ABDIMAS: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang
Vol.10(3) August 2025, 543-553
p-ISSN: 2721-138X e-ISSN: 2548-7159
http://jurnal.unmer.ac.id/index.php/jpkm

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Application of recirculation technology to improve Tilapia breeding productivity in tarpaulin ponds

Pahmi Ansyari[1], Slamat Slamat[1], Noor Arida Fauzana[1], Irma Febrianty[2]

[1]*Department of Aquaculture, Faculty of Fisheries and Marine Science*
[2]*Department of Socio-economic fisheries, Faculty of Fisheries and Marine Science*
Lambung Mangkurat University
Jl. A. Yani Km 36. Banjarbaru, South Kalimantan, 70714, Indonesia

ARTICLE INFO:

Received: 2025-05-01
Revised: 2025-06-05
Accepted: 2025-07-24
Published: 2025-08-28

Keywords:

Hatchery, Recirculation, Tarpaulin pond, Tilapia

ABSTRACT

Tilapia farming continues to grow and requires seeds that are very large in number and superior in quality. This community service activity is the application of tilapia hatchery technology with a recirculation system in tarpaulin ponds, which is a modern technology, capital-intensive, but highly productive. The strategic intermediate target audience is the members of the Badan Pengembangan Usaha Pasantren (BPUP) Nurul Muhibbin, Halong, Balangan Regency, South Kalimantan. The method of delivering technology dissemination is a theoretical explanation with lecture and FGD methods, then demonstration and mentoring. The results of the activity from the parameters of egg hatchability with recirculation 57,6 percent and survival 49,3 percent higher than without recirculation, and the production of tilapia seed size 1 - 3 cm, 156,000 fish during 4 months of activity, and these results show high productivity. The profit obtained for 4 months was Rp 15,400,000.00 B/C ratio = 1.89 and RPI = 3.13, which means it is very feasible to be cultivated. Furthermore, the results of the mean equality test of the pre-test and post-test target audiences showed a significant increase 96 percent in knowledge and skills, compared to before the activity, only 67 percent.

How to cite: Ansyari, P., Slamat, S., Fauzana, N. A., Febrianty, I. (2025). Application of recirculation technology to improve Tilapia breeding productivity in tarpaulin ponds. *Abdimas: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang, 10*(3), 543-553. https://doi.org/10.26905/abdimas.v10i3.15828

1. INTRODUCTION

Nurul Muhibbin Halong Islamic Boarding School was established in 2024 and is located in Binjai Punggal Village, Halong District, Balangan Regency, South Kalimantan. This Islamic boarding school has added value, providing not only religious education but also formal education, such as junior high school, with one of its curricula emphasizing entrepreneurship. With this entrepreneurial vision, the Islamic boarding school established the Islamic Boarding School Business Development Agency (BPUP). This agency functions to run businesses to finance the operation and development of the Islamic boarding school. Business activities managed by BPUP include agriculture, plantations, livestock, and fisheries, with each student in a group involved in running these businesses. One of the businesses run is a tilapia hatchery business, where this business is run traditionally, with minimal technology and innovation, resulting in very low productivity. This Islamic boarding school has approximately 1.4 hectares of earthen fish ponds and consists of 16 pond plots. The ponds are mostly used for the enlargement business, while the others are used for a tilapia hatchery.

Corresponding Author: **Pahmi Ansyari**: Tel. +62 511 477212 | E-mail: pahmi.ansyari@ulm.ac.id

The traditional tilapia fish hatchery business run by the Nurul Muhibbin Halong Islamic Boarding School faces many obstacles, including low egg hatchability, low larval survival, poor seed quality, as well as slow growth. Traditional methods rely solely on natural spawning without control, utilizing earthen ponds, and using simple techniques so that it can be carried out with minimal capital and technology, with low production. According to Makli (2023), this traditional tilapia fish hatchery production system is inadequate, and seed quality is not guaranteed, due to uncontrolled wild mating, which can result in poor quality and stunted seeds. In addition, traditional tilapia fish hatchery systems in earthen ponds are prone to pests and diseases and are difficult to harvest.

In order to increase seed production and overcome pests and diseases in the pond, the traditional hatchery system of earthen ponds can be transferred to more controlled circulating tarpaulin ponds. If in earthen ponds, the frequency of tilapia spawning will continue to occur, the energy is used up to mature the gonads and carry out uncontrolled spawning, resulting in low fry quality. Tilapia broodstock that spawn conventionally in earthen ponds can be transferred to a more modern system, namely a recirculation system (Anton et al., 2024). The use of a recirculation system is necessary in order to increase productivity, be efficient in water use, and be environmentally friendly. This is because the recirculation system is a water reuse system by rotates it through a filter, so that the water that comes out in the form of waste is filtered by the filter and re-enters the system in a state of excellent water quality (Fauzia & Suseno, 2020). The use of a recirculation system in tarpaulin ponds allows the eggs to be stirred optimally, and the water supply is well maintained. The use of circulating ponds can significantly increase the hatchability of tilapia eggs to reach 90-95 percent (Nugroho et al., 2021; Rahmadi et al., 2020). The results of research by Panjaitan et al. (2024) on a tilapia hatchery incubator or recirculation system obtained egg hatchability of 81.05 percent and larval survival of 83.4 percent. Furthermore, research obtained hatchability of tilapia eggs in a circulating system of 93.7 percent and survival of 90.66 percent.

The application of tilapia hatchery technology with a recirculation system in tarpaulin ponds is new and certainly important to be disseminated. This is in order to increase tilapia seed production to meet the needs of a large number of enlargement farmers. The provision of quality fish seeds is one of the main needs in increasing the productivity of freshwater fish farming, including tilapia (Saputry & Latuconsina, 2022). Recirculation system tilapia hatchery activities consist of broodstock selection, spawning, egg hatching, larval rearing, feeding, water quality monitoring, and seed harvesting (Addo et al., 2023). The implementation of tilapia hatchery technology at the Nurul Muhibbin Islamic Boarding School aims to upgrade the hatchery system from traditional to recirculating tarpaulin ponds. It is hoped that this technology will improve the quality and productivity of tilapia fry, and ultimately increase the Islamic Boarding School's profitability.

2. METHODS

Activity Plan

Community Service activities are carried out in the span of September to November 2022, located at Islamic boarding School Nurul Muhibbin, Halong District, Balangan Regency, South Kalimantan. In this activity, the partners are the administrators of the Islamic Boarding School Business Development Agency, starting from the Chairperson, Secretary, to members, totaling 12 people plus 10 students, so that the number of partners involved is 22 people. The main facilities used in this activity are 6 tarpaulin pools with a diameter of 3.5 meters, complete with recirculation system installations and physical filters, in the form of palm fiber and biological filters in the form of water plants, as well as simple roof structures in the form of nets.

The technology developed is a recirculation technology in tarpaulin ponds, where the water is circulated, the remaining water is removed, and after passing through physical and biological filters, the water is reused and re-entered into the tarpaulin pond system. On the other hand, each tarpaulin pond is provided with three aeration units. The application of this technology is by inserting mature tilapia broodstock, consisting of 5 males and 15 females, into the recirculating tarpaulin pond, resulting in mass spawning or mating. The result of mass mating is fish eggs, which, after a while, hatch into tilapia larvae. The tilapia larvae must be immediately transferred to a hapa or net measuring 2 m x 1 m x 0.75 m installed in a regular earthen pond for rearing. During rearing, from larvae to fry measuring 2-3 cm, they are fed with flour and crumb feed with a protein content of 30 percent.

Program Implementation Method

In the process of implementing the dissemination of technology for tilapia hatchery in the recirculating Terpaulin pond system, the technology transfer is carried out in three stages, with methods, namely: (1) The first stage used the lecture and FGD method, which involved a brief explanation accompanied by leaflet materials. The explanation was conducted with simple language and was easy to understand by the target audience, so that the target understanding of the transferred technology could be successful. After the explanation ended, a question-and-answer session, discussion, or Focus Discussion Group (FGD) was conducted. (2) Stage two, using the simulation or demonstration method, which consists of three activities, namely: (a) Simulation by the community service team; (b) The target audience practices, but is still accompanied by the Community Service Team, and (c) The target audience independently practices the skills provided directly; and (3) Stage third, assistance, carried out by the Community Service Team continuously to the target audience in the funnel system tilapia hatchery business. The team routinely accompanies the selection of broodstock, the spawning process, egg collection, egg hatching, larval rearing, larval rearing to fry size (1-3 cm), and harvesting.

This Community Service activity (technology dissemination) in its implementation is evaluated using outcome indicators to obtain the success rate of the activity. The evaluation includes Hatchability of eggs in the tilapia hatchery funnel system, which is calculated by the Equation 1.

$$\text{Hatching Rate} = \frac{\text{Number of eggs hatched (egg)}}{\text{Total number of eggs (egg)}} \text{ x } 100 \text{ percent} \qquad \text{(Eq. 1)}$$

The production of 1–3 cm tilapia fry is the harvest of tilapia fry, which are raised from the larval stage to a size of 1–3 cm over a period of approximately one month, and is calculated using Equation 2.

Fry production = Number (individual) of 1–3 cm tilapia fry harvested. (Eq. 2)

Business feasibility, with calculations of profit, BEP, Pay Back Period, and R/C Ratio, using these equations. Profit, calculated using Equation 3.

Profit = Revenue - (Fixed Costs + Variable Costs) (Eq. 3)

Break-Even Point (BEP), which is the point where revenue equals total costs, resulting in neither profit nor loss, calculated using Equation 4. Meanwhile, B/C Ratio, calculated using Equation 5.

$$\text{BEP (units)} = \frac{\text{Fixed Cost}}{\text{Selling Price per Unit} - \text{Variable Cost per Unit}} \qquad \text{(Eq. 4)}$$

$$\frac{B}{C}\ \text{Ratio} = \frac{\text{Total Benefit}}{\text{Total Cost}} \qquad \text{(Eq. 5)}$$

If the B/C ratio > 1, then the business is profitable (feasible). If the B/C ratio = 1, then the business is neither profitable nor loss-making (break-even). If the B/C ratio < 1, then the business is loss-making (not feasible). Payback Period, which is the period required to recover the initial investment made by investors through cash inflows from the investment, calculated using Equation 6.

$$\text{Payback Priode} = \frac{\text{Initial Investment}}{\text{Annual Cash Flow}} \qquad \text{(Eq. 6)}$$

The level of knowledge and skills of the target audience in absorbing the transferred technology. A comparison was made between before and after the program, using a comparison test, namely a test of average similarity (t-test), with the Equation 7 and Equation 8.

$$t = \frac{X1 - X2}{s\sqrt{\frac{1}{n1} - \frac{1}{n2}}} \qquad \text{(Eq. 7)}$$

$$S2 = \frac{n(n-1)x^2}{2!} \qquad \text{(Eq. 8)}$$

X1 and X2 are sample means; S_1^2 and S_2^2 are sample variances, and n_1 and n_2 are sample sizes of each group.

Implementation Schedule and Stages

The schedule and stages of implementation of community service activities are presented in Table 1 below.

3. RESULTS AND DISCUSSION

Results

Implementation stages

The activity phase begins with problem identification through discussions with partners about the traditional tilapia fish hatchery system that has been implemented so far. The main obstacle is low seed productivity, due to uncontrolled spawning or mating of tilapia fish. In addition, there are problems with pests and diseases, and uncontrolled water quality. By conducting Focus Group Discussions (FGDs) with partners and the results of a survey of potential tilapia fish hatchery locations using the recirculation system in tarpaulin ponds, it is planned to build tarpaulin ponds along with recirculation installations to implement recirculation-based tilapia fish hatchery technology in tarpaulin ponds. Six tarpaulin ponds were built, each measuring 3.5 m in diameter and 1.2 m in height, equipped with net roofs and recirculation installations. Nets are also provided for maintaining broodstock, larvae, and fry placed in the earthen ponds.

Table 1. Stages of activity implementation

1st Activity	Initial Survey	Time
Activities	Discussion on the conditions and problems of the tilapia fish hatchery business currently being run by partners.	Fourth week of July 2022
Goals	Identify problems and potential for increasing the productivity of tilapia fish seed business, so that it is more feasible and profitable.	
2nd Activity	**Focus Discussion Group (FGD)**	
Activities	Discussion between the Community Service Team and Partners regarding the preparatory steps for implementing the recirculation system for tilapia seed technology.	First week of August 2022
Goals	Coordination and synchronization of purchasing materials and equipment, as well as the construction of circular tarpaulin pools and their recirculation installations.	
3rd Activity	**Building a Circular Tarpaulin Pool**	
Activities	Building a circular tarpaulin pool with a nets roof and recirculation and aeration installations.	Second week to third week of August 2022
Goals	As a spawning ground for tilapia with a recirculation system to increase productivity.	
4th Activity	**Tilapia Broodstock Cultivation**	
Activities	Cultivation of tilapia broodstock and keeping them in nets placed in earthen ponds, where the male and female broodstock are separated in containers, and then the broodstock are given nutritious food.	First week of September 2022
Goals	Maturing the gonads of male and female tilapia broodstock, so that they are ready to spawn or mate.	
5th Activity	**Theoretical Explanation of Tilapia Fish Breeding**	
Activities	Theoretical explanation and FGD (training) on Tilapia Fish Breeding in Tarpaulin Ponds with a Recirculation System (Theoretical explanation and FGD).	Second week of September 2022
Goals	Providing theoretical knowledge and understanding about the characteristics of tilapia fish and the breeding of recirculation systems in circular ponds, to increase productivity.	
6th Activity	**Tilapia Fish Breeding Practices**	
Activities	Tilapia Fish Breeding Practice in Tarpaulin Ponds with a Recirculation System.	Third week of September 2022
Goals	Providing skills on tilapia fish breeding in tarpaulin ponds with recirculation, with materials on parent selection, spawning, feed management, water quality, and harvesting of larvae and seeds.	
7th Activity	**Monitoring and Evaluation of Seed Productivity**	
Activities	Conducting monitoring and evaluation of various productivity parameters of tilapia fish breeding businesses.	First week of October to the third week of December 2022
Goals	Calculating success indicators (growth, survival, and business analysis) of the tilapia fish breeding that has been developed.	

The implementation steps for this community service activity are explained, where, stages consist of: (1) Theoretical explanation and Focus Group Discussion (FGD); (2) Demonstration by the Service Team; (3) Planning of tilapia breeding by the target audience, assisted by the Service Team; (4) Implementation of breeding, assisted by the Service Team; and (5) Monitoring and evaluation of breeding success. The activity materials presented to the target audience were about tilapia breeding technology using a recirculation system in tarpaulin ponds. The materials were presented in the form of theoretical explanations, demonstrations, and hands-on practice, including: (1) cultivation of tilapia broodstock with nutritious feed; (2) selection of tilapia broodstock; (3) characteristics of fish in gonadal maturity and ready for spawning/breeding; (4) spawning of fish in tarpaulin ponds; (5) egg control and hatching; (6) harvesting of larvae transferred to net in ponds; (7) growing larvae into fingerlings size (1-3 cm); (8) feed management; (9) water quality management; and (10) fingerling harvest management.

The material was presented using a lecture method (presentation and FGD) by the Service Team members in turn according to their respective competencies, as shown in Figure 1 and Figure 2.


Figure 1. Discussion of the community service team's activity planning with partners
Figure 2. Presentation of the explanation of the theory of tilapia fish breeding with a recirculation system in tarpaulin ponds

For this technology to be applied by the target audience, the material presented included not only theoretical explanations but also demonstrations, simulations, and hands-on practice conducted by the Community Service Team, as shown in Figure 3 and Figure 4.


Figure 3. Training in tilapia breeding skills (practical): Distinguishing between males and females
Figure 4. Training in tilapia breeding skills (practical): Placing male and female broodstock in a ratio of 1:3

Tilapia seed production

The main objective of this activity is to enable the target audience to produce tilapia seeds using tilapia seed production technology with a recirculation system in tarpaulin ponds. The recirculating tarpaulin ponds used for tilapia breeding/hatchery have a diameter of 3.5 meters and a height of 1.2 meters, with a total of 6 units. The recirculation system uses a submersible pump with a capacity of 11,400 liters per hour. However, for broodstock cultivation, only two 4 m x 3 m x 1.2 m Hapa (nets) are used for male and female broodstock, which are separated. An illustration of the broodstock nets and recirculation system tarpaulin pond is shown in Figure 5 and Figure 6.

Figure 5. Enlarged image of prospective broodstock
Figure 6. tarpaulin pond for spawning/mating

Tilapia breeding is carried out on a large scale in circulating tarpaulin ponds. The broodstock used for spawning/breeding consists of 10 male and 30 female fish (ratio of 1:3) in each of the six tarpaulin ponds. The results of tilapia breeding are presented in Table 2.

Table 2. Results of tilapia breeding using a recirculation system in tarpaulin ponds for the Nurul Muhibbin Islamic Boarding School Business entity, Halong, over a period of 4 months (Sept - Dec 2022)

Parameter	Year 2022				Number	Average/Month
	Sept	Oct	Nov	Dec		
Estimated number of eggs (pieces)	140,000	150,000	148,000	154,000	592,000	148,000
Hatchability rate (%)	83.6	85.2	82.1	87.3	-	84.55
Larval Survival Rate (up to 4 days old) (%)	84.1	87.4	81.2	82.3	-	83.75
Seedling Survival Rate (up to seedling size) (%)	67.3	70.2	72.8	68.8	-	69.76
Seed Production 1 – 3 cm size (individual)	36,400	38,700	41,200	40,200	156,500	39,125

Business feasibility

Business feasibility is calculated over a 4-month operational period (September to December 2022), assuming 6 tarpaulin ponds, each with a diameter of 3.5 m and a height of 1.2 m, stocked with 10 male and 30 female tilapia broodstock per pond, resulting in a total of 60 male and 180 female broodstock. A breeding pen measuring 4 m x 3 m x 1.2 m is also required. Additionally, a simple structure with a net's roof and a recirculation and aeration system using pumps and blowers is needed. Production of fingerlings (1–3 cm in size) is maintained for approximately one month, with a production of around 156,500 fish.

Based on the above assumptions, after calculations, a profit of Rp. 15,400,000 per 4 months was obtained, with a break-even point (BEP) price of Rp. 108, meaning that if the price per seedling is only Rp. 108, there will be no profit or loss (break-even). The B/C ratio = 1.89, meaning that the revenue obtained exceeds 1.89 times the total costs incurred. The return on investment (ROI) parameter is 3.13, meaning that the capital invested in this business is recovered in 3.13 production cycles, because this business is capital-intensive, so capital recovery requires 3 additional production cycles. To maximize profits and accelerate capital recovery, this business can be expanded by adding more than six units of circulating tarpaulin ponds.

Level of knowledge and skills of the target audience

The target audience, in this case, is the members of the Nurul Muhibbin Islamic Boarding School Business Development Agency (BPUP) in Halong, South Kalimantan. The evaluation of the target audience includes their level of knowledge and skills after the Service Team conducted dissemination in the form of theory, practice, demonstrations, and mentoring for 4 months. Data analysis using a two-tailed t-test for mean equality, according to Usmadi (2020), on the initial knowledge level in the pre-test and post-test yielded a calculated t-value of 12.84 > table t-value of 2.88 (0.99), indicating an increase in the target audience's knowledge following the theoretical explanations and focus group discussions (FGD) in this activity. Similarly, for skill levels before and after demonstrations, simulations, and direct practice, the calculated t-value was 8.32 > t-table = 2.88 (0.99), indicating a significant increase in skills among the target audience. Through data analysis, it was found that the level of knowledge and skills of the target audience (partners) showed that the skills of breeding tilapia fish increased from 67 percent to 96 percent.

Discussion

Table 1 indicate satisfactory outcomes, particularly the hatchability rate, which ranges from 82.1 percent to 87.3 percent. According to the hatchability rate of tilapia eggs in a recirculation system reaches 81.05 percent. However, according to Rahmadi et al. (2021), the funnel-recirculation system can significantly increase tilapia egg hatching rates to reach 90–95 percent. This recirculation breeding system represents an improvement from traditional systems toward modern systems, resulting in increased hatching rates and nearly double the production of fry (Anton et al., 2024). The advantages of tilapia egg hatching in a recirculation system are: (1) more uniform fry; (2) hatching rate exceeding 90 percent; (3) effective and efficient; (4) increased production; (5) reduced production time; and (6) environmentally friendly (Ansyari et al., 2024).

Tilapia breeding using a recirculation system in tarpaulin ponds is a modern fish breeding system, in which water flows in a circular motion (recirculation), carrying oxygen-rich water, stabilizing water temperature, and cleaning the water of feed residues and fish feces, so that the levels of ammonia, nitrate, and nitrite, which are toxic to fish, are very low. Furthermore, the success of recirculating aquaculture systems depends on the system's ability to manage organic waste from uneaten feed, fish feces, and urine. Recirculation systems are always equipped with aeration systems, which naturally increase dissolved oxygen levels. Oxygen levels are essential for fish growth, health, disease prevention, and stress reduction (Cahyanti et al., 2022), as well as reducing ammonia levels, making the system environmentally friendly (Sahetapy et al., 2022). Recirculation systems use biological filters that can convert ammonia into nitrates and nitrites—compounds that are harmless to fish—through the nitrification process (Maldino et al., 2023).

A recirculation system is a system that reuses water that has already been used by continuously circulating the water repeatedly through various filters, usually physical, chemical, and biological filters. The recirculation system enhances the carrying capacity of the aquaculture medium, as the water used can be effectively and efficiently controlled while being environmentally friendly toward egg hatching rates, larval survival, and fish seed development (Lembang & Kuing, 2022). Additionally, the recirculation system can stabilize the water temperature of the aquaculture medium, and at a stable temperature, it can improve egg hatching rates and the feeding activity of larvae and fish fry (Maldino et al., 2023). The recirculation system is a solution for sustainable fish farming that can produce continuously and reduce its water use, maintain water quality at an optimal level, and, most importantly, achieve very high productivity (Martini, 2024).

After the eggs hatch and become larvae, the next task is to feed them, care for them in a special larval hapa (nets), and maintain stable water quality. The feed given is Fengli-0 in powder form, but after approximately 15 days, the feed is replaced with Fengli-1 in crumble form. The yield of fingerlings (1–3 cm in size) obtained is quite good, averaging 39,125 per month. The tilapia hatchery using a recirculation system at the People's Hatchery Unit (UPR) in Sleman has achieved a production of 108,000 fingerlings of 5–7 cm in size per month with a larval stocking density of 5,000 per square meter, compared to the conventional system's 500 per square meter, meaning its capacity is ten times greater (Suryana & Amanda, 2018). Tilapia breeding technology using the Recirculating Aquaculture System (RAS) has successfully increased the efficiency and productivity of tilapia breeding in Pudak Payung Village.

The feasibility study of a tilapia hatchery using a recirculation system in tarpaulin ponds shows that all parameters, including net profit, break-even point (BEP), B/C ratio, and payback period, indicate positive results, making it feasible to undertake. According to the feasibility study of tilapia breeding using a recirculation system at PT. Indo Aqua, Majalengka, West Java, yielded a profit of Rp 533,413. 867 per year, a Payback Period of 2 years, 3 months, and 18 days, and a Benefit-Cost Ratio (B/C Ratio) of 1.49. Therefore, this recirculating system for the tilapia breeding business is highly viable for implementation.

Economically, tilapia hatchery businesses using a recirculation system in tarpaulin ponds are very feasible, because various economic parameters, such as profit, BEP, B/C ratio, and payback period, are positive and exceed the minimum requirements. However, a viable business must also have risk identification and management in place to minimize losses (Fitriani et al., 2022). Additionally, the business must be realistic and have the potential for future development.

In several dissemination activities on fish farming to fish farming groups, the level of knowledge and skills of the target audience increased significantly (Amar et al., 2022; Delis, 2022). The level of knowledge and skills of the target audience is greatly influenced by their prior background. The target audience, who are managers and members of the Nurul Muhbbin Halong Islamic Boarding School Business Management Board, are primarily farmers (rice and horticulture) and fish farmers, so they already had knowledge and skills in tilapia farming before the activity. However, they still lacked knowledge and skills in breeding technology, especially with the recirculation system technology in tarpaulin ponds.

4. CONCLUSION AND RECOMMENDATIONS

The program was carried out with the aim of introducing and applying tilapia hatchery technology using a recirculation system in tarpaulin ponds as an effort to improve productivity, business feasibility, and community capacity in aquaculture. The results showed that the use of this modern, capital-intensive, but highly productive technology produced an average egg hatch rate of 57.6 percent and a survival rate of 48.3 percent, which were higher than traditional breeding in earthen ponds. In terms of economic feasibility, the four-month implementation generated a profit of IDR 15,000,000.00 with a B/C ratio of 1.89 and an RPI of 3.13, indicating that the business is highly feasible. Furthermore, the dissemination activities succeeded in significantly increasing the knowledge and skills of the target partners, from 67 percent before training to 96 percent after training, thereby demonstrating the effectiveness of the program in strengthening both technical competence and entrepreneurial capacity within the community.

The implementation of recirculating tilapia seeding technology in tarpaulin ponds faces several challenges, including poor water quality due to the source of the water coming from swamps and the lack of guidance from the local Fisheries Service. Therefore, the following recommendations are made: (1) There is a need for supporting technology to stabilize the quality of swamp water so that it can be used properly for tilapia fish breeding activities; (2) After the activity is completed, for the development to be sustainable, there needs to be a development program from the local agency, namely the Fisheries Agency, Balangan Regency, South Kalimantan Province; and (3) It is necessary to announce that the tilapia fish breeding activity using the recirculation system in the tarpaulin pond will be an entrepreneurial learning activity for the students of the Nurul Muhibbin Islamic Boarding School, Halong, Balangan Regency.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the Head of Yayasan Adaro Bangun Negeri (YABN) for supporting the funding of this activity, through the Decree of the ULM Chancellor regarding the Implementation of the 2022 Matching Fund Program, Number: 891/UN8/PP/2022, dated August 18, 2022. We would also like to thank the Head of Pondok Pasantren Nurul Muhibbin, Halong, for providing facilities for the dissemination of this recirculation system tilapia breeding technology.

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