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REVIEW: THE EFFECT OF CULTURE METHODS ON THE *FEED CONVERSION RATIO* (FCR) OF SALINE TILAPIA (OREOCHROMIS NILOTICUS) USING A COMPARATIVE APPROACH FROM RELATED SPECIES

Review: Pengaruh Metode Budidaya Terhadap Nilai Rasio Konversi Pakan (Fcr) Ikan Nila Salin (*Oreochromis niloticus*) Dengan Pendekatan Komparatif Dari Spesies Sejenis

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ABSTRACT

Tilapia salin (Oreochromis niloticus) is one type of fish for consumption that has economic value and quite high market demand in Indonesia because of its savory meat taste (Baihaqi et al. 2024). In fisheries cultivation, one important aspect in fish farming activities is feed management. This is because it can affect the growth rate of fish and the resulting feed conversion ratio (FCR) value (Budayati et al. 2023). The feed conversion ratio (FCR) value is one of the parameters used to assess the efficiency of feed utilization by fish. This research method uses a qualitative descriptive method with a literature review approach that examines and describes the results of previous studies regarding the effect of cultivation methods on the feed conversion ratio (FCR) value in tilapia salin (Oreochromis niloticus) in Indonesia. This study shows that the cultivation method has a significant effect on the feed conversion ratio (FCR) value in tilapia salin (Oreochromis niloticus). The biofloc system provides the best efficiency with the lowest FCR value (up to 1.07), followed by the recirculation system (RAS) and floating net cages (KJA) with relatively low and stable FCR values. In contrast, the pond system shows the most variable FCR values, even tending to be high, especially if water quality and feed management are not maintained.

Keywords: Salin tilapia, Feed conversion ratio (FCR), Cultivation methods

ABSTRAK

Ikan nila salin (*Oreochromis niloticus*) adalah salah satu jenis ikan konsumsi yang memiliki nilai ekonomi dan permintaan pasar yang cukup tinggi di Indonesia karena rasa dagingnya yang gurih (Baihaqi *et al*. 2024). Dalam budidaya perikanan, salah satu aspek penting dalam kegiatan budidaya ikan adalah manajemen pemberian pakan. Hal ini karena dapat mempengaruhi kecepatan pertumbuhan ikan serta nilai rasio konversi pakan (FCR) yang dihasilkan (Budayati *et al*. 2023). Nilai rasio konversi pakan (FCR) adalah salah satu parameter yang digunakan untuk menilai efisiensi pemanfaatan pakan oleh ikan. Metode penelitian ini menggunakan metode deskriptif kualitatif dengan pendekatan studi literatur (*literature review)* yang mengkaji dan mendeskripsikan hasil-hasil penelitian terdahulu mengenai pengaruh metode budidaya terhadap nilai rasio konversi pakan (FCR) pada ikan nila salin (*Oreochromis niloticus)* di Indonesia. Kajian ini menunjukkan bahwa metode budidaya memiliki pengaruh signifikan terhadap nilai rasio konversi pakan (FCR) pada ikan nila salin (*Oreochromis niloticus*). Sistem bioflok memberikan efisiensi terbaik dengan nilai FCR terendah (hingga 1,07), diikuti oleh sistem resirkulasi (RAS) dan keramba jaring apung (KJA) dengan nilai FCR yang relatif rendah dan stabil. Sebaliknya, sistem tambak menunjukkan nilai FCR yang paling bervariasi, bahkan cenderung tinggi, terutama jika kualitas air dan manajemen pakan tidak terjaga.

Kata Kunci: Ikan nila salin, *Feed convertion ratio* (FCR), Metode budidaya

INTRODUCTION

Indonesia has great potential in tilapia fisheries, as evidenced by the export of 4,700 tons of frozen tilapia fillets in the first half of 2023 supported by the government's focus on expanding export markets amidst slowing production in China (FAO 2023). National production *of* aquaculture in Indonesia reached 15.3 million tons in 2023, and tilapia is the second largest contributor after seaweed (KKP 2024). This shows the great potential of tilapia in Indonesia and the demand in the international market. One of the tilapia that has the potential to be developed in Indonesia is salin tilapia.

Salin tilapia (Oreochromis niloticus) is a type of consumption fish that has economic value and quite *high* market demand in Indonesia because of its delicious meat (Baihaqi *et al*., 2024). In addition, this fish has a fast growth rate and the ability to adapt to various environmental conditions. This fish is euryhaline which can survive in a wide range of salinity, allowing this fish to live in both brackish and sea waters (Sustiawan *et al*., 2024).

In fish farming, one important aspect in fish farming activities is feeding management. This is because it can affect the growth rate of fish and the resulting feed conversion ratio (FCR) value (*Budayati et al*., 2023). The feed conversion ratio (FCR) value is one of the parameters used to assess the efficiency of feed utilization by fish. A lower FCR value indicates that feed is used more efficiently in the process of fish biomass growth (Tahir *et al*., 2023). This value is also an important indicator in evaluating the performance of aquaculture production which plays an important role in calculating the efficiency of operational costs during the maintenance period (Gompi *et al*., 2023).

Optimal feed conversion value requires stable water quality parameter control. This is because these parameters indicate the overall environmental conditions of maintenance. A well-*managed* environment will create physiological conditions that support efficient feed utilization, thus enabling the achievement of optimal cultivation results in accordance with the designed production targets (Gompi *et al*., 2023).

Each fish cultivation method has its own characteristics in managing the quality of its environment, especially water quality which is a key factor in supporting fish health and growth. Optimal water quality plays a direct role in the efficiency of metabolism, appetite, and nutrient utilization, *which* ultimately affects the feed conversion ratio (FCR) value. The better the quality of the cultivation environment, the higher the efficiency of feed use and the FCR value tends to decrease. Therefore, differences in cultivation methods have the potential to produce variations in FCR values, depending on the effectiveness of each method in maintaining environmental stability.

Research on the feed *conversion* ratio (FCR) in saline tilapia is still limited, especially in the context of various cultivation methods. Therefore, a comparative approach through studies on freshwater tilapia which have similar physiological characteristics is used to explore the effect of cultivation methods on FCR values. The aim of this study was to analyze the relationship between different cultivation methods and feed conversion ratio values as a basis for technical recommendations in determining the most efficient and sustainable cultivation methods for cultivating saline tilapia (*Oreochromis niloticus*) in Indonesia

RESEARCH METHODS

This research method uses a qualitative descriptive method with a literature review approach that examines and describes the results of previous studies on the effect of cultivation methods on the feed conversion ratio (FCR) value of saline tilapia (Oreochromis niloticus) in Indonesia. The qualitative method aims to understand and explain social phenomena in depth (Hardani *et al*., 2020). The approach used is comparative, by analyzing secondary data from freshwater tilapia and several other cultivated species that have similar physiological characteristics. The studies included in this study are studies that report the feed conversion ratio (FCR) values obtained through various cultivation systems, including ponds, floating net cages (KJA), biofloc, and recirculating aquaculture systems (RAS). Data were collected through searches of national scientific journals with a publication time limit, namely a maximum of the last ten years (2015–2025), to ensure the validity, accuracy, and recency of the information analyzed.

RESULT

Feed conversion ratio (FCR) is used as an indicator of feed efficiency in producing fish biomass growth. In saline tilapia cultivation in Indonesia, there are four most commonly applied methods, namely pond systems, floating net cage systems (KJA), biofloc systems, and recirculating systems (Recirculating Aquaculture System). Each of these methods has different characteristics in managing its environment, which directly affects the FCR value through water quality management, dissolved oxygen availability, and stability of the maintenance environment.

Table 1. Results of the study on saline tilapia FCR

No	Cultivation Methods	Researchers and Years	FCR	Density of Distribution	Types of Feed	Maintenance Period (days))
1	Pond	Setiyadi *et al.,* (2015)	Nila larasati 5.21±0.38, local red nila 5.59±0.48, and local black nila 7.98±0.64	10 tails/ hapa	Commercial pellets (35% protein)	30
2	Pond	Hendriana *et al.,* (2022)	1,38-1,42	5 tails m^{-2}	Fish feed plus vitamin C	49
3	Pond	Fradina & Latuconsina (2022)	2,07	-	FENGLI 1 Platinum type floating pellets	-
4	KJA	Warsa *et al.,* (2021)	1,73	15 tails	Commercial feed	75
5	KJA	Budiardi *et al.,* (2022)	1,19	10.000-12.000 tails	Feed (protein 28-30%)	125
6	KJA	Panjaitan & Manullang (2022)	1,8	-	Commercial feed	60
7	Biofloc	Yunarty *et al.,* (2021)	1,07	120 tails/m^3	Floating pellets (30% protein)	30
8	Biofloc	Safsafubun *et al.,* (2023)	1,2	150 tails/m^3	Fermented pellets	45
9	Biofloc	Rijal *et al.,* (2021)	2,35	-	Commercial feed supplemented with garlic extract powder	120
10	RAS	Hapsari *et al.,* (2020)	1,47	25 tails/m^2	Commercially made feed	30
11	RAS	Renaldi *et al.*, (2024)	1,23	15 tails	Pellets plus viterna plus supplements	30
12	RAS	Christin *et al.*, (2021)	2,26.	-	Commercial feed	90 days

Table 2. Results of the study on water quality during maintenance in different cultivation methods

No	Cultivation Methods	Researchers and Years	Water Quality
1	Pond	Setiyadi *et al.,* (2015)	- Temperature: 27-32ºC - Dissolved oxygen: 4-9 mg/l - pH : 7,8 - 8,6 - Salinity : 17-27 ppt
2	Pond	Hendriana *et al.,* (2022)	- Temperature : 30,5–33 ºC - Dissolved oxygen: 2,46–7,70 mg/l - Salinity: 4–6 ppt
3	Pond	Fradina & Latuconsina (2022)	- Temperature: 26,7 - 29°C - pH : 7,6 – 12 - Dissolved oxygen: 9,5 – 19,6 mg/l
4	KJA	Warsa *et al.,* (2021)	-
5	KJA	Budiardi *et al.,* (2022)	- Temperature: 28,5-29,7ºC - Dissolved oxygen: 3,1-4.1 mg/l in cages - Dissolved oxygen: 7,9 mg/l outside the cage - pH : 6,4-7,9 - Hardness: 10 mg/l - Alkalinity: 24,41-36,6 mg/l - Ammonia : 0-0,0007 mg/l - Nitrite : 0-<0,02 mg/l
6	KJA	Panjaitan & Manullang (2022)	-
7	Biofloc	Yunarty *et al.,* (2021)	- Temperature: 25,2 - 28,2 ºC - Dissolved oxygen: 3,5 - 4,28 mg/l - pH : 4,58 – 6,10 - NH_3 : 0,1673 mg/l - NO_2 : 0,113 – 0,119 mg/l
8	Biofloc	Safsafubun *et al.,* (2023)	- Temperature: 27,2°C - Dissolved oxygen: 5,05 mg/l - pH : 5,40 - Ammonia : 0,58 - Nitrite (NO_2) : 1,12 - Nitrate (NO_3) : 25,21
9	Biofloc	Rijal *et al.,* (2021)	- Temperature: 26 – 27 °C - pH : 6 – 7,5
10	RAS	Hapsari *et al.* (2020)	- Temperature: 26 27 °C - pH : 7 - Dissolved oxygen: > 5 mgL^{-1} - TAN : < 1 mgL^{-1}
11	RAS	Renaldi *et al.,* (2024)	- Temperature: 28-29.9 °C - pH : 6.10-7.73 - Dissolved oxygen: 3.10-5,80 mg/l - Ammonia : 0.001-0.014 mg/l
12	RAS	Christin *et al.,* (2021)	- Temperature: 28,33–29,45ºC - pH : 7,29–7,67

	- Dissolved oxygen: 6,9–7,99 mg/l - Total dissolved solids value (TDS) : 308,28 361,06 mg/l

DISCUSSION

Comparison of Cultivation Methods Based on FCR Values

Feed Conversion Ratio (FCR) is the number of kg of feed needed to increase the weight of fish by 1 kg, or the number of kg of feed converted into kg of meat (Safari *et al*., 2017). There are differences in the value of the feed conversion ratio (FCR) between various cultivation methods in terms of feed utilization efficiency, which directly reflects the success of a cultivation system in optimizing fish growth against the amount of feed given. According to Tanjung *et al*., (2019), the lower the feed conversion value, the better the level of efficiency of feed utilization used for growth, conversely if the feed conversion is large, the level of feed utilization efficiency is less good. According to FAO (2017), the average FCR of tilapia raised to harvest weight ranges from 180 to 750 g, which is between 1.25 and 1.90.

Of all the methods analyzed, the biofloc system recorded the lowest FCR value, which is 1.07 based on the research results of Yunarty *et al*., (2021). This shows that only 1.07 kg of feed is needed to produce 1 kg of fish biomass. This efficiency is driven by the basic principle of biofloc which utilizes heterotrophic microorganisms to process organic waste such as ammonia into nutrient-dense floc that can be consumed again by fish. This is in line with Yunarty (2020) who stated that biofloc technology is a system for utilizing inorganic nitrogen waste with the help of probiotic bacteria for feed efficiency and minimizing waste. Another advantage of biofloc is its ability to support cultivation with very high stocking densities (120–150 fish/m³) without causing a drastic decrease in water quality, as long as aeration and floc management are carried out properly. This system is very suitable for application in limited land, and is considered environmentally friendly because it reduces the need for water replacement and minimizes waste.

On the other hand, the Recirculating Aquaculture (RAS) system also shows good FCR efficiency, ranging from 1.23–2.26. The working principle of this recirculation system is to reuse water repeatedly so that the distribution of temperature, oxygen and others becomes more even (Tanjung *et al*., 2019). Control over environmental parameters such as temperature, pH, dissolved oxygen levels, and ammonia is very high in this system, allowing optimal conditions for fish growth. Although the FCR value of RAS is slightly higher than biofloc in some studies, this system excels in environmental stability and flexibility of cultivation locations because it does not depend on open water sources. One example of the success of RAS was shown by Renaldi *et al*., (2024) with an FCR of 1.23 when the feed was supplemented with supplements such as Viterna, which contributed to increasing nutrient efficiency. The Floating Net Cage (KJA) method recorded an FCR value between 1.19–1.8, which is also considered efficient.

Floating net cages (KJA) are one of the technologies used in fisheries cultivation systems in waters such as the sea, lakes, reservoirs or rivers. In tilapia cultivation, floating net cages are one of the appropriate technologies that are often used by farmers because the use of KJA has high efficiency and economic value (Diarta *et al*., 2016). The use of floating net cage systems in tilapia cultivation activities can accommodate high densities so that it can increase fish production. However, the water quality in KJA is highly dependent on the conditions of the surrounding waters, and can change due to external factors such as weather or pollution. The efficiency of FCR in KJA is largely determined by location selection and feed management. A study by Budiardi *et al*., (2022) noted that FCR was as low as 1.19 in cultivation in relatively clean and stable rivers. The advantages of this method are low investment costs and high scalability for cultivation activities in large water areas.

In contrast, the pond system showed the most varied FCR values and in some cases tended to be high, ranging from 1.38 to 7.98, depending on the management applied. In the study of Setiyadi *et al*., (2015), the FCR of tilapia even reached almost 8, indicating very low feed efficiency. This is likely due to a combination of factors such as high temperatures, salinity fluctuations, low water quality, and suboptimal feed utilization. However, not all ponds showed poor results. The study of Hendriana *et al*., (2022) recorded an FCR between 1.38–1.42, which is close to the efficiency of a closed system, when feed is given in a measured manner and enriched with immunostimulants such as vitamin C, and water quality is well managed. This shows that although ponds tend to be more difficult to control, efficient results can still be achieved with the application of appropriate technology and management.

Overall, the analysis shows that closed systems such as biofloc and RAS offer higher FCR efficiency because they provide better control over the quality of the culture environment, while open systems such as ponds and KJA are more dependent on external conditions and more complex daily management. This is important to consider in the development of saline tilapia culture, because although this tilapia is euryhaline and tolerant to various salinities, its growth efficiency is still greatly influenced by environmental stability and nutrient availability. Thus, a culture system that is able to provide a controlled environment and support efficient feed conversion needs to be a priority in the sustainable saline tilapia development scheme in Indonesia.

The Role of Water Quality on Feed Efficiency

Water quality management is carried out to maintain water quality according to fish quality standards (Hendriana *et al*., 2022). Water quality is one of the determinants of success for fish life in cultivation (Hapsari *et al*., 2020). Parameters such as temperature, pH, dissolved oxygen (DO), ammonia, nitrite, and nitrate have a direct influence on fish physiology, especially in the process of metabolism and appetite, which ultimately determines how efficiently feed can be converted into biomass. Good temperature values for cultivation are 25-30o C (BSN 2009), DO values >3 mg/L (BSN 2009), pH values in the range of 6.5-8.5 (BSN 2009), Ammonia <0.2 (Ariyanto et al 2019), Nitrite <0.05 (Ariyanto *et al*., 2019) and salinity values 17-20 ppt (SNI 2009)

A low feed conversion ratio (FCR) value can only be achieved if the environmental conditions of maintenance support optimal growth. For example, in the biofloc system of Yunarty *et al*. (2021), the FCR was recorded at 1.07 with fairly stable water quality even though the pH was slightly acidic (4.58–6.10) and DO in the range of 3.5–4.28 mg/L. The temperature value of 25.2-28.2 is included in the safe range for fish cultivation. The stability of these parameters can be achieved because biofloc is able to dampen fluctuations in water quality through the activity of heterotrophic microbes that absorb nitrogen waste, so that the concentrations of ammonia and nitrite remain within tolerance limits. In the recirculation system (RAS), feed efficiency is also closely correlated with strict water quality control through mechanical and biological filtration. Research by Renaldi *et al*., (2024) showed that an FCR of 1.23 can be achieved under conditions of temperature 28–29.9°C, pH 6.10–7.73, and DO 3.10–5.80 mg/L. The low concentration of ammonia (0.001–0.014 mg/L) also supports the stability of the ideal environment for fish growth.

In the Floating Net Cage (KJA) system, water quality is greatly influenced by the conditions of the open waters where the cages are installed. However, this system still shows good feed efficiency with FCR values between 1.19 and 1.8. Budiardi *et al*., (2022) recorded an FCR of 1.19 with a temperature of 28.5–29.7°C and dissolved oxygen of 3.1–4.1 mg/L in the cage. Water quality in KJA is generally more stable because there is continuous natural water exchange, but it also depends heavily on external environmental conditions such as currents, pollution, and seasons. The low ammonia and nitrite contents reported in this study (0–0.0007 mg/L and <0.02 mg/L, respectively) are indicators that KJA in clean waters is able to support feed efficiency almost equivalent to a closed system. However, the challenge of KJA lies in its dependence on external factors that are difficult to control.

In contrast, high FCR values are often found in cultivation in pond systems that have greater fluctuations in water quality. For example, Setiyadi *et al*., (2015) reported that the FCR of Larasati tilapia was 5.21 and local black tilapia reached 7.98, where the temperature ranged from 27–32°C, salinity 17–27 ppt, and high pH up to 8.6. Although the pH value is still within the tolerance range of tilapia, it is possible that high salinity and variability in other parameters cause physiological stress in fish, thus inhibiting the absorption of nutrients from feed. In addition, dissolved oxygen (DO) levels that are too low also have a negative effect on feed efficiency. Fish that live in an environment with DO below the optimal threshold (around <3 mg/L) tend to experience decreased appetite and poor feed conversion. In the study (Hendriana *et al*., 2022) the DO value was recorded as low as 2.46 mg/L, but the FCR remained low (1.38–1.42) due to good feed management and the provision of immunostimulants. This shows that non-ideal water quality can still be compensated for with feed and supplement interventions, but ideally water quality remains the main priority in the cultivation system.

Therefore, success in achieving high feed efficiency is largely determined by the ability of farmers to monitor and maintain water quality parameters within the optimal range. In the context of saline tilapia cultivation, which is able to survive in a wide range of salinities, water quality management becomes increasingly important because salinity that is too high without adjustment of feed and environment can reduce metabolic efficiency and have a direct impact on FCR values. Thus, proactive and data-based water quality management is a key strategy to increase feed efficiency and the success of sustainable saline tilapia cultivation..

The Role of Feed Type and Supplements on Feed Efficiency (FCR)

The type and quality of feed given in fish farming activities play an important role in determining the efficiency of feed conversion, as reflected in the Feed conversion ratio (FCR) value. Commercial pellet feed is the most common type of feed used in saline tilapia farming, both in pond systems, KJA, biofloc, and RAS. The nutritional content of the feed, especially the protein content, as well as the physical form and digestibility are key factors that influence how much feed can be utilized by the fish for biomass growth. For example, in cultivation with the KJA system by Budiardi *et al*. (2022), the provision of commercial feed with a protein content of 28–30% produced a very good FCR value, which was 1.19, indicating high efficiency in nutrient utilization. Likewise, in pond cultivation carried out by Setiyadi *et al*. (2015), commercial feed with 35% protein was used, but the FCR value was high (5.21 to 7.98), indicating that high nutrient content alone is not enough without proper environmental management and feeding.

Supplementation or additional treatment of feed has been shown to increase feed efficiency. Hendriana *et al*., (2022) reported that the addition of immunostimulants in the form of vitamin C to feed during the early stages of cultivation and periodically every week was able to reduce the FCR value to 1.38–1.42 in the pond system. The provision of vitamin C is believed to increase the immune system of fish and improve physiological functions that support optimal nutrient absorption. In addition, in the biofloc system, Safsafubun *et al*., (2023) used fermented pellet feed and produced an FCR of 1.2, which shows that fermentation can increase feed digestibility and enrich feed with enzymes and probiotic microorganisms that help the digestion process. The use of natural ingredients was also found in the study of Rijal *et al*. (2021), where commercial feed was supplemented with garlic extract powder, which functions as an antibacterial and immunostimulant, although the FCR results were recorded as relatively high (2.35), possibly due to less than optimal environmental influences. In the RAS system, feed efficiency is also increased by adding supplements such as Viterna Plus, as noted by Renaldi *et al*. (2024), which produced a low FCR of 1.23.

In general, these findings indicate that standard commercial feed can provide efficient results if supported by appropriate nutrient formulation and proper feeding techniques. However, supplementation such as vitamin C, fermentation products, and natural additives have been shown to further increase feed effectiveness, especially in challenging environmental conditions. Therefore, in an effort to achieve maximum feed efficiency in saline tilapia cultivation, not only the selection of feed types must be considered, but also strategies for increasing the functional value of feed through supplements and additional treatments. The application of this adaptive feed technology is important, especially considering that saline tilapia is cultivated in environments with medium to high salinity, which can affect fish metabolism and make it difficult to absorb nutrients if not balanced with high-quality and easily digestible feed.

The Role of Stocking Density on Feed Efficiency (FCR)

Aquaculture activities are closely related to the amount of production of cultivated commodities, and one of the factors that greatly influences the amount of production is stocking density, so that to obtain high production values, it is necessary to increase stocking density in cultivated commodities (Engle *et al*., 2017). In addition, stocking density is one of the important technical factors in fish farming that directly or indirectly affects the value of the feed conversion ratio (FCR). The density of fish in a certain volume or area unit will affect the dynamics of the cultured water environment, including the availability of dissolved oxygen, the level of competition between individuals, and the accumulation of organic waste. In high stocking density conditions, if not balanced with a good water and feed management system, fish will experience stress, decreased appetite, and slow growth, which ultimately increases the FCR value. However, several studies have shown that high stocking density is not always directly proportional to high FCR, as long as the cultivation system and management support it. For example, in the biofloc system by Yunarty et al. (2021), a very low FCR value (1.07) was achieved even though the stocking density reached 120 fish/m³, even in the study of Safsafubun *et al*., (2023) it reached 150 fish/m³. This high efficiency is possible because biofloc is able to process organic waste and provide additional nutrients from microbial flocs, and is equipped with an intensive aeration and water control system.

On the other hand, in the pond system, the stocking density tends to be lower, such as in the study of Setiyadi *et al*., (2015) which only applied a stocking density of 10 fish per hapa, but the FCR was high, ranging from 5.21 to 7.98. This shows that low stocking density does not guarantee feed efficiency if it is not supported by stable water quality and proper feeding. The KJA system also shows efficient FCR results at medium to high stocking densities. For example, Budiardi *et al*., (2022) used 10,000–12,000 fish in 3×6 m cages (equivalent to ±556 fish/m³), with an FCR result of 1.19, supported by good natural water quality and provision of commercial feed with sufficient protein. On the other hand, the RAS system in the study of Hapsari *et al*., (2020) showed an FCR of 1.47 at a stocking density of 25 fish/m², and Renaldi et al. (2024) recorded an FCR of 1.23 with a stocking density of 15 fish, indicating that a closed system still requires optimal density settings so that water filtration and oxygen availability continue to support fish metabolism.

From this comparison, it can be concluded that high stocking densities can be applied without sacrificing feed efficiency, as long as the cultivation system supports oxygen supply, waste disposal, and the availability of high-quality feed. Biofloc and RAS systems are very suitable for high stocking densities because they have strong environmental engineering capabilities, while open systems such as ponds and KJA must consider the natural carrying capacity of the waters so that there is no decline in water quality that has an impact on FCR. In the context of saline tilapia cultivation which has a fairly wide environmental tolerance, stocking density settings must still pay attention to the fish's ability to adapt to salinity, space competition, and oxygen availability in order to optimize growth and feed efficiency sustainably.

Relevance of Study Results on Tilapia Salin (Oreochromis niloticus).

Although this study mostly relies on data from freshwater tilapia and has not been fully sourced from direct research on saline tilapia, the results obtained still have high physiological and applicative relevance. This is because saline tilapia (Oreochromis niloticus) is taxonomically the same species as freshwater tilapia, only cultivated in environmental conditions with moderate to high salinity. Saline tilapia is a type of euryhaline fish, namely organisms that have a wide ability to adapt to changes in salinity. Therefore, although differences in salinity have the potential to affect metabolic processes, feed efficiency, and growth rates, the basic principles of cultivation concerning water quality management, types and supplements of feed, and stocking densities still apply and can be used as technical references in the development of saline tilapia cultivation.

This relevance is also strengthened by the fact that several studies referred to in this document come from cultivation practices in low to medium salinity environments, such as pond and KJA systems in coastal areas, which actually reflect saline tilapia cultivation conditions. An example is the study by Setiyadi *et al*., (2015) who recorded salinity between 17–27 ppt in pond systems, and Hendriana et al. (2022) with salinity of 4–6 ppt, both of which have shown variations in FCR values that depend on cultivation management, not just salinity. This shows that in the salinity range that is still tolerable by tilapia, environmental variables such as DO, pH, temperature, and quality and feeding strategies remain the main factors determining cultivation efficiency. In addition, studies using closed system approaches such as biofloc and RAS also have great potential to be applied to saline tilapia, because this system allows stable water salinity engineering, so that fish do not experience extreme environmental fluctuations and can still grow efficiently. However, it should be emphasized that the specific effect of salinity on feed efficiency and FCR still needs to be studied further directly in saline tilapia, especially in higher salinity ranges (>20 ppt).

CONCLUSION

This study shows that the cultivation method has a significant effect on the feed conversion ratio (FCR) value in saline tilapia (Oreochromis niloticus). The biofloc system provides the best efficiency with the lowest FCR value (up to 1.07), followed by the recirculation system (RAS) and floating net cages (KJA) with relatively low and stable FCR values. In contrast, the pond system shows the most variable FCR value, even tending to be high, especially if water quality and feed management are not maintained. Feed efficiency is influenced by various factors, including water quality (temperature, DO, pH, ammonia, nitrite), stocking density, type and feed supplements used. Closed systems such as biofloc and RAS have been shown to be able to support high stocking densities and provide a stable environment, making them very suitable for saline tilapia cultivation that requires controlled environmental conditions. Although the data used in this study mostly come from freshwater tilapia cultivation, the results are still relevant for saline tilapia because both are the same species with euryhaline physiological characteristics. Therefore, this approach can be the basis for designing efficient and sustainable saline tilapia cultivation strategies. In the future, further research is needed that specifically examines the effect of salinity on feed efficiency and growth performance of saline tilapia in various cultivation systems to strengthen technical recommendations based on specific data. With the selection of the right cultivation method and optimal management of feed and water quality, saline tilapia cultivation has the potential to become one of the leading commodities in supporting food security and the fisheries economy in Indonesia.

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