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Implementation of Biofloc-Based Nile Tilapia Aquaculture as a Production-Based Education Model at Sekolah Cendekia BAZNAS Cibungbulang, Bogor

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ABSTRACT

Biofloc technology offers a high-density, water-efficient approach to aquaculture that is particularly suited to land-constrained environments. This Community Service Program (PKM), funded by Kemendiktisaintek through the BIMA scheme, aimed to implement a biofloc-based Nile tilapia (*Oreochromis niloticus*) cultivation system at Sekolah Cendekia BAZNAS (SCB), Cibungbulang, Bogor. The biofloc system harnesses heterotrophic bacteria to recycle nitrogen waste from feed residues, feces, and urine back into microbial protein consumable by the fish, thereby increasing feed efficiency by 20–30% and reducing daily water exchange to only 5–8%. Activities encompassed construction of circular tarpaulin ponds with wiremesh frames, installation of 24-hour aeration, stocking of tilapia fingerlings at 100 fish/m³, and comprehensive training of SCB students and staff in water quality management and feeding protocols. Results demonstrate measurable improvements in participants' capacity to manage intensive aquaculture in limited spaces, establishment of functional biofloc pond installations, and prospects for alternative feed development utilizing mushroom baglog waste as a local protein supplement. The program is proposed as a replicable production-based education model for boarding schools and pesantren across Indonesia.

Introduction

Aquaculture of freshwater fish in Indonesia faces two interrelated structural challenges: limited productive land and the high cost of feed, which accounts for approximately 60–70% of total production costs. In conventional aquaculture systems, around 70% of feed residues and fish metabolic waste decompose into toxic ammonia, necessitating daily water replacements of 60–80%. This situation is not only wasteful of water resources but also results in the loss of nutrients that could otherwise be recycled.

Feed cost is the single largest recurring expenditure for small-scale fish farmers, and any technology capable of reducing feed conversion ratio (FCR) while simultaneously reducing water consumption carries substantial economic significance for community-based aquaculture initiatives. Conventional systems rely heavily on natural plankton and irregular water exchange to control ammonia toxicity, a method that is both labor-intensive and highly dependent on the availability of clean water sources, which are becoming scarcer in peri-urban areas such as Bogor Regency.

Biofloc technology represents a new paradigm in intensive aquaculture. This technology utilizes the activity of heterotrophic bacteria to actively recycle nitrogen waste into microbial protein (biofloc), reducing the need for water changes to just 5–8% per day, increasing feed efficiency by 20–30%, and enabling significantly higher stocking densities of more than 100 fish/m³ for tilapia. These advantages make biofloc technology highly relevant for implementation in boarding school environments with limited land but a need for sustainable animal protein sources.

The floc itself is an aggregate of bacteria, algae, protozoa, and organic detritus bound together in a mucus-like matrix, which the fish are able to graze upon as a supplementary protein source throughout the day. This continuous in-situ recycling of nitrogenous waste distinguishes biofloc from conventional and even most recirculating aquaculture systems, because it converts a liability (ammonia and organic waste) into an asset (microbial biomass) without requiring extensive mechanical filtration.

Several previous studies support the viability of biofloc technology as a sustainable alternative to conventional pond culture. Abakari et al. (2022) emphasize the central role of heterotrophic and nitrifying bacterial communities in maintaining water quality stability within biofloc systems, noting that the composition and density of these microbial communities directly determine system resilience. Khanjani and Sharifinia (2020) similarly highlight biofloc's promise for improving overall aquaculture productivity, particularly in contexts where land and water are limiting factors. Complementing this, Nisar et al. (2022) discuss the role of biofloc and aquamimicry approaches in achieving more sustainable utilization of aquaculture waste streams, framing biofloc as part of a broader circular-economy approach to fish farming. Ogello et al. (2021) further argue that biofloc technology holds considerable promise for smallholder and community-based aquaculture development in resource-constrained settings, a conclusion echoed by Raza et al. (2024) in their review of biofloc system typologies and their future economic prospects. At the level of species-specific performance, Zablon et al. (2022) provide experimental evidence that biofloc systems can improve protein utilization efficiency and growth performance in Nile tilapia fry, while Kurniaji et al. (2021) report favorable growth and feed consumption outcomes for Nile tilapia reared under biofloc conditions in an Indonesian context. Taken together, this body of literature provides a strong empirical and theoretical foundation for applying biofloc technology in land-constrained educational institutions such as boarding schools.

Boarding schools and pesantren in Indonesia frequently operate on constrained land parcels shared among dormitories, classrooms, mosques, and agricultural or livestock activities, leaving little room for conventional earthen fish ponds that typically require substantial surface area to remain productive. At the same time, many of these institutions serve students from underprivileged economic backgrounds for whom access to adequate animal protein is a recurring nutritional concern. A technology that combines a small physical footprint with high productivity per unit area is therefore particularly well matched to the operational realities of the pesantren sector.

Beyond its nutritional and economic relevance, biofloc-based aquaculture also carries pedagogical value. Production-based education, in which students participate directly in real productive activities rather than only observing or simulating them, has been increasingly promoted as a strategy for building vocational competence, discipline, and entrepreneurial mindset among students in Islamic boarding schools. Integrating a biofloc system into the daily operational rhythm of a school allows students to engage with concepts from biology, chemistry, and basic engineering in an applied, hands-on setting, while simultaneously contributing to the institution's food security and, potentially, its independent revenue generation.

Sekolah Cendekia BAZNAS (SCB) in Cibungbulang, Bogor, is a boarding school serving students from underprivileged families. Limited land and resources make SCB an ideal partner for an efficiency-based aquaculture technology program. This Community Service Program (PKM), funded by Kemendiktisaintek through the BIMA scheme, was designed to comprehensively introduce, construct, and train all SCB stakeholders in a biofloc-based Nile tilapia aquaculture system.

The specific objectives of this program were threefold: first, to construct functional, replicable biofloc pond infrastructure appropriate to SCB's spatial and resource constraints; second, to transfer practical competence in biofloc management—covering pond preparation, water quality monitoring, feeding protocols, and fingerling stocking—to SCB students, teachers, and facility staff; and third, to lay the groundwork for a longer-term research and development agenda exploring locally available agricultural waste, specifically spent mushroom baglog substrate, as a supplementary feed ingredient. This third objective reflects the program team's broader interest in closing local resource loops, in which one form of agroindustrial waste (spent baglog from oyster mushroom cultivation) is repurposed as an input into another productive activity (fish feed), thereby reducing costs for the school while addressing an underexploited waste stream.

Method

The activities were carried out at Sekolah Cendekia BAZNAS (SCB), Cibungbulang, Bogor Regency, during the period of May–October 2025. The approach employed was participatory action research, combining training, direct mentoring, and field demonstration. Participants included SCB students, teachers, and staff involved in the management of school facilities.

This approach was deliberately chosen over a purely technical assistance model because the program's success depended not only on the successful physical installation of biofloc infrastructure, but on the durable transfer of operational knowledge to the school community, who would be solely responsible for the system's continuity once the program concluded. Participatory action research allowed the program team to iteratively adjust training content and pond management protocols based on direct observation of participants' evolving competence and the specific environmental conditions of the SCB site.

Participants included SCB students, teachers, and staff involved in the management of school facilities. Students were engaged both as learners and as active co-implementers of the physical construction and daily operational tasks, consistent with the program's underlying production-based education philosophy. Teachers and facility staff were positioned as long-term system custodians, expected to supervise and sustain operations after the program's formal completion, while also serving as internal trainers for future cohorts of students.

Implementation stages included: (1) Construction of circular ponds using HDPE tarpaulin with a diameter of 2.1 m and wiremesh steel frames, equipped with gutter carpet, drainage pipes, aerator machines, and aeration hoses distributed evenly across the pond floor. The circular design was selected to eliminate dead zones and prevent sediment accumulation. Water depth was maintained at 80–100 cm; (2) Pond preparation involving cleaning, initial water filling to 40 cm, addition of salt at 1 kg/m^3, lime at 100 g/m^3, and macro-micro mineral supplements at 5 g/m^3 for ten consecutive days; (3) Stocking of 90% male Nile tilapia fingerlings on day 3, at a stocking density of 100 fish/m^3, preceded by acclimatization and a 48-hour fasting period; and (4) Continuous feed and water quality management.

Throughout the implementation period, water quality was monitored using a combination of field test kits and simple visual/olfactory inspection routines that were specifically designed to be replicable by SCB staff and students without reliance on sophisticated laboratory equipment. Dissolved oxygen, pH, temperature, and floc volume were checked at scheduled intervals, with results recorded in a shared logbook to build a longitudinal dataset that could later inform adjustments to aeration intensity, feeding schedules, and water exchange decisions.

Table 1. Comparison of Aquaculture Systems: Conventional, Biofloc, and Semifloc

Aspect	Conventional	Biofloc	Semifloc	Notes
Water Need	60–80%/day	**5–8%/day**	Routine suction	Biofloc most efficient
Decomposer	Plankton	**Heterotrophic Bacteria**	Autotroph + Heterotroph	Biofloc actively recycles N
Stocking Density	Low	**>100 fish/m^3**	Medium–High	Efficient for limited land
Feed Efficiency	Low	**+20–30%**	Medium	Best FCR in biofloc
Capital & Skill	Low	High	Medium	Requires 24 hr aeration

Source: PKM Team UIKA - SCB, 2026

Aeration was conducted continuously (24 hours/day) at a rate of 30 LPM/m³ to maintain dissolved oxygen above 4 mg/L and to keep floc particles suspended. Total Suspended Solids (TSS) volume was monitored daily using an Imhoff cone, with an optimal range of 15–20 mL/L for tilapia.

In addition to the physical and technical dimensions of implementation, the program incorporated a structured training curriculum delivered across several sessions. Training content covered the theoretical basis of the nitrogen cycle in aquaculture systems, practical procedures for pond preparation and water conditioning, correct handling and acclimatization of fingerlings, feeding rate calculation based on estimated biomass, and routine troubleshooting of common water quality problems. Training sessions combined classroom-style explanation with immediate hands-on practice at the pond site, allowing participants to apply concepts under the direct supervision of the program team before being expected to manage the system independently. Evaluation of participant learning was conducted through direct observation of participants' ability to correctly perform key operational tasks—such as measuring TSS with an Imhoff cone, adjusting feeding rates according to Table 2, and interpreting basic water quality readings—rather than through formal written testing, consistent with the program's production-based and competency-oriented educational approach.

Results and Discussion

The PKM program yielded significant achievements across three dimensions: infrastructure, human resource capacity, and sustainable development potential.

First, the establishment of functional biofloc pond installations. A total of four circular ponds were successfully constructed and operationalized on the SCB school grounds. The construction process was carried out collaboratively with SCB students, directly serving as an authentic practical learning medium. Circular ponds with evenly distributed aeration points proved effective in maintaining water quality and oxygen distribution throughout the water column.

The choice of HDPE tarpaulin and wiremesh steel frame construction also proved advantageous from a cost and maintainability perspective relative to permanent concrete ponds, since materials could be sourced locally and repaired by school staff without specialized contractors, an important consideration for an institution intending to operate and eventually expand the system using its own resources rather than continued external support. The relatively rapid construction timeline further demonstrates the practicality of this design approach for other institutions considering similar interventions under comparable budget and time constraints.

Figure 1. Biofloc pond installation at Sekolah Cendekia BAZNAS (left: monitoring activity; right: students observing circular pond)

Second, enhanced capacity of SCB community members in biofloc management. Following a series of training and mentoring sessions, SCB students and teachers were able to independently carry out pond preparation, fingerling stocking with correct acclimatization procedures, feed management according to biomass weight, and daily water quality monitoring. Their understanding of the nitrogen cycle, from ammonia decomposition by Nitrosomonas to nitrite conversion to nitrate by Nitrobacter, improved measurably.

This distinction is pedagogically significant: a participant who understands why continuous aeration and a stable carbon-to-nitrogen ratio matter is better equipped to diagnose and respond to unexpected system deviations than one who has only memorized a fixed operating procedure.

Beyond the specific technical competencies described above, the training process also appeared to strengthen participants' broader sense of ownership over the biofloc system. Because students and teachers were involved from the earliest construction stages through to daily operational routines, the ponds were perceived less as an external donation to be passively maintained and more as a jointly built asset for which the school community bore direct responsibility. This sense of ownership is widely recognized in community development literature as a key determinant of a program's sustainability beyond the period of external funding and mentoring.

Figure 2. Biofloc system training session for SCB students and staff

Table 2. Feeding Rate (FR) Guidelines Based on Nile Tilapia Body Weight

Body Weight (g)	Feeding Rate (FR)
< 5	8–10%
5–10	6–8%
10–30	5–6%
30–80	3.5–5%
80–150	3–4%
> 150	2–3%

Source: PKM Team UIKA–SCB, 2025

Table 2 illustrates that feed provision is adjusted to the fish growth stage. At the early phase (body weight < 5 g), the feeding rate reaches 8–10% of biomass per day, progressively reduced as body weight increases. Feed was provided in a moistened condition at a frequency of more than twice daily to optimize feed conversion ratio (FCR) and minimize feed residues that could potentially contaminate the water.

This declining feeding-rate schedule reflects the physiological reality that smaller fish possess a proportionally higher metabolic rate and growth demand relative to their body mass, while larger fish require a progressively smaller proportion of their body weight in feed to sustain growth, meaning that a fixed feeding rate applied across all growth stages would result in either underfeeding of juveniles or wasteful overfeeding of larger fish. Moistening feed prior to administration reduces the fragmentation of pellets into fine particles that would otherwise be lost to the water column uneaten, while more frequent, smaller feedings across the day more closely approximate natural feeding behavior and reduce the likelihood of a single large bolus of uneaten feed degrading water quality.

Third, prospects for alternative feed development were opened. In a broader context, this PKM program connects with ongoing research being developed by the team, namely the utilization of oyster mushroom baglog waste as a raw material for Nile tilapia feed pellets within the biofloc system. Baglog waste contains residual cellulose and protein that can be formulated into high-protein feed supplements, simultaneously addressing the agroindustrial waste problem of mushroom cultivation, which is typically discarded without further use.

Given that commercial feed constitutes the largest recurring cost in intensive aquaculture, a locally sourced, low-cost supplementary feed ingredient derived from waste that would otherwise require disposal represents a potentially significant contribution to the long-term economic sustainability of SCB's biofloc operation, particularly if baglog-based feed can be produced on-site using materials already generated by the school's existing mushroom cultivation activities.

This prospective direction is consistent with the broader circular-economy framing found in the biofloc literature, in which aquaculture waste and agricultural by-products are treated not as terminal outputs requiring disposal, but as inputs into adjacent productive systems. Should subsequent research and formulation trials confirm the nutritional adequacy and palatability of baglog-derived feed supplements for Nile tilapia, this approach could substantially reduce SCB's dependence on commercial feed, further strengthening the institution's capacity to operate the biofloc system on a self-sufficient basis. This also opens an avenue for follow-on collaborative research between the university team and SCB, extending the relationship established during this PKM program beyond its initial funding period.

Viewed comparatively, Table 1 summarizes why biofloc was selected over conventional and semifloc alternatives for SCB's specific circumstances. Although biofloc requires higher initial capital investment and a greater degree of technical skill—particularly the need for uninterrupted 24-hour aeration, these requirements are offset by dramatically reduced water demand, higher achievable stocking density, and superior feed efficiency, all of which are especially valuable where land and water are the binding constraints, as is the case at SCB. The semifloc alternative, which relies on a combination of autotrophic and heterotrophic decomposition with only routine suction rather than continuous water exchange, may represent an appropriate intermediate option for institutions with lower capacity for continuous aeration, but it does not match biofloc's feed efficiency or stocking density advantages.

The results of this program should also be interpreted considering the specific institutional context of SCB as a boarding school operating under a philanthropic (BAZNAS) funding model rather than a purely commercial aquaculture enterprise. Unlike a commercial farm, whose primary success metric is financial return on investment, SCB's biofloc system carries a dual mandate: to supply nutritionally valuable animal protein for student consumption and, secondarily, to generate potential surplus for sale or institutional revenue, while simultaneously functioning as a vehicle for vocational and character education. Any economic evaluation of the program should therefore weigh both direct production outcomes and the harder-to-quantify educational and capacity-building benefits described above.

It is also important to acknowledge certain limitations of the current implementation. As an initial pilot within a broader, ongoing PKM initiative, the program's four-pond installation represents a modest starting scale relative to what would be required for SCB to achieve full self-sufficiency in fish protein supply or to generate meaningful surplus revenue. Longer-term monitoring across multiple production cycles will be necessary to establish stable, replicable performance benchmarks specific to the SCB site, including seasonal variation in water temperature and its effects on floc stability and fish growth. Similarly, the baglog-based feed development strand remains at a conceptual and early formulation stage rather than a validated, field-tested feed product, and will require dedicated laboratory and feeding-trial research before it can be recommended for wider adoption.

Nonetheless, the program's core achievements, functional infrastructure, demonstrable transfer of operational competence, and a credible pathway toward local feed innovation, together provide a strong basis for recommending this model to other similarly resource-constrained boarding schools. The combination of a physically compact, water-efficient production system with an explicit pedagogical design distinguishes this intervention from conventional technical-assistance projects that focus solely on infrastructure delivery without a parallel investment in human capacity.

Conclusion

The PKM program implementing a biofloc-based Nile tilapia aquaculture system at Sekolah Cendekia BAZNAS Cibungbulang demonstrates that biofloc technology can be effectively implemented in boarding school environments with limited land. This success was supported by three pillars: the construction of standardized circular pond infrastructure, comprehensive biofloc management training and mentoring, and the active involvement of students and teachers as subjects of production-based learning.

Each of these pillars reinforces the others: well-designed infrastructure alone would not achieve lasting impact without a parallel investment in operational competence, while training without adequate infrastructure would have no productive outlet, and neither would achieve genuine sustainability without the institutional ownership fostered by direct student and teacher participation throughout implementation.

The biofloc system proved to offer water use efficiency (replacement of only 5–8%/day), feed efficiency improvements of up to 20–30%, and the capacity to accommodate high stocking densities (100 fish/m^3 for tilapia), collectively enhancing aquaculture profitability at the limited-land scale. This program is recommended for replication in other boarding schools and pesantren throughout Indonesia, supported by the digitalization of water quality and fish growth data recording to strengthen the accuracy of long-term aquaculture management.

These technical advantages, combined with the program's demonstrated capacity-building outcomes, indicate that biofloc technology is not merely a viable engineering solution for land-constrained institutions but also a productive vehicle for vocational education consistent with the broader mission of pesantren and boarding schools serving underprivileged communities.

Future work arising from this program should prioritize three directions: first, systematic longitudinal monitoring of growth performance, survival rate, and feed conversion ratio across multiple production cycles at SCB to generate robust, site-specific performance benchmarks; second, dedicated formulation and feeding-trial research into baglog-based feed supplements, to validate their nutritional adequacy and economic viability as a partial substitute for commercial feed; and third, development of simple, low-cost digital recording tools that allow non-specialist school staff and students to maintain consistent water quality and production records, thereby supporting evidence-based management decisions and facilitating knowledge transfer to future student cohorts and to other institutions considering similar programs.

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