bibliometric Analysis, Freshwater,Technical efficiency*

INTRODUCTION

Aquaculture production has skyrocketed from 35.5 million tons in 2000 to over 120 million tons by early 2024 (FAO, 2024), driven by high demand, increased awareness of healthier animal protein consumption, and technological advancements. The projected global population of 9.7 billion by 2050 presents a significant challenge in providing sufficient food, especially animal protein, which is crucial for human nutrition (Connor et al., 2021; Vignesh et al., 2023; Niu et al., 2024). As the population grows and demand for animal-based food products rises, aquaculture, particularly freshwater fish farming, has emerged as a key solution (Leaver, 2011). Indonesia, ranking third among the world's leading aquaculture producers, has experienced significant economic contributions from its freshwater, marine, and brackish water fish farming sectors (Rahim, et.al 2024). However, Indonesia still faces challenges and opportunities to improve production through advanced aquaculture technology, farmer education, and environmentally friendly farming practices. Enhancing production, product quality, and environmental sustainability can also strengthen Indonesia's position in International fish market.

Efforts to improve efficiency in fish farming, both technically and managerially, are crucial to enhancing productivity, especially amid declining wild fish catches and increasing environmental pressures. Over the past twenty years, there has been significant growth in research focused on improving technical efficiency in fish farming, indicating its importance and increasing interest (See et al., 2021). Technical efficiency in

aquaculture is vital as it involves the optimal use of resources, leading to cost reduction and increased profitability. Efficient use of inputs such as feed, labor, and capital can maximize production benefits while minimizing waste. Focusing on technical efficiency not only boosts economic performance but also supports environmental sustainability by reducing ecological footprints and preserving aquatic ecosystems. Technical efficiency analysis also helps producers identify areas for improvement, facilitating the adoption of better farming practices and appropriate technologies. For policymakers, a thorough understanding of technical efficiency is crucial for developing policies and regulations that promote sustainable practices in the aquaculture industry. Additionally, technical efficiency helps identify best practices and unique challenges in different regions with varying characteristics (Samat et al., 2024).

In assessing technical efficiency in aquaculture, two commonly used methods are Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). SFA is a parametric approach that separates inefficiency from random noise using statistical techniques. However, it has limitations, such as the assumption of a specific functional form that may not accurately represent the production process and reliance on certain distributions for error and inefficiency. SFA is also less effective in scenarios involving multiple outputs. On the other hand, DEA is a non-parametric method that uses linear programming to evaluate the relative efficiency of decision-making units by comparing them with the best performers in the sample. However, DEA is sensitive to extreme values or outliers and does not differentiate between inefficiency and random noise, which can lead to misleading interpretations. These limitations suggest that using both SFA and DEA together or exploring alternative approaches can provide a more comprehensive assessment of efficiency in aquaculture (Iliyasu, 2014). There has been a significant shift from the use of stochastic translog production functions to data envelopment analysis over time, reflecting various research objectives. The study also highlights that factors such as education, experience, and age of fish farmers are often analyzed to explain variations in technical efficiency. While acknowledging that research in this field is not yet fully mature, it is essential to address methodological gaps. These findings provide valuable insights for future research and practical applications in fish farming efficiency and productivity (See et al., 2021).

The main goal of this study is to review the existing research on technical efficiency in aquaculture through a bibliometric analysis. This method helps identify gaps in the current literature—areas that have not been thoroughly explored by previous researchers. By identifying these gaps, the study aims to guide future research efforts, highlighting important trends, collaborations, and topics that require further attention in aquaculture efficiency.

METHODS

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework has been used by many researchers for literature reviews, as well as for bibliometric analysis (See et al., 2021). This framework ensures a systematic, transparent, and unbiased approach to identifying, filtering, and selecting studies from available literature sources. PRISMA provides a structured method for systematically searching and identifying publications, ensuring a comprehensive and thorough selection process. the PRISMA method ensures comprehensive inclusion of publications in bibliometric analysis through systematic identification, selection, and analysis techniques, as well as the use of specific databases and visualization tools (Hyk et.al., 2022; Gronthy et al., 2023).

PRISMA uses four phases: identification, selection, exclusion, and justification for exclusions. These phases outline the flow of information through a bibliometric review, as described in the PRISMA framework (Image 1). Due to limited academic access to Scopus, the identification process in this study was conducted solely using Scopus as the search tool. Scopus is a research database that provides access to scientific and academic journals, articles, books, and conference papers. The search in the Scopus database used keywords such as "Technical Efficiency" OR "Economic Efficiency" AND "Fish Farming" OR "Aquaculture" OR "Fish Culture" OR "Freshwater Aquaculture." The initial search parameters included documents in the final stage and in English, resulting in 233 documents found, with a research period limited to "2000–2024." The inclusion criteria were articles containing keywords that were included in the abstract description. The exclusion criteria were all documents in the form of articles, excluding document types such as reviews, conference papers, book chapters, errata, and short surveys. The source type was limited to journals, excluding book categories. All articles were fully open access.

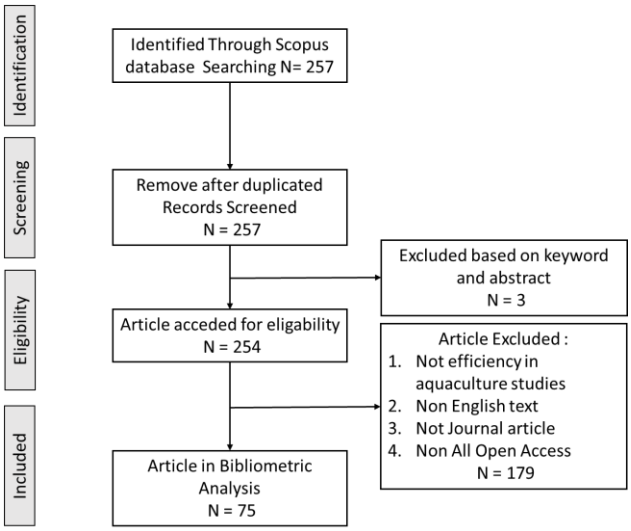

Image 1 Procedure for Obtaining Literature Using PRISMA

Bibliometrics is a quantitative method used to analyze and measure the quantity and quality of written publications, such as books and journal articles, through mathematical and statistical techniques (Karla et al., 2022). The articles obtained are analyzed using data mining tools; in this study, Biblioshiny, a statistical programming tool in R, is used for quantitative evaluation. Biblioshiny is employed to analyze, evaluate, and develop graphical visualizations from the obtained database. Another tool used is VOSviewer, a freely available software designed to construct, visualize, and explore bibliometric maps of science, developed by Nees Jan van Eck and Ludo Waltman (Nees et al, 2009; Kalya et al., 2024). This program uniquely combines VOS mapping techniques with advanced visualization features, making it highly user-friendly for the bibliometric research community.

RESULTS AND DISCUSSION

Publication trends

The results of data mining with bibliometric analysis began with examining the data on technical efficiency and economic efficiency in general, including publication trends, author productivity, networks, institutions, country of origin, and number of citations. The data were visualized and analyzed. An overview of the data from 75 articles analyzed

from 2000 to 2024 comes from 44 Scopus-indexed journal sources. Based on the chosen themes and keywords, the average number of articles grew by 7.75% per year, with an average of 12.92 citations per document. The total number of authors is 290, with an average of 4.31 co-authors per document.

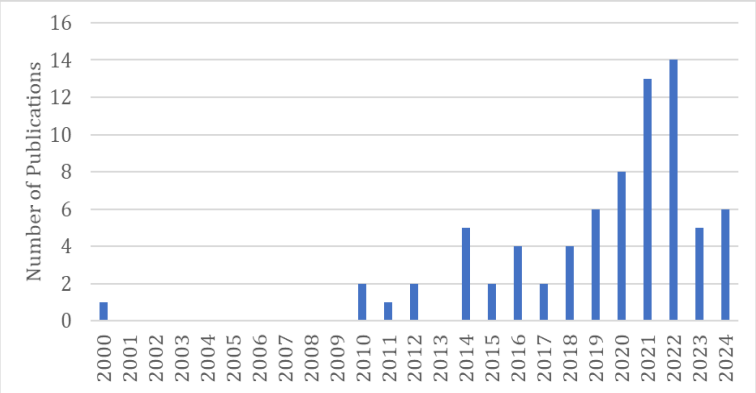

Image 2. Number of publications on technical efficiency in fish farming activities from 2020 to 2024.

Over the ten years from 2000 to 2009, only one publication found that the DEA analysis indicated the technical efficiency of fish farming in Rajasthan, India, could still be improved (0.95). However, the impact of fish farming was noted to have significantly transformed the lives of the local population. The period from 2010 to 2014 saw a growing interest in both technical and economic efficiency, with research expanding to different regions and species. This period also highlighted variations in efficiency due to regional differences, farming practices, and species-specific issues,).

During 2015 and 2019, there was an increased focus on environmental sustainability and total factor productivity (TFP), along with the impacts of socio-economic and environmental factors on efficiency. Researchers began utilizing advanced methodologies like stochastic frontier analysis (SFA) and data envelopment analysis (DEA), as evidenced by Iliyasu et al. (2016). In the recent period of 2020 to 2024, studies have increasingly emphasized the integration of technical efficiency with ecological and economic considerations. There is a noticeable trend towards exploring the impacts of environmental regulations, technological advancements, and socio-economic factors on the sustainability and productivity of aquaculture. New themes such as green development, gender roles in decision-making, and the use of probiotics in fish farming have also emerged, reflecting a broadening scope in aquaculture research and an increasing complexity in addressing efficiency and sustainability challenges.

Most Produtive Country

Asian countries tend to dominate research on aquaculture efficiency and productivity (Image 3-A), likely due to several factors. Firstly, Asia is a region with very high aquaculture production, including countries like China, India dan Indonesia. China is the most productive country in publishing correspondence on technical efficiency in fish farming, with 12 articles (16%), significantly surpassing Egypt, which ranks second with 6 articles (8%)(Image 3-B). There is a tendency to rely on the aquaculture sector as an important source of animal protein for food security, which drives increased research to enhance production and efficiency in fish farming. Additionally, the rich biodiversity and natural resources in Asia enable research on various fish species and farming techniques. These countries also view aquaculture as a crucial sector for economic

development, focusing on improving technical and economic efficiency to maximize business profitability.

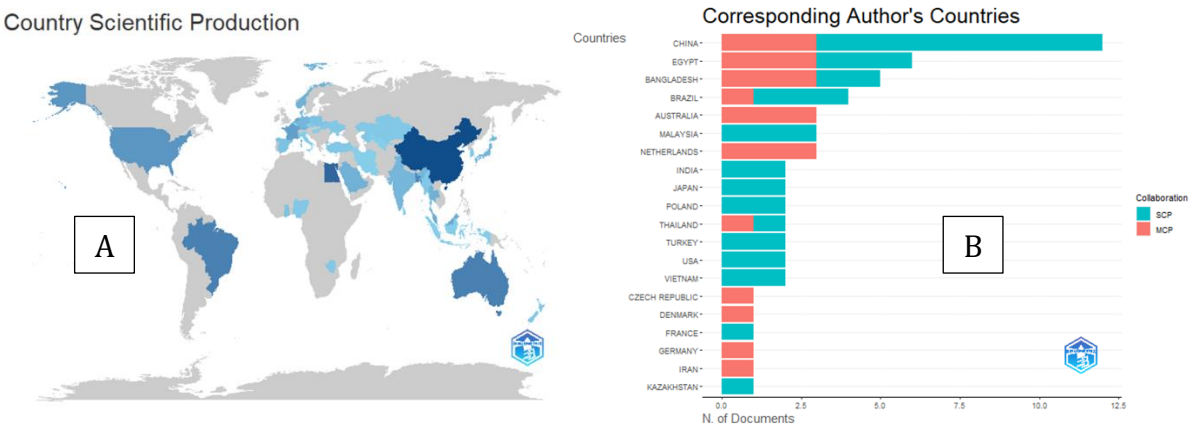

Image 3. The countries with the most corresponding authors in studies and scientific Production on technical efficiency in fish farming activities from 2020 to 2024.

Most Productive Author and Their Collaborations

The table provides bibliometric data on a group of authors, including h-index, g-index, m-index, total citations (TC), number of publications (NP), and the year they started publishing (PY_start). The h-index measures the productivity and citation impact of an author's publications, with Iliyasu A and Mohamed Za having the highest total citations at 126 and both an h-index and g-index of 4, indicating significant impact and productivity. Meanwhile, Hossain, M.E and Nielsen R have an m-index of 1, suggesting a consistent impact since they began publishing. The starting publication years range from 2010 for Islam, S to 2021 for Ankamah-Yeboah I, demonstrating diversity in the active research periods among these authors. This data provides insights into the influence and productivity of researchers in their respective fields, as well as their academic contributions over time (Tabel 1).

Table 1. Top 10 Most Productive Authors in Technical Efficiency Research of Fish Farming activities from 2020 to 2024

No	Author	h_index	g_index	m_index	TC	NP	PY_start
1	ILIYASU A	4	4	0,364	126	4	2014
2	KHAN MA	4	4	0,8	82	4	2020
3	MOHAMED ZA	4	4	0,364	126	4	2014
4	NIELSEN R	4	4	0,8	106	4	2020
5	ISMAIL MM	3	3	0,2	62	3	2010
6	YUAN Y	3	3	0,6	57	3	2020
7	ANKAMAH-YEBOAH I	2	2	0,5	37	2	2021
8	DEY MM	2	2	0,286	30	2	2018
9	ELOKABY MA	2	2	0,4	14	2	2020
10	LI Z	2	2	0,182	27	2	2014

Image 4 is a visualization of the collaboration network among authors in research on technical efficiency in fish farming. Each node represents an author, with the size and color of the nodes indicating the frequency of collaboration and possibly their influence

or productivity. The connections between authors are depicted by lines connecting the nodes, reflecting collaborations in publications. Some authors, such as Khan MA, Nielsen R, and Iliyasu A, have larger nodes, indicating a higher number of collaborations or publications within this network. There are also distinct clusters that show groups of authors who frequently work together. For instance, Iliyasu, A and Nielsen R are in the same cluster along with several other authors, suggesting strong collaboration among them. In contrast, authors like Helal, A. M and Yin X appear more isolated from the main groups, indicating fewer collaborations or a more specific research focus. Overall, this figure illustrates the structure of the collaboration network among authors in research on technical efficiency in fish farming.

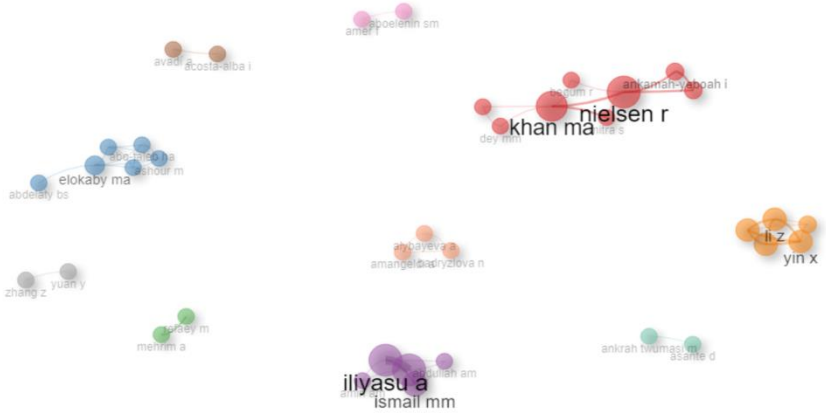

Image 4. Collaboration Network Among Authors in Technical Efficiency Research of Fish Farming activities from 2020 to 2024.

Most Relevant Affiliations

From Image 5, where the horizontal axis shows the number of articles published by each institution and the vertical axis lists the names of the institutions, it can be seen that "Wageningen University & Research" and the "Chinese Academy of Agricultural Sciences" are at the top with 8 articles each, indicating a significant contribution to this research area. "Bangladesh Agricultural University" and "WorldFish" follow with 5 articles each, along with several other institutions with slightly smaller contributions. These institutions play a dominant role in research on technical efficiency in fish farming, which can be interpreted as centers of excellence or primary research focuses in this field. This review highlights the importance of institutional roles in developing research and providing a foundation for other researchers in the field of aquaculture.

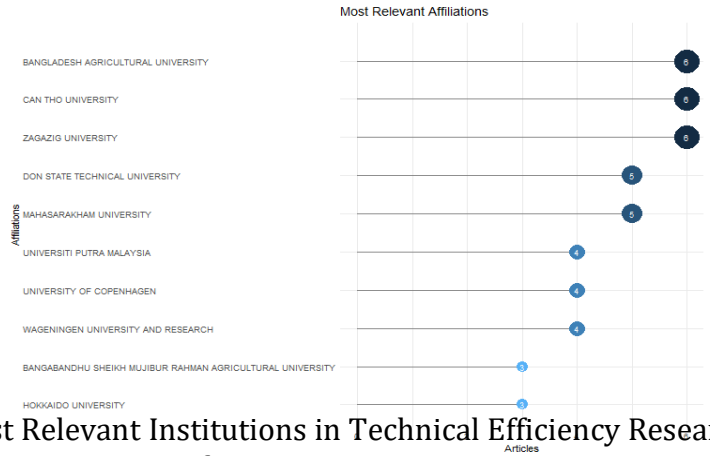

Image 5. Most Relevant Institutions in Technical Efficiency Research in Fish Farming activities from 2020 to 2024.

Most Relevant Source

The mapping of several academic journals shows their relevance and publication count, potentially measured by citations or other indices. The X-axis indicates the number of publications from each journal, while the circle sizes represent the journal's impact or significance. The Journal Of The World Aquaculture Society stands out with 8 publications, Aquaculture Economics & Management with 7, and both Aquaculture Research and Aquaculture Reports with 6 and 5 publications, respectively. Other notable journals, like Fisheries, International Journal Of Fisheries And Aquatic Studies, and PLOS ONE, have fewer publications but are still key contributors to aquaculture research. These journals are regarded as highly influential and important, demonstrating substantial contributions in publications and their impact on research concerning technical efficiency in fish farming.

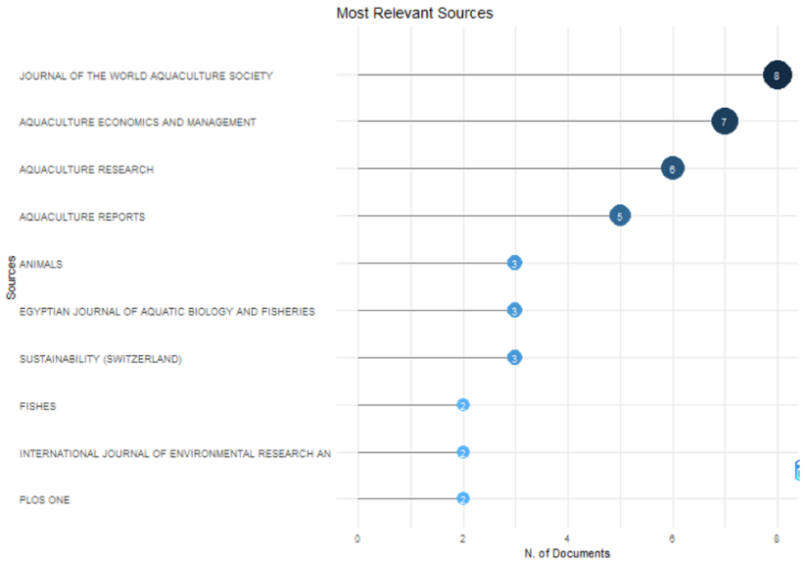

Image **6.** The Most Influential Journal in Technical Efficiency of Fish Farming Activities from 2020 to 2024.

Trend Analysis

Word Cloud of Keywords

Image 7. Key Themes and Areas of Focus in Aquaculture Research from 2020 to 2024.

The size of the words in the image reflects their frequency or relevance in the literature, with larger words indicating more frequent appearances. Words like "Technical Efficiency" and "Aquaculture" are the most prominent, highlighting a primary focus on technical efficiency and the overall field of aquaculture. Additionally, "Data Envelopment Analysis" is a key term, representing a frequently used analytical method in assessing efficiency in this sector. Other key terms, such as "Productivity," "Economic Efficiency," and "Stochasticity," show a focus on productivity, economic efficiency, and uncertainty within the context of aquaculture. Countries like "China" and "Vietnam" also appear, indicating frequent research focus on their contributions to aquaculture production. Moreover, environmental aspects such as "Environmental Protection," "Environmental Impact," and "Climate Change" emphasize concerns about environmental impact and protection in aquaculture practices. The image also includes words related to research methodology, such as "Controlled Study" and "Animal Experiment," as well as outcomes like "Growth Rate," providing a comprehensive overview of the main topics in aquaculture research.

A conceptual network map created using VOSviewer software, depicting the relationships between various concepts and keywords in research related to aquaculture and technical efficiency. Each node represents a frequently occurring keyword or topic in the publications, with lines connecting the nodes indicating relationships or associations between them. The size of the nodes reflects the frequency or importance of the concepts in the research dataset, while the color of the clusters indicates similar themes or thematic categories. For example, aquaculture, as the largest node in red, signifies that this topic is central to much of the research, closely linked with concepts like feed conversion ratio, controlled study, and economic efficiency. Meanwhile, technical efficiency in green is associated with topics such as stochasticity, fishery management, and efficiency.

Additionally, this illustration highlights specific geographical and thematic focuses in the existing literature. For instance, the blue cluster includes aquaculture production and Bangladesh, emphasizing the research focus on aquaculture production in the country. China also emerges as a significant keyword associated with the aquaculture industry, indicating that research in this country is also a major focus. This network helps visualize how different topics in aquaculture and technical efficiency research are interrelated, providing a broader understanding of how this field is evolving. It also shows how research in various countries is interconnected and contributes to the global discourse on this topic.

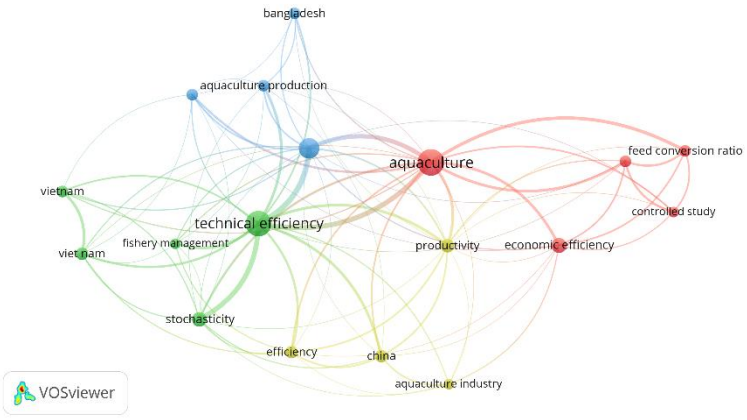

Image 8. A conceptual network map in Aquaculture Research from 2020 to 2024.

Determinant of Technical efficiency aquaculture

In this literature review, various factors influencing technical efficiency have been identified, including the social-demographic characteristics of fish farmers, such as age, experience, and education. The review findings indicate that age can significantly impact technical efficiency, with older or younger ages potentially having positive or negative effects depending on the specific context of the aquaculture practice (Iliyasu et al., 2016; Nguyen et al., 2018). Experience in fish farming also contributes to enhancing technical efficiency, as more experienced farmers typically possess better skills in resource management and production optimization (Iliyasu et al., 2016). The educational level of fish farmers is also crucial, with findings suggesting that higher education levels tend to increase technical efficiency due to better knowledge of aquaculture practices (Nguyen et al., 2018; Aung et al., 2021).

Another important factor is involvement in technical guidance and training programs. The intensity of contact with aquaculture extension agents and active participation in training has been proven to significantly enhance technical efficiency, providing farmers with access to the latest knowledge and techniques in aquaculture (Iliyasu et al., 2016; Aung et al., 2021). Additionally, infrastructural and production factors, such as pond size, fingerling size, and feed usage, also affect technical efficiency. Research indicates that larger ponds and the use of appropriately sized fingerlings can improve production efficiency (Yin et al., 2014). Moreover, the involvement of women in decision-making within the aquaculture sector positively influences technical efficiency, highlighting the importance of gender inclusion in agricultural management (Aung et al., 2021). Lastly, experience in dealing with climate change impacts, such as flooding or salinity intrusion, can help farmers adapt to dynamic environmental conditions, thereby affecting technical efficiency (Nguyen et al., 2018). These factors demonstrate that technical efficiency in fish farming results from a complex combination of social-demographic factors, training, production infrastructure, gender, and environmental factors.

Unexplored potential determinants that may influence technical efficiency in aquaculture include factors identified in the study by Long et al. (2020), which noted that access to formal credit and larger farm sizes can enhance technical efficiency. Besson et al. (2014) highlighted the importance of genetic selection technology in improving production efficiency. Aswathy and Joseph (2019) pointed out that stocking density and the amount of feed used have a significant impact on both economic and technical efficiency.

Other potential determinants that may influence technical efficiency in aquaculture, yet remain underexplored, have been Tidentified in various abstracts. One such determinant is the impact of regulatory environments. The study by Van Senten et al. (2018) indicated that stringent regulations could affect technical efficiency and the economic competitiveness of baitfish and sportfish producers in the United States. Factors such as the frequency of annual permit renewals and the amount of labor required for regulatory compliance were found to be significant in explaining variations in efficiency levels. Research by Khan et al. (2021) emphasized the importance of access to extension services and capital in enhancing the technical efficiency of farmers in Bangladesh. They found that farmers with better access to extension services tended to be more efficient. Factors such as farm size, type of feed used, and feeding intensity were also noted as significant variables affecting productivity.

Based on the review findings, significant gaps have been identified in the use of SFA and DEA methods for efficiency measurement, as they often lack a standardized approach. Consequently, research may yield inconsistent findings. Therefore, comparative studies are needed to evaluate the effectiveness of these methodologies and develop a more uniform framework for assessing efficiency in fish farming activities (See et al., 2021). Additionally, many studies focus on specific regions and species, particularly in Asian countries, leaving other aquaculture regions underrepresented. More comprehensive research, encompassing a wider variety of species and regions, is required to provide a more thorough understanding of technical efficiency (Wang et al., 2021). Research opportunities related to technical efficiency in Indonesia remain vast, particularly in the fish farming sector. The limited number of studies exploring technical efficiency in the local context indicates a need for further research in this area. With unique geographical and environmental conditions, as well as the diversity of fish species being cultivated, Indonesia offers numerous aspects to be studied to understand the factors influencing technical efficiency.

CONCLUSIONS

This study highlights significant gaps in the application of efficiency measurement techniques, such as Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA), in aquaculture practices. These gaps are critical in the context of increasing demand for animal protein and the need for sustainable food production. The findings emphasize the necessity for comparative studies to develop a more standardized framework for assessing efficiency, which would provide more consistent and reliable results.

Moreover, the review reveals that existing research predominantly focuses on specific regions and species, particularly in Asian countries, leaving other regions underrepresented. This underscores the need for more comprehensive studies that encompass a wider variety of species and geographic areas to achieve a more complete understanding of the industry's efficiency.

The study also identifies several potential determinants of technical efficiency that have not been thoroughly explored, such as the impact of regulatory environments, access to formal credit, and genetic selection technology. These unexplored factors present opportunities for future research to deepen our understanding of the complexities of aquaculture efficiency. Specifically in Indonesia, there is significant potential for further research on technical efficiency due to its unique geographical and environmental conditions and the diversity of cultivated fish species. Addressing these research gaps can contribute to the development of more effective and sustainable aquaculture practices, ultimately supporting global food security and environmental conservation.

REFERENCES

.Ahmed, N., Zander, K. K., & Garnett, S. T. (2011). Economic efficiency analysis of fish farming in Bharatpur District, Rajasthan: A corporate social responsibility (CSR) initiative. Australian Journal of Agricultural and Resource Economics, 55(2), 199–219.

Ankamah-Yeboah, I., Nielsen, R., & Llorente, I. (2021). Capital structure and firm performance: Agency theory application to Mediterranean aquaculture firms. Aquaculture Economics and Management, 25(4), 367–387.

Ankrah Twumasi, M., Asante, D., Brako, J. N., Ding, Z., & Jiang, Y. (2023). Chronic non-communicable diseases of fish farm household members and their quantitative impacts on fish farm production efficiency. International Journal of Environmental Research and Public Health, 20(5), 4175.

Ariman Karabulut, H., Kurtoğlu, İ. Z., & Kirtan, Y. E. (2019). Effects of the feeds containing hazelnut meal as a plant protein source on growth performance and body composition of Siberian sturgeon (Acipenser baeri) and economic profitability value. Turkish Journal of Veterinary and Animal Sciences, 43(2), 244–252.

Ashour, M., Abo-Taleb, H. A., Hassan, A.-K. M., Shaban, W. M., & Mansour, A. T. (2021). Valorization use of amphipod meal, Gammarus pulex, as a fishmeal substitute on growth performance, feed utilization, histological and histometric indices of the gut, and economic revenue of grey mullet. Journal of Marine Science and Engineering, 9(12), 1336.

Aung, Y. M., Khor, L. Y., Tran, N., Shikuku, K. M., & Zeller, M. (2021). Technical efficiency of small-scale aquaculture in Myanmar: Does women's participation in decision-making matter? Aquaculture Reports, 21, 100841.

Besson, M., Komen, H., Aubin, J., Vandeputte, M., & Van Arendonk, J. A. (2014). Economic values of growth and feed efficiency for fish farming in recirculating aquaculture system with density and nitrogen output limitations: A case study with African catfish (Clarias gariepinus). Journal of Animal Science, 92(12), 5394–5405.

Bunkar, K., Prakash, S., Ramasubramanian, V., & Krishnan, M. (2022). Economic efficiency analysis of fish farming in Bharatpur District, Rajasthan: A corporate social responsibility (CSR) initiative. Indian Journal of Fisheries, 69(4), 109–114.

Connor, D. J., & Mínguez, M. I. (2012). Evolution not revolution of farming systems will best feed and green the world. *Global Food Security, 1*(2), 106-113.

Da Silva, R. S., Lopes, J. R. T., do Espírito Santo, R. V., Martins Júnior, H., & de Lourenço Júnior, J. B. (2020). Effects of palm kernel meal (Elaeis guineensis) as corn (Zea mays) substitutes in tambaqui (Colossoma macropomum) diets. Aquaculture Research, 51(8), 3358–3366.

FAO. (2024). *The state of world fisheries and aquaculture 2024: Blue transformation in action*. Food and Agriculture Organization of the United Nations.

Gilson, F., Rodrigues, L. A., New, M. B., Bueno, G. W., & Valenti, W. C. (2024). A description of the culture of tambatinga (Colossoma macropomum x Piaractus brachypomus) in a South American tropical region and the interaction of farm size with value chains. Aquaculture Reports, 34, 101888.

Gronthy, U. U., Biswas, U., Tapu, S., Samad, M. A., & Nahid, A.-A. (2023). A bibliometric analysis on arrhythmia detection and classification from 2005 to 2022. Diagnostics, 13(10), Article 1732.

Gwazani, R., Gandiwa, E., & Poshiwa, X. (2022). Rural small-scale aquaculture: An assessment of farmers' perceptions and technical efficiency in Masvingo, Zimbabwe. Cogent Food and Agriculture, 8(1), 2139817.

Gwazani, R., Gandiwa, E., & Poshiwa, X. (2022). Rural small-scale aquaculture: An assessment of farmers' perceptions and technical efficiency in Masvingo, Zimbabwe. Cogent Food and Agriculture, 8(1), 2139817.

Helal, A. M., Essa, M. A., Abdelaty, B. S., & Elokaby, M. A. (2020). The effect of pond soil types and stocking weight of Mugil capito fingerlings reared in poly-culture system on production performance. Egyptian Journal of Aquatic Biology and Fisheries, 24(1), 431–441.

Hossain, M. E., Khan, M. A., Dey, M. M., & Alam, M. S. (2022). The relationship between chronic non-communicable diseases of fish farm household members and

production efficiency: The case of Ghana. International Journal of Environmental Research and Public Health, 20(5), 4175.
Hyk, V., Vysochan, O., & Vysochan, O. (2022). Integrated reporting of mining enterprises: Bibliometric analysis. *Studies in Business and Economics*, 17(3), 90–99.
Iliyasu, A., Mohamed, Z. A., Ismail, M. M., Abdullah, A. M., Kamarudin, S. M., & Mazuki, H. (2014). A review of production frontier research in aquaculture (2001-2011). *Aquaculture Economics and Management, 18*(3), 221-247.
Iliyasu, A., Mohamed, Z. A., Ismail, M. M., Amin, A. M., & Mazuki, H. (2016). Evaluation of technical efficiency in exotic carp polyculture in Northern India: Conventional DEA vs. bootstrapping methods. Aquaculture Research, 47(1), 101–113.
Iliyasu, A., Mohamed, Z. A., Terano, R. (2016). Comparative analysis of technical efficiency for different production culture systems and species of freshwater aquaculture in Peninsular Malaysia. Aquaculture Reports, 3, 51–57.
Iliyasu, A., Mohamed, Z. A., Terano, R. (2016). Comparative analysis of technical efficiency for different production culture systems and species
Iliyasu, A., Mohamed, Z. A., Terano, R., Mazuki, H., & Abdullah, A. M. (2014). Elements which delimitate technical efficiency of fish farms in Ghana. Journal of the World Aquaculture Society, 41(4), 506–518.
Islam, S., Mitra, S., & Khan, M. A. (2023). Commercial aquaculture in Bangladesh influences the technical and cost efficiency. Journal of Agriculture and Food Research, 12, 100581.
Johnson, K., Engle, C., & Wagner, B. (2014). Comparative economics of US catfish production strategies: Evidence from a cross-sectional survey. Journal of the World Aquaculture Society, 45(3), 279–289.
Kalya, Dinda, Az-Zahra., Debora, Engelien, Christa, Jaya., Xenna, Mutiara., Heri, Septya, Kusuma. (2024). Exploring research publication trends on clove oil as an antibacterial using bibliometric analysis with VOSviewer based on Scopus database. Science Talks, 11:100376-100376.
Karla, Salinas-Ríos., Ang´élica, Janneire, García, López. (2022). Bibliometrics, a useful tool within the field of research. Journal of basic and applied psychology research, 3(6):9-16.
Kibria, A. S. M. G., & Jashimuddin, M. (2012). Economic efficiency of land-use systems in the seasonally flooded areas of Comilla, Bangladesh. Journal of Land Use Science, 7(3), 349–363.
Kularatne, M. G., Pascoe, S., Wilson, C., & Robinson, T. (2019). Efficiency of culture-based fisheries production in village irrigation systems of Sri Lanka. Aquaculture Economics and Management, 23(1), 65–85.
Leaver, J.D. (2011). Global food supply: A challenge for sustainable agriculture. *Nutrition Bulletin, 36*(4), 416-421.
Liu, Y., Tveteras, S., & Xie, J. (2021). Efficiency in Chinese large yellow croaker aquaculture: Implication for sustainable aquaculture in China. Sustainability (Switzerland), 13(24), 13952.
Liu, Y., Tveteras, S., & Xie, J. (2021). Technical efficiency and environmental impact of seabream and seabass farms. Journal of World Aquaculture Society, 52(3), 476–490.
Lu, Y.-H., Huang, Y.-W., Lee, J.-J., & Huang, S.-J. (2022). Technical efficiency of freshwater milkfish (Chanos chanos) aquaculture in Taiwan. Fishes, 7(5), 224.
Mehrim, A., Refaey, M., Salem, M., Zenhom, O., & Eldanasoury, M. (2022). Evaluation of Pell-Gel-Dry® as a feed binder and growth promoter agent for the Nile tilapia, Oreochromis niloticus (Linnaeus, 1758). Animals, 12(7), 1620.

Mkuna, E., & Baiyegunhi, L. J. S. (2019). Analysis of the technical efficiency of Nile perch (Lates niloticus) fishers in the Tanzanian portion of Lake Victoria: A stochastic frontier analysis. Lakes and Reservoirs: Science, Policy and Management for Sustainable Use, 24(3), 228–238.

Nasr, M. A. F., Reda, R. M., Ismail, T. A., & Moustafa, A. (2021). Growth, hemato-biochemical parameters, body composition, and myostatin gene expression of Clarias gariepinus fed by replacing fishmeal with plant protein. Animals, 11(3), 1–16, 889.

Nees, Jan, van, Eck., Ludo, Waltman. (2009). VOSviewer: A Computer Program for Bibliometric Mapping. Research Papers in Economics,

Ngo, T., Vu, H. V., Ho, H., Dao, T. T. T., & Nguyen, H. T. H. (2019). Performance of fish farms in Vietnam: Does financial access help improve their cost efficiency? International Journal of Financial Studies, 7(3), 45.

Ngo, T., Vu, H. V., Ho, H., Dao, T. T. T., & Nguyen, H. T. H. (2019). Performance of fish farms in Vietnam: Does financial access help improve their cost efficiency? International Journal of Financial Studies, 7(3), 45.

Nguyen, L. A., Pham, T. B. V., Bosma, R., De Silva, S., & Lansink, A. O. (2018). Technical efficiency of different farm sizes for tilapia farming in China. Journal of the World Aquaculture Society, 49(3), 570–581.

Niu, Dongle & Zhang, Min & Mujumdar, Arun & Yu, Dongxing. (2024). Novel Drying Technologies for Future Animal- and Plant-Derived Protein Foods: Research Progress, Challenges, and Potential Applications. Food and Bioprocess Technology. 1-21.

Onumah, E. E., Brümmer, B., & Hörstgen-Schwark, G. (2010). Elements which delimitate technical efficiency of fish farms in Ghana. Journal of the World Aquaculture Society, 41(4), 506–518.

Raftowicz, M., Kalisiak-Medelska, M., & Struś, M. (2020). Developing short supply chains for carp market in Poland: Challenges and opportunities. Sustainability (Switzerland), 12(7), 2934.

Rahim, A., Hastuti, D. R. D., & Malik, A. (2024). *Pembangunan Ekonomi Biru di Indonesia*. Penerbit NEM.

Rego, M. A. S., Sabbag, O. J., Soares, R. B., & Peixoto, S. (2018). Technical efficiency analysis of marine shrimp farming (Litopenaeus vannamei) in biofloc and conventional systems: A case study in northeastern Brazil. Anais da Academia Brasileira de Ciências, 90(4), 3705–3716.

Samat, N., Goh, K. H., See, K. F., Ibrahim, R. A., Chan, N. W., Tan, M. L., Lee, L. K., Seow, T. W., & Sabjan, M. A. (2024). A meta-analysis of aquaculture technical efficiency studies. *Reviews in Aquaculture*, 16(1), 452-472.

See, K. F., Ibrahim, R. A., & Goh, K. H. (2021). Aquaculture efficiency and productivity: A comprehensive review and bibliometric analysis. Aquaculture, 544, 736881.

Spencer, D. M., Brown, I. W., Doubell, M. J., & Zhang, H. (2019). Environmental impacts of prawn farming: Case study of spanner crab catchability. Fisheries Oceanography, 28(3), 317–326.

Taylor, N. (2020). Models suggest pathogen risks to wild fish can be mitigated by acquired immunity in freshwater aquaculture systems. Scientific Reports, 10(1).

Tran, T. H. N., & Honti, M. (2017). Application of different evapotranspiration models to calculate total agricultural water demand in a tropical region. Periodica Polytechnica Civil Engineering, 61(4), 904–910.

Troell, M., Naylor, R. L., Métian, M., Beveridge, M. C. M., Tyedmers, P., Folke, C., … & Zeeuw, A. d. (2014). Does aquaculture add resilience to the global food system?. Proceedings of the National Academy of Sciences, 111(37), 13257-13263.

Van Senten, J., Dey, M. M., & Engle, C. R. (2018). Effects of regulations on technical efficiency of U.S. baitfish and sportfish producers. Aquaculture Economics and Management, 22(3), 284–305.

Vignesh, K., Yadav, D. K., Wadikar, D. D., & Semwal, A. D. (2023). Exploring sustenance: Cereal-legume combinations for vegan meat development. *Sustainable Food Technology*, 2(1), 32-47.

Wang, Z., Chen, X., Shi, L., Zhang, X., & Hu, Y. (2024). Productivity versus environmental sustainability: A broadscale assessment of freshwater aquaculture's technical efficiency and ecological efficiency in China's inland provinces. Journal of the World Aquaculture Society, 55(3), e13057.

Wangkahart, E., Kersanté, P., Phudkliang, J., Soonngam, L., & Pakdeenarong, N. (2023). Effects of a free amino acid mixture in replacing dietary fishmeal and reducing Nile tilapia (Oreochromis niloticus) production costs. Aquaculture Reports, 32, 101739.

Yamamoto, A., Huynh, T. K. U., Saito, Y., & Matsuishi, T. F. (2022). Assessing the costs of GHG emissions of multi-product agricultural systems in Vietnam. Scientific Reports, 12(1), 18172.

Yan, W., & Zhong, C. (2022). The coordination of aquaculture development with environment and resources: Based on measurement of provincial eco-efficiency in China. International Journal of Environmental Research and Public Health, 19(13), 8010.

Yang, D., & Wang, Q. (2023). Evaluation of China's Marine Aquaculture Sector's Green Development Level Using the Super-Efficiency Slacks-Based Measure and Global Malmquist–Luenberger Index Models. Sustainability.

Yin, X., Wang, A., Zhou, H., Li, Z., & Shao, P. (2014). Technical efficiency of different farm sizes for tilapia farming in China. Aquaculture Research, 51(1), 307–315.

Yuan, Y., Yuan, Y., Dai, Y., Gong, Y., & Yuan, Y. (2020). Technical efficiency of different farm sizes for tilapia farming in China. Aquaculture Research, 51(1), 307–315.

Zhang, H., Nisar, U., & Mu, Y. (2022). Socioeconomic aspects of rice-fish farming in Bangladesh: Opportunities, challenges, and production efficiency. Fishes, 7(4), 168.

Zhang, Z., Fang, X., & Sun, L. (2022). Comparison for ecological economic performance of Chinese sea perch (Lateolabrax Maculatus) under different aquaculture systems. Aquaculture and Fisheries, 7(6), 683–692.

Zhang, Z., Fang, X., & Sun, L. (2022). Insights of freshwater carp polyculture in Bangladesh: Inefficiency, yield gap, and yield loss perspectives. Aquaculture, 557, 738341.

Zhong, S., Li, A., & Wu, J. (2022). The total factor productivity index of freshwater aquaculture in China: Based on regional heterogeneity. Environmental Science and Pollution Research, 29(11), 15664–15680.