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IMPLEMENTATION OF IOT-BASED SMART AQUACULTURE TO EMPOWER NILA FARMERS IN BAGINDA VILLAGE

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Abstract

This community service program was carried out at the fish farmer group (POKDAKAN) Tirta Mukti in Baginda Village, Sumedang Selatan District, with the main focus on implementing IoT-based Smart Aquaculture in a biofloc system to improve the quality and productivity of Nile tilapia culture. The situation analysis showed several priority problems: the absence of real-time water quality monitoring devices, non-systematic recording of production and feed conversion ratio (FCR), weak business management, and the absence of digital marketing and attractive, licensed processed products. The implemented method combined socialization, training, field implementation, mentoring, and sustainability planning in a participatory approach. The solutions included installation of four water quality sensors (dissolved oxygen, pH, temperature, turbidity) integrated with a web-based monitoring application (https://smartaqua.my.id/), an automatic feeder, training on biofloc and business management, preparation of simple bookkeeping templates, and development of digital marketing tools (social media, WhatsApp Business, packaging design, and PIRT draft). The results show increased partner capacity in using IoT technology, improved efficiency of feed use, more structured production and financial recording, and the initiation of online-based marketing. This program demonstrates that the integration of IoT, biofloc technology, and digital marketing can enhance productivity, added value, and sustainability of small-scale tilapia farming in rural areas.

Keywords: Community Service, Smart Aquaculture, Internet of Things, Biofloc, Digital Marketing

INTRODUCTION

Aquaculture plays a strategic role as one of the pillars of food security and rural economic development in Indonesia. Nile tilapia (*Oreochromis niloticus*) is one of the leading commodities with stable market demand and relatively fast growth, making it suitable for small-scale farmers. However, at the grassroots level, many farmer groups still face low productivity due to limited land, inefficient feed use, suboptimal water quality management, and weak access to profitable markets.

One of the innovations that has been proven to increase production efficiency is the

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biofloc system, a high-density culture technique that utilizes microorganisms to convert organic waste into additional feed biomass. When combined with smart aquaculture technology—such as water quality sensors, automated feeders, and digital monitoring dashboards—this system can support more precise and data-driven decision-making. In parallel, the development of digital marketing through social media and e-commerce platforms opens opportunities to expand market access and increase the added value of both fresh and processed fish products.

POKDAKAN Tirta Mukti in Baginda Village, Sumedang Selatan District, is a group of tilapia farmers consisting of around 10 active members. The existing biofloc facilities are limited to three tarpaulin ponds (diameter 2–4 meters), with constraints in aeration devices and supporting equipment. Baseline conditions show several key problems:

1. **Production problems (upstream)**:
   - Water quality is managed manually without real-time monitoring tools, so parameters such as dissolved oxygen, pH, and temperature are not optimally controlled.
   - Feed is given based on rough estimation without reference to biomass, resulting in a relatively high FCR (±1.7).
   - Stocking densities tend to be high without adequate aeration capacity, leading to elevated fish mortality.
2. **Business management problems**:
   - There is no systematic recording of growth, mortality, feed use, and production costs.
   - Financial planning and simple feasibility analysis such as break-even point (BEP) have not been carried out.
   - Digital literacy among group members is still limited.
3. **Marketing problems (downstream)**:
   - Marketing still relies on conventional channels through middlemen, with relatively low selling prices.
   - Processed products such as tilapia jerky and fillets do not yet have proper branding, packaging, or distribution permits.
   - Digital marketing media such as Instagram, Facebook, marketplace, or WhatsApp Business have not been utilized.

These conditions indicate the need for an integrated empowerment program combining technological innovation (IoT-based smart aquaculture), strengthening of business management, and development of digital marketing. The university, through a community service scheme, plays a role as facilitator and provider of appropriate technology to bridge the gap between academic innovation and the real needs of the community.

The objectives of this community service program are:

1. To implement IoT-based smart aquaculture technology in the tilapia biofloc system at POKDAKAN Tirta Mukti.
2. To improve the capacity of farmers in technical aspects of biofloc, business management, and digital literacy.
3. To develop digital marketing channels and value-added products for tilapia, thereby increasing income and business sustainability.

IMPLEMENTATION METHOD

This community service program adopts a participatory approach, where partners are actively involved in all stages of the activity, from problem identification to evaluation and sustainability planning. The implementation stages are adapted from the progress report and adjusted to the ABDIDOS journal format as follows.

1. Socialization and Needs Assessment

The first stage was an initial socialization meeting with the board and members of POKDAKAN Tirta Mukti, as well as village government representatives. Activities included:

a. Presentation of program objectives, benefits, outputs, and implementation stages.
b. Focus Group Discussion (FGD) to map technical, managerial, and marketing problems faced by the group.
c. Identification of local human resources who could be prepared as technology cadres.

The output of this stage was a joint agreement on priority issues and an implementation schedule that is aligned with farmers' culture and routines.

2. Technical and Non-Technical Training

The second stage was capacity building through several training sessions:

a. Technical training on biofloc:
    - Preparation and management of biofloc (use of molasses, probiotics, aeration management).
    - Introduction to water quality parameters and their impact on fish health.
b. Training on smart aquaculture and IoT:
    - Introduction to sensor devices (dissolved oxygen, pH, temperature, turbidity).
    - Demonstration of the web-based application for monitoring water quality and feed scheduling.
c. Training on business management and financial literacy:
    - Simple financial recording, cost classification, and profit-loss analysis.
    - Introduction to BEP and basic business planning.
d. Training on digital marketing and product branding:
    - Creation and management of social media accounts and WhatsApp Business.
    - Basic content creation (photo/video, captions, posting schedules).
    - Basic packaging design and label/logo introduction.

These trainings were delivered in interactive formats combining lectures, demonstrations, and hands-on practice.

3. Field Implementation of Technology

The third stage focused on the practical application of the introduced technology at the partner's site, including:

a. Installation of four units of water quality sensors integrated with the web-based application.
b. Setup of an automatic feeder (auto-feeder) in the biofloc ponds.
c. Activation and configuration of the smart aquaculture application that can be accessed via the URL https://smartaqua.my.id/.
d. Adjustment of stocking density to recommended ranges and strengthening of aeration systems.
e. Initial implementation of digital production and financial recording using simple

templates.

Output of this stage: all devices were installed and operated by the farmers with guidance from the team, and the first production cycle under the IoT-assisted system was initiated.

4. Mentoring and Periodic Evaluation

In the mentoring stage, the team conducted regular visits and online consultations to:

a. Monitor sensor readings, feed schedules, and fish growth.
b. Assist partners in interpreting data from the application dashboard and adjusting management actions.
c. Evaluate digital marketing activities (type and frequency of content, interaction with potential buyers).
d. Identify obstacles in using devices and applications, and provide on-site troubleshooting.

Evaluation was carried out qualitatively through interviews and observations, as well as quantitatively through simple indicators such as changes in FCR, survival rate, and sales volume.

5. Sustainability Planning (Exit Strategy)

The final stage focused on ensuring the sustainability of the program beyond the funding period, through:

a. Formation of a small working group within POKDAKAN responsible for the management of IoT devices and digital marketing.
b. Preparation of Standard Operating Procedures (SOP) for biofloc operations and the use of smart aquaculture applications.
c. Coordination with related government agencies (Fisheries Service, MSME Office) for continued support and potential scale-up.
d. Planning for the development of additional ponds and diversification of processed products.

RESULTS AND DISCUSSION

1. Strengthening Production through Smart Aquaculture Biofloc

Implementation of IoT-based smart aquaculture at POKDAKAN Tirta Mukti resulted in several tangible outcomes in the production aspect:

1. **Installation of water quality sensors**

Four types of sensors (dissolved oxygen, temperature, pH, and turbidity) were installed and successfully integrated with the web-based application. Farmers can now monitor water quality in real-time via smartphones, allowing rapid response to fluctuations in environmental conditions.

2. **Use of automatic feeder**

The auto-feeder enables more controlled feed dosing and scheduling. Farmers reported that feed distribution became more even and overfeeding was reduced. Although full quantitative FCR data for the entire cycle are still being compiled, early indications show a trend of decreased feed use compared to previous cycles.

3. **Optimization of stocking density and biofloc management**

Through training and mentoring, the group adjusted stocking densities and improved aeration management. Biofloc quality was better maintained, reducing the risk of

ammonia spikes. Farmers reported a decrease in fish mortality, especially in critical weeks approaching harvest.

These findings align with previous studies that demonstrate the effectiveness of biofloc systems and sensor-based monitoring technologies in increasing productivity and feed efficiency in tilapia culture.

Figure 1. IoT Smart Aquaculture Device Network at Partner's Pond
Source : Program Documentation

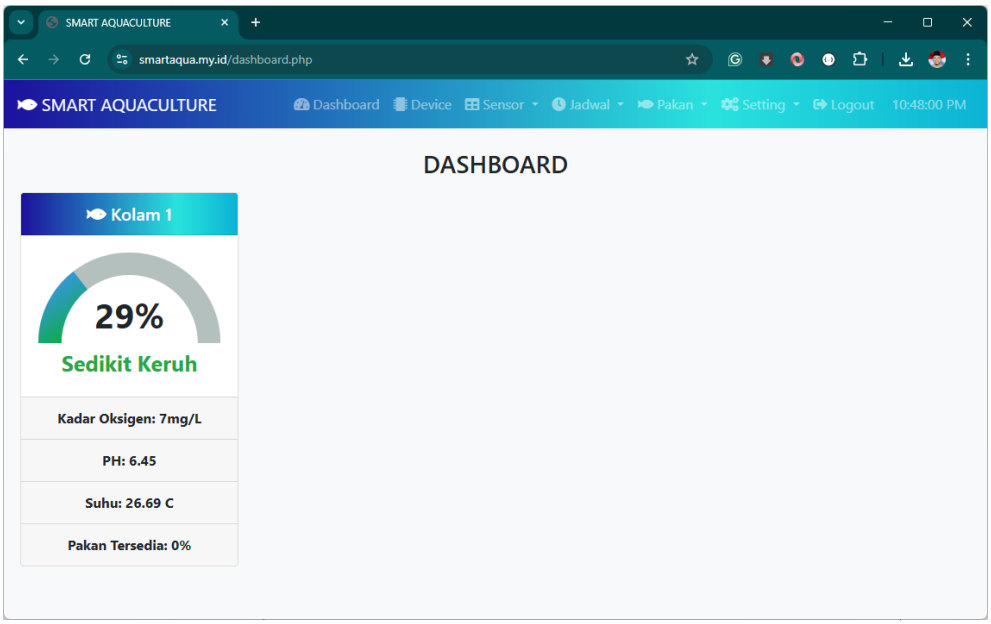

Figure 1. IoT Smart Aquaculture Dashboard
Source : Program Documentation

2. Improvement of Business Management and Digital Literacy

In addition to technical aspects, the program also strengthened partners' management capacities:

a. **Simple production and financial recording system**

A Microsoft Excel–based template was introduced to record feed usage, fish growth, mortality, and sales. Farmers began to realize the importance of data-based evaluation in determining stocking strategies, harvesting schedules, and selling prices.

b. **Financial literacy and business planning**

Training on simple bookkeeping, cost identification, and BEP analysis helped farmers understand their cost structure and potential profit margins. This is an important step toward transforming the group from subsistence-level operations to more commercially oriented business units.

The combination of digital record-keeping and real-time water quality data supports evidence-based decision-making, reducing dependence on intuition alone.

To assess the impact of training and mentoring on non-technical aspects, the team conducted a simple **pre–post test** using a questionnaire scored on a 0–100 scale. The first dimension measured partners' understanding of **business management and financial record-keeping**, while the second dimension measured their understanding of **digital marketing and product branding**.

Before the program, the average score of Pokdakan members on business management and financial recording was **55**, reflecting that most members were not yet familiar with systematic bookkeeping, cost classification, and basic profit–loss analysis. After a series of trainings and hands-on mentoring on the use of simple digital recording templates, the average score increased to **83**, a gain of **28 points** or about **50.9%**.

An even higher improvement was observed in the dimension of **digital marketing and product branding**. The average pre-test score was only **48**, indicating limited knowledge and skills in utilizing social media, WhatsApp Business, and basic content marketing techniques. Following the training sessions and mentoring activities, the average post-test score rose to **85**, an increase of **37 points** or approximately **77.1%**. This improvement is consistent with the program outputs, including the creation of business social media accounts, activation of WhatsApp Business with a product catalogue, development of packaging and logo design, and the initial trial of a pre-order system through WhatsApp.

Table 1. Average pre–post test scores on business management and digital marketing

Assessed aspect	Average Pre-test Score (0–100)	Average Post-test Score (0–100)	Increase (points)	Relative increase (%)
Business management and financial record-keeping	55	83	+28	50.9%
Digital marketing and product branding	48	85	+37	77.1%

Overall, the pre–post test results suggest that the combination of training and on-site mentoring was effective in enhancing the business and digital literacy of the fish farmers. These improved competencies provide an important foundation for the sustainable use of IoT

technology and for strengthening the bargaining position of the farmer group within the local aquaculture value chain.

3. Development of Digital Marketing and Value-Added Products

On the downstream side, the program produced several outputs related to marketing and product development:

a. Creation of a business social media account and WhatsApp Business with a product catalog.
b. Design of branding elements (logo and packaging label) for processed tilapia products such as jerky and fillets.
c. Preparation of PIRT draft documents as an initial step toward obtaining simple distribution permits.
d. Trial of pre-order systems through WhatsApp Business for local customers.

These efforts are in line with the trend of increasingly digitalized food markets, where product visibility and consumer trust are strongly influenced by branding and online presence. The introduction of digital marketing also opens opportunities for targeting higher-value segments, such as urban consumers and culinary businesses.

Table 2. Summary of Outputs Achieved in the Community Service Program

No	Aspect	Output
1	Production (upstream)	4 water quality sensors, auto-feeder, improved biofloc management
2	Business management	Training, Excel-based recording templates
3	Marketing and value-added	Social media & WA Business, packaging design, PIRT draft, pre-order
4	Publications and dissemination	Draft journal article, video, poster, online news article

4. Impact on Empowerment and Productivity

Qualitative observations indicate an increase in the empowerment level of partner communities, both in production and marketing aspects. Farmers expressed increased confidence in managing technology-based aquaculture systems and interacting with the market through digital channels.

From the productivity perspective, there are indications of improvement in survival rate, growth, and the potential to reduce FCR, although comprehensive quantitative data for multiple cycles are still being collected. In the long term, the synergy between technology adoption and improved management is expected to increase income and welfare for group members.

Table 3. Comparison of FCR, production, and survival rate before and after the implementation of smart aquaculture

Indicator	Before Program	After Program (1 IoT-based biofloc cycle)
Average FCR	1.7	1.25
Total feed per cycle (kg)	510	487.5
Total harvest production (3 biofloc tanks, kg)	300	390
Average production per tank (kg/tank)	100	130
Survival rate (%)	75%	88%
Average individual weight at harvest	300 g	340 g

(g/fish)

Table 1 clearly shows that the integration of IoT technology and automatic feeders not only reduced the FCR but also increased biomass production and survival rate without significantly increasing feed usage, highlighting the potential of smart aquaculture to improve both technical and economic performance of tilapia farming at the community level.

CONCLUSION

Based on the implementation of the IoT-based smart aquaculture program at Pokdakan Tirta Mukti in Baginda Village, several important conclusions can be drawn:

1. **Improved technical performance of tilapia biofloc culture.** The integration of water quality sensors, a web-based monitoring application, and automatic feeders in the biofloc system successfully improved key production indicators. The average FCR decreased from **1.7** before the program to **1.25** after one IoT-assisted production cycle (a reduction of approximately **26.5%**), while total harvest production from three biofloc tanks increased from **300 kg** to **390 kg** (around **30%** increase). At the same time, total feed use per cycle slightly decreased from **510 kg** to **487.5 kg**, and the survival rate improved from **75%** to **88%**. These results demonstrate that smart aquaculture can simultaneously enhance feed efficiency, survival, and biomass productivity in small-scale tilapia farming.
2. **Strengthened business management and digital literacy of farmer groups.** Training and mentoring activities substantially increased partners' understanding of business management and marketing. The average score for *business management and financial record-keeping* rose from **55** to **83** (an increase of **28 points** or **50.9%**), while the score for *digital marketing and product branding* increased from **48** to **85** (an increase of **37 points** or **77.1%**). These improvements are reflected in the adoption of simple digital bookkeeping templates, the establishment of social media and WhatsApp Business accounts, and the development of basic branding and packaging for processed tilapia products.
3. **Contribution to community empowerment and business sustainability.** The combination of appropriate technology (IoT-based smart aquaculture), improved business management, and the initial implementation of digital marketing has strengthened the capacity and self-confidence of Pokdakan Tirta Mukti members in managing their aquaculture business. In the long term, this integrated approach is expected to enhance income, bargaining power, and business sustainability, and it has the potential to be replicated in other small-scale aquaculture communities with similar characteristics.

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