Interreg
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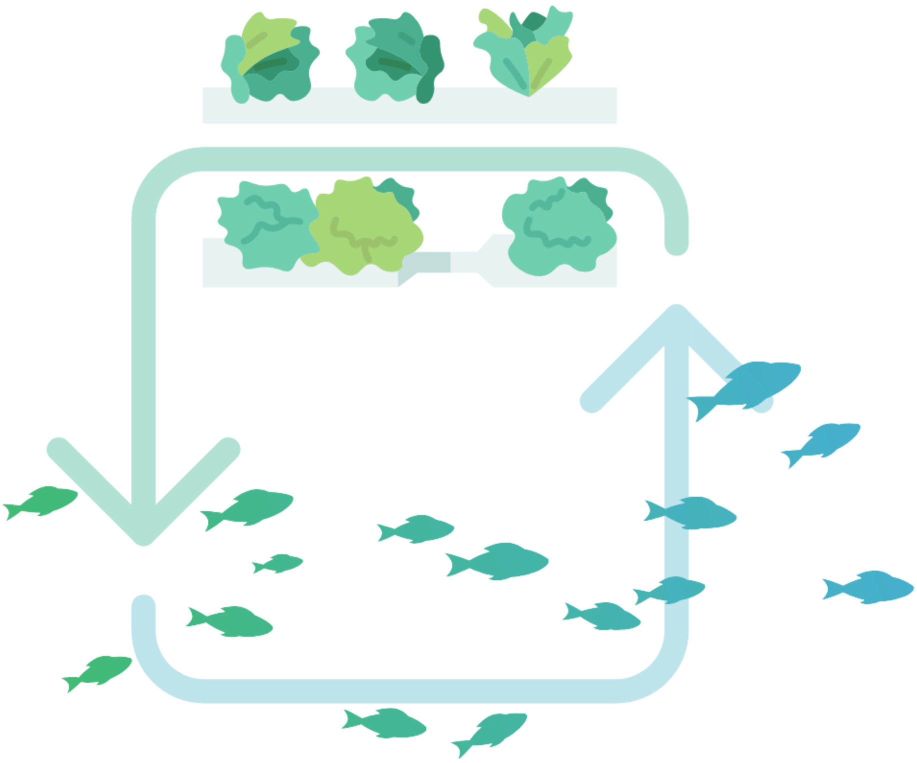
TransFarm

DEMONSTRATION UNIT CONSTRUCTION



UNIVERSITY OF LATVIA

D.2.3.2. – Short report - Demo construction in Latvia

Abstract

This report documents the construction, installation, and early start-up of an indoor aquaponics demonstration unit developed within the TransFarm project at the University of Latvia, House of Nature, Riga. The demonstration unit was established as a permanent, small-scale system designed to showcase integrated fish and plant production in a closed-loop configuration, with a particular focus on knowledge transfer, education, and resilience-oriented local food production under Latvian conditions. The report focuses on the practical aspects of implementation, including site-specific constraints, space preparation, structural assembly, installation of utilities, system integration, and start-up procedures. The demonstration unit was installed in a previously unused basement room with limited floor area and constrained electrical capacity, which strongly influenced system layout and design decisions. Emphasis was placed on compactness, modularity, gravity-driven water flow, and operational robustness, while maintaining high explainability and visibility of system processes for demonstration purposes. Key challenges encountered during construction and early operation are described, including spatial limitations, electrical load management, hydraulic safety in the absence of floor drainage, and the establishment of biological filtration during system cycling. Solutions and recommendations are presented based on hands-on experience gained during implementation. The report does not aim to provide detailed technical design calculations, long-term biological performance results, or economic optimisation analyses. Instead, it offers a realistic and transparent account of how a demonstration-scale aquaponics system can be built, commissioned, and prepared for use as an educational, research, and stakeholder engagement platform. The documented experience provides practical guidance for similar demonstration or pilot installations seeking to support resilient and decentralised food production systems

Keywords: *TransFarm, aquaponics, building, growth systems, demonstration*

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Contents

Introduction

1.1. TransFarm project

There are several environmental and social challenges that the food sector has to face: Agriculture is a sector particularly affected by climate change, our seas are overfished, and the world population is estimated to continue growing, being about 9.7[1] billion people by 2050. Countries in the Baltic Sea Region are strongly dependent on food import, especially for vegetables, fruit and fish; in recent years the pandemics and the war in Ukraine have exposed the need for more self-sufficient food systems. Moreover, agriculture and aquaculture are among the main contributors to the eutrophication of the Baltic Sea.

To answer these challenges TransFarm project wants to bring food production closer to consumers by promoting soil-less farming methods that can be implemented even indoors and allow it to grow all year round. Examples of these methods are hydroponics, where plants are grown in water, and aquaponics, which combines hydroponics with aquaculture.

Aquaponics is a circular, closed-loop system, where water from the fish culture is used to grow plants. The fish waste within the water is microbiologically transformed by a biofilter, absorbed by plants and then cleaner water returned to the fish. The system has a completely circular water flow allowing nutrient reuse without emissions of nutrients in the environment. Since the fish, plants and microorganisms in an aquaponics system function in close symbiotic relationships, antibiotics or pesticides are not used, which in turn provides cleaner, healthier produce.

TransFarm will demonstrate aquaponics in Sweden, Estonia and Latvia as well as test alternative water sources such as rainwater and reclaimed greywater: Partners from these countries will build demonstration facilities with different characteristics and aims. The experiences exchanged from the different demos will contribute to knowledge co-creation and the facilities will be the opportunity to inspire and educate future aquaponics farmers. The knowledge gathered from the construction and monitoring of the demos will result in education material available for all the actors interested in aquaponics.

The project will also investigate business models, run activities to inform consumers about the quality of the aquaponics produced, educate entrepreneurs who want to start an aquaponics system as well as inform civil servants and policy makers about the reduced environmental impact of circular soil-less farming methods.

TransFarm project duration is three years (2023-2026), and it is coordinated by **Turku School of Economics** at the University of Turku (Turku, Finland). Project partners are the **Estonian University of Life Sciences** (Tartu, Estonia), **University of Latvia** (Riga, Latvia), **Norrtälje Vatten och Avfall** and **Coompanion** (Norrtälje, Sweden).

TransFarm project is funded by the EU's Interreg Central Baltic program, the total budget of the project is 1.87 million euros, EU financing covers 1.5 million euros.

[1] UN DESA publications – World population prospects 2022

1.2. Purpose of the demonstration unit and the scope of this report

The purpose of the demonstration unit is to showcase the practical feasibility of an integrated aquaponics system as a resilient, locally adaptable food production model under Latvian conditions. The unit has been developed within the framework of the TransFarm project to demonstrate how fish and plant production can be combined in a resource-efficient, closed-loop system capable of operating independently, including in situations where conventional food supply chains may be disrupted. By making system processes visible and understandable, the demonstration unit aims to support knowledge transfer and raise awareness of innovative food production approaches that can contribute to improved food resilience at local and regional levels.

The demonstration unit is not intended to function as a commercial production facility. Instead, it serves as a proof-of-concept and a replicable model that illustrates key technical principles, operational requirements, and practical challenges associated with aquaponics systems. The unit is designed to be accessible and informative for a broad target audience, including students, researchers, farmers, policymakers, project stakeholders, and the general public. Its demonstration character is defined by its modular layout, transparent system operation, integrated monitoring, and the ability to communicate both successful solutions and encountered challenges. The scope of this report focuses primarily on the physical construction, installation, and early operational phase of the demonstration unit. Particular emphasis is placed on documenting the practical steps involved in assembling the system, integrating its components, and bringing it into initial operation. In addition, the report highlights lessons learned during the construction and installation process, providing insights that may be useful for similar demonstration, educational, or pilot-scale systems.

Detailed technical design of the demo unit is described in Transfarm project report “D 2.3.1. Report of designing the demo in Latvia”, and the demonstration unit functionality and monitoring is described in project report “D.2.4.1. – Short report - Demo testing & monitoring in Latvia”. By concentrating on the build-up and commissioning stages, this report aims to provide a clear and realistic account of how the demonstration unit was implemented in practice and how it can function as a knowledge-transfer and awareness-raising tool for sustainable and resilient food systems.

2. Demonstration unit site and building context

2.1. Location, spatial and technical constraints

The demonstration unit is located at the University of Latvia, House of Nature, Jelgavas iela 1, Riga, Latvia. The system is installed indoors in the basement of the building as a permanent setup. The selected room was previously unoccupied and unused (Figure 1.), providing a suitable opportunity to establish the demonstration unit without interfering with existing activities. The space is separated from public access by closed doors, which supports controlled operation and helps reduce the risk of contamination. At the time of installation, the room did not contain any infrastructure specific to aquaponics systems and functioned as a blank space equipped only with basic utilities, including electricity, internet connectivity, and a water supply with drainage.

The available room area is approximately 12.74 m², with a ceiling height of 3.13 m. While the ceiling height provided sufficient vertical clearance, the limited floor area represented the primary spatial constraint. As a result, efficient use of space became a central design consideration, particularly with respect to the size and placement of plant growing beds and technical components. These constraints strongly influenced the overall system layout and motivated the consideration of vertical cultivation solutions, which are planned for future installation to increase production capacity without expanding the system footprint. From a technical perspective, the room was supplied by a single electrical circuit with a maximum available power of approximately 3400 W. This limitation required careful balancing of electrical loads, especially for artificial lighting, pumps, and aeration equipment. Water supply and drainage were available but were both located in one corner of the room, necessitating the use of extended piping to connect system components positioned elsewhere in the space. Ventilation was provided by the building's central system, which resulted in very low air humidity during winter months and required additional consideration for plant growth and system operation. Operational constraints related to noise and climate control were also identified. Due to the small room volume and continuous operation of pumps and air blowers, noise levels within the space are relatively high. While no condensation issues were observed during the initial monitoring period, the absence of a floor drain requires careful management of potential leaks, as drainage is available only via an elevated outlet in the corner of the room. Seasonal temperature variation was addressed by maintaining suitable indoor temperatures during winter and planning for active cooling during summer through the use of a dedicated air-conditioning unit.

Figure 1. Room prior the demonstration unit construction.

Overall, the location and existing building conditions required the demonstration unit to be designed in a manner that maximises spatial efficiency while remaining compatible with the technical limitations of the room. These constraints played a key role in shaping the system layout and informed both current design decisions and planned future upgrades.

3. General concept and design overview

3.1. Demonstration unit concept

The demonstration unit is conceived as a small-scale aquaponics system that integrates fish and plant production in a closed-loop setup, where nutrients originating from fish metabolism are reused to support plant growth. The system demonstrates how biological processes, including fish metabolism and microbial nutrient transformation, can be harnessed to produce food efficiently while minimising external inputs. Conceptually, the unit is designed to illustrate the interdependence between fish, plants, and microorganisms and to make nutrient cycling processes visible and understandable. By linking fish feeding, microbial nitrification, and plant nutrient uptake within a single system, the demonstration unit provides a practical example of how waste streams can be transformed into valuable resources. This approach highlights key principles of resource efficiency, circularity, and resilience in food production systems. The demonstration unit represents a realistic and buildable model rather than an experimental laboratory installation or a commercial production facility. At the same time, it serves as an educational tool where system behaviour can be observed, monitored, and discussed. The system is intentionally designed to be technically simple (Figure 2), relying primarily on gravity-driven water flow and a single recirculation pump, while being supported by extensive monitoring of water quality and environmental parameters. This combination allows for both operational reliability and detailed observation of system dynamics. A defining feature of the demonstration unit is the visibility of system limitations, adjustments, and responses to changing conditions. Failures and corrective actions are considered an integral part of the learning process and are openly documented and discussed. Rather than presenting an idealised or fully optimised setup, the unit reflects real-world constraints related to space, energy availability, and indoor environmental conditions. The concept is tailored to be transferable and relevant for Latvian conditions, with potential applicability for households, educational institutions, and community-scale initiatives. The unit is not intended to demonstrate industrial-scale production or full automation, but instead to provide a transparent and adaptable reference model that supports learning, discussion, and informed decision-making around resilient local food production systems.

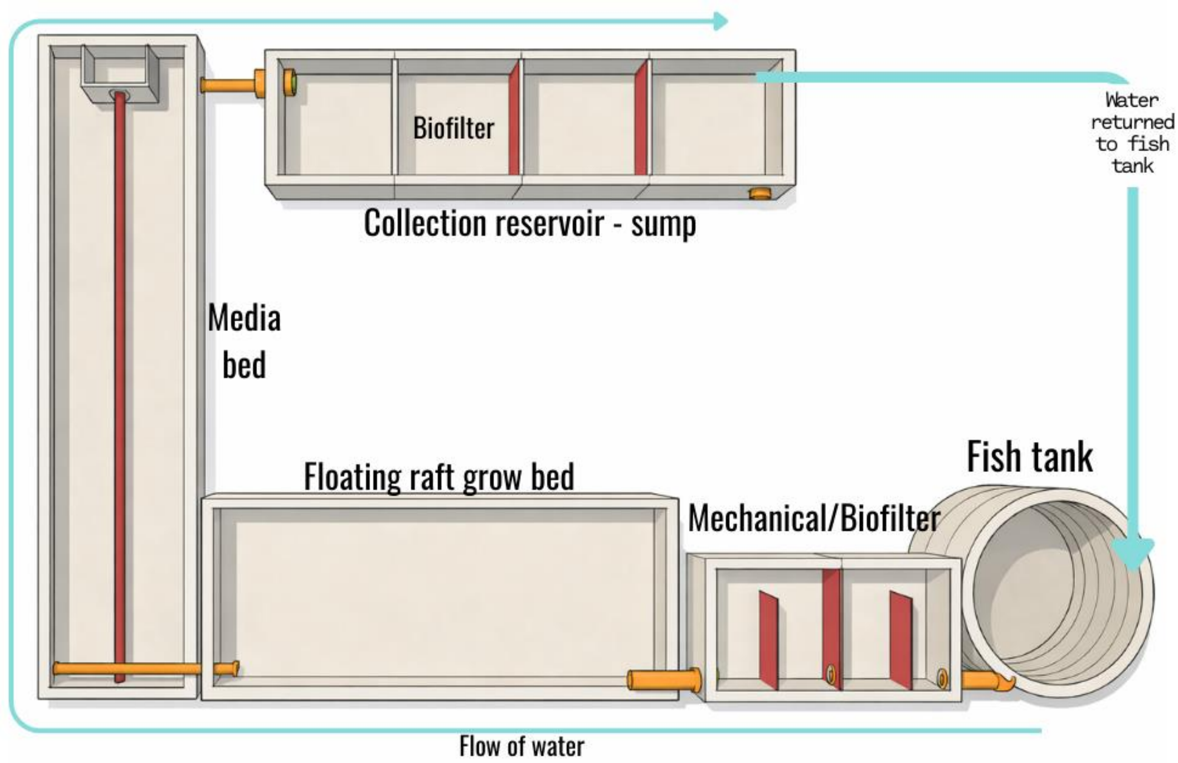

Figure 2. Demonstration aquaponics main parts and their location.

3.2. Key design principles

The design of the demonstration unit was guided by a set of practical and pedagogical principles aimed at balancing simplicity, robustness, and explainability while maintaining realistic system behaviour. From the outset, the unit was conceived as a compact, reliable, and easily interpretable system that could demonstrate aquaponics principles under real-world conditions rather than optimised laboratory settings. A core technical principle was the use of gravity-driven water flow wherever possible, combined with a single main pump to recirculate water through the system. This approach reduces mechanical complexity, limits potential points of failure, and makes the overall system logic easier to understand. Minimising the number of active components also supports operational stability and simplifies maintenance, which is particularly important for a permanent demonstration installation. Modularity and accessibility were central to the system layout. Individual components such as the fish tank, filtration units, plant beds, and sump are clearly separated and physically accessible, allowing for straightforward inspection, maintenance, and future modification. This modular structure also supports incremental system upgrades, including the planned addition of vertical growing elements, without requiring fundamental redesign of the existing setup.

Although energy efficiency was not defined as a primary design objective, it emerged naturally as a consequence of the system's small scale and simplified architecture. The initial design intentionally avoided vertical stacking of plant beds in order to limit additional lighting requirements and electrical load, particularly given the constrained power availability in the installation space. Vertical solutions were considered as a future expansion once baseline system performance and stability were established. Monitoring and controllability were deliberately emphasised as defining features of the demonstration unit. While the physical system remains relatively simple, it is extensively monitored to provide detailed insight into water quality, environmental conditions, and system dynamics. This results in a system that is physically straightforward yet information-rich, enabling users to directly link observed system behaviour to measured parameters and management decisions. Safety and robustness were also key design considerations. To minimise the risk of water-related damage, all tanks are equipped with overflow outlets connected directly to the building's drainage system. This design choice reduces the likelihood of uncontrolled flooding and enhances operational safety, particularly in the absence of a floor-level drain. Conservative loading during system start-up and durable construction materials, primarily polypropylene (PP), were selected to ensure long-term reliability and resistance to mechanical and chemical stress. Finally, explainability and transferability were fundamental guiding principles. The system was designed so that water flow paths, functional units, and biological processes can be understood quickly by visitors with varying levels of technical background. Wherever possible, commonly available components were used, and custom solutions were avoided. As a result, the demonstration unit serves as a realistic reference model that can be adapted for households, educational institutions, or community-scale applications under Latvian conditions.

4. Construction and installation

4.1. Space preparation and internal layout

Before installation, the designated room was empty, featuring bare walls, a finished laminate floor, and only basic utilities, including electrical outlets, a water supply point, and a drain. The absence of existing equipment or infrastructure provided a blank starting point for the installation of the demonstration unit and allowed full flexibility in planning the internal layout.

Initial space preparation focused on cleaning the room and carefully measuring the available floor area. Based on these measurements, the planned layout of the demonstration unit was marked on the floor to define the position of major system components, including tanks, plant beds, and circulation pathways. This step was essential for verifying that the system could be accommodated within the limited space while maintaining accessibility and clear movement routes. Electrical infrastructure was adapted to meet the needs of the system. Power connections were routed to the required locations using protective conduits, and water-resistant plug sockets were installed to improve operational safety in the humid environment. Given the laminate floor surface and the presence of water-based systems, the floor was protected before installation to reduce the risk of damage during construction and operation. The internal layout was designed to maximise efficient use of space while allowing safe and convenient movement within the room. Component placement was guided by the need to maintain a logical system arrangement, where water flow paths and functional units are visually clear and easy to explain during demonstrations. At the same time, sufficient space was left for walking paths, routine maintenance, and cleaning, ensuring that the unit remains accessible and presentable. During installation, the planned layout proved largely accurate. Minor adjustments were required when certain tanks were found to be slightly oversized for the shelving system used to support plant beds and filtration units. This issue was resolved by modifying the corners of the tanks to allow them to fit securely within the shelves, without compromising structural integrity or functionality. These adaptations are well documented in the construction photographs.

Space preparation focused primarily on creating a safe, organised, and efficient layout that supports both system operation and demonstration activities. The resulting arrangement balances compactness with accessibility and provides a clear spatial framework for understanding system function.

4.2. Structural assembly and mounting

Following space preparation and layout definition, the structural assembly of the demonstration unit was carried out by installing the supporting framework and mounting the main system components (Figure 3.). Given the limited room size and the need for efficient space utilisation, shelving systems were used to support tanks, plant beds, and filtration units while maintaining a compact footprint and clear access for operation and maintenance. The shelving structures were assembled first and positioned according to the predefined layout. These structures served as the primary load-bearing elements for the aquaponics system and were selected to provide sufficient strength and long-term stability under wet operating conditions. Once installed, the shelves defined the vertical and horizontal alignment of system components and ensured consistent spacing between functional units.

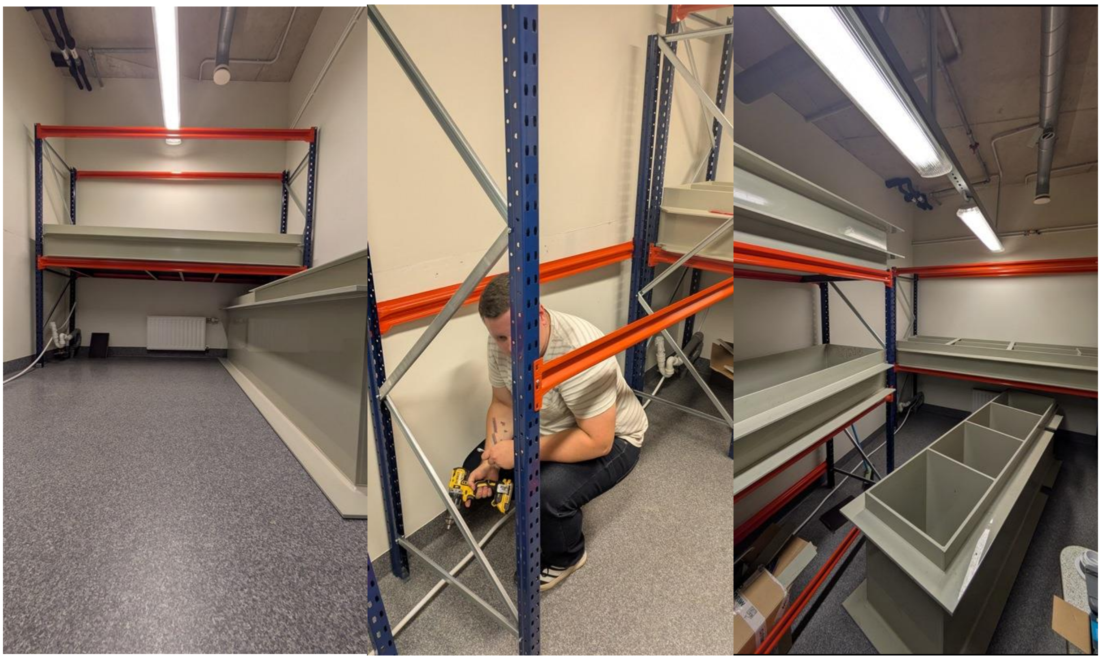

Figure 3. Mounting supporting framework, and mounting the main system components.

Tanks and plant beds were subsequently placed onto the shelving system. During this phase, it became evident that certain tanks slightly exceeded the available shelf dimensions. To resolve this, the corners of the tanks were carefully modified to allow proper fitting within the shelving structure (Figure 4). This adjustment enabled secure placement without affecting the functional volume or integrity of the tanks and allowed the planned layout to be maintained. The modification process and final placement are clearly documented in the construction photographs.

Figure 4. Modifying of containers to allow proper fitting within the shelving structure, and preparing overflow fittings.

Mounting and positioning of system components were performed with attention to stability, accessibility, and safety. All tanks were levelled to ensure uniform water distribution and proper overflow function. Components were positioned to allow visual inspection of water levels, flow paths, and system operation, which is particularly important for demonstration and educational purposes. Given the drywall construction of the room, wall-mounted elements were kept to a minimum. Where necessary, fixings were installed carefully to avoid structural damage while providing adequate support. The majority of the system weight and structural load was transferred through the shelving system to the floor, reducing reliance on wall-mounted supports. The structural assembly process prioritised robustness, modularity, and ease of access. The resulting structure provides a stable foundation for the aquaponics system while supporting future modifications and expansions, including the planned addition of vertical growing elements.

Media bed was designed to have a bell siphon that would raise the water level and completely drain it every 8-10 minutes (Figure 5). Adjustments of the bell siphon design were done several times. First, the bell siphon would not be able to achieve the necessary vacuum within to start the cycle. Once the start of the cycle was adjusted, the siphon would not break properly and continuous flow from the media bed would continue endlessly. To fix this a longer outflow pipe was installed with two 90 degree elbows at the end – this allowed to carefully regulate the flow so that the cycling would start once the water level reached the overflow of the siphon pipe and the siphon would break and allow backflow of air. Below are the first design on the left and the final design of the siphon now properly functioning.

Figure 5. Initial siphon design (left) and the final, functioning siphon with fill up time of 10 minutes and bed emptying time of 45 sec.

4.3. Installation of utilities and environmental systems

The installation of utilities and environmental systems was carried out after completion of the structural assembly and positioning of the main system components. Given the absence of aquaponics-related infrastructure in the room prior to installation, all required utility systems were implemented from the ground up. Electrical installation was performed by a certified electrician, who created new electrical lines dedicated to the demonstration unit. A separate fuse box was installed to supply the system, providing clear electrical separation and improved operational safety. Two electricity counters were integrated into the setup to independently monitor the energy consumption of lighting and of pumps and other electrical equipment in the room. All electrical sockets were wall-mounted and equipped with water-resistant outlets suitable for use in humid environments. Electrical cables were routed in an organised manner to minimize exposure to water and to maintain a clean and accessible workspace.

Artificial lighting for plant cultivation was installed by suspending grow lights from the shelving system using adjustable hanging lines. This configuration allows the vertical position of the lamps to be easily adjusted as plants grow or as lighting conditions are optimised. Lighting operation is controlled via fixed timers, ensuring consistent photoperiods and reducing the need for manual intervention.

Water supply infrastructure was installed using fixed piping connected directly to the fish tank. In addition, a small worktable equipped with a sink providing both cold and hot water was installed in the room to support routine maintenance, cleaning, and system operation (Figure 6.). Manual water top-ups are performed by opening the dedicated tap connected to the fish tank, allowing controlled replenishment of system water when required. Drainage is provided via a single drain located in the corner of the room. This drain is connected to overflow outlets installed on all major tanks, ensuring that excess water is safely discharged in the event of overfilling. The drain is also used for wastewater from the sink, consolidating water discharge within the available building infrastructure.

Figure 6. Water supply system and newly built electricity circuit lines and fuse box.

Ventilation within the room is provided by the building's central ventilation system, and no additional ventilation equipment was installed during the construction phase. To address potential seasonal environmental challenges, an air-conditioning unit and a humidifier were placed in the room and prepared for use. Although these devices were not required during the initial operational period, their availability allows rapid response to elevated temperatures in summer or excessively low humidity during winter. Environmental and system monitoring equipment was installed after completion of all technical and utility installations. This sequencing ensured that sensors and monitoring devices were not exposed to construction-related disturbance and could be calibrated under stable operational conditions.

5. System integration and commissioning

5.1. Integration of components

After completion of structural assembly and installation of utilities, the individual components of the demonstration unit were integrated into a single, functioning aquaponics system. This phase focused on establishing hydraulic connectivity, ensuring logical water flow, and verifying that all system elements operated together as intended.

Integration began with connecting the fish tank, filtration units, plant growing beds, and sump into a closed-loop water circulation system. Water flow paths were designed to follow a clear and easily understandable sequence, allowing demonstration of system logic and nutrient transport. Wherever possible, gravity-driven flow was used between components, while a single main pump was installed to return treated water from the sump back to the fish tank, completing the circulation loop. Mechanical and biological filtration units were connected upstream of the plant growing beds to ensure effective removal of suspended solids and conversion of nitrogen compounds prior to plant nutrient uptake. Plant beds were integrated downstream of filtration units, allowing nutrient-rich but clarified water to reach plant roots. Overflow connections from each major tank were linked directly to the drainage system to provide an additional safety layer during integration and testing.

During integration, particular attention was given to component alignment, pipe connections, and sealing. All joints, fittings, and valves were assembled to allow easy inspection and future adjustment. Pipe routing was organised to avoid unnecessary bends and to maintain visual clarity of water movement, which is important for demonstration and educational purposes. Electrical integration was carried out in parallel with hydraulic connections. Pumps, aeration devices, lighting, and control equipment were connected to the dedicated electrical system installed earlier. Power distribution was organised so that individual components could be isolated if necessary, supporting both safety and troubleshooting. Throughout the integration process, components were installed incrementally rather than all at once. This stepwise approach allowed verification of correct placement and connectivity at each stage and reduced the risk of compounded errors. The integration process is well documented through construction photographs, which illustrate the sequential assembly and final interconnection of system components. By the end of this phase, all major elements of the demonstration unit were physically and functionally connected, forming a coherent aquaponics system ready for initial testing and commissioning.

5.2. Initial testing and functional checks

Following the integration of all system components, a series of initial testing and functional checks were carried out to verify the correct operation of the demonstration unit prior to full start-up. This phase focused on ensuring hydraulic integrity, functional performance of technical components, and overall system safety. Testing began with the gradual filling of the system using the fixed water supply connected to the fish tank. Water was introduced in stages, allowing visual inspection of tanks, pipe connections, and fittings at increasing water levels (Figure 7). Particular attention was paid to joints, seals, and overflow outlets to detect any leaks or unintended water loss. The staged filling approach allowed potential issues to be identified and corrected early, minimising the risk of damage. Once the system was filled, the main circulation pump was activated, and water flow through the system was tested. Flow direction and flow rates were visually confirmed across all system components, including the fish tank, filtration units, plant growing beds, and sump. Gravity-driven sections were checked to ensure smooth and uninterrupted water movement, while the return flow from the sump to the fish tank was verified for stable and continuous operation.

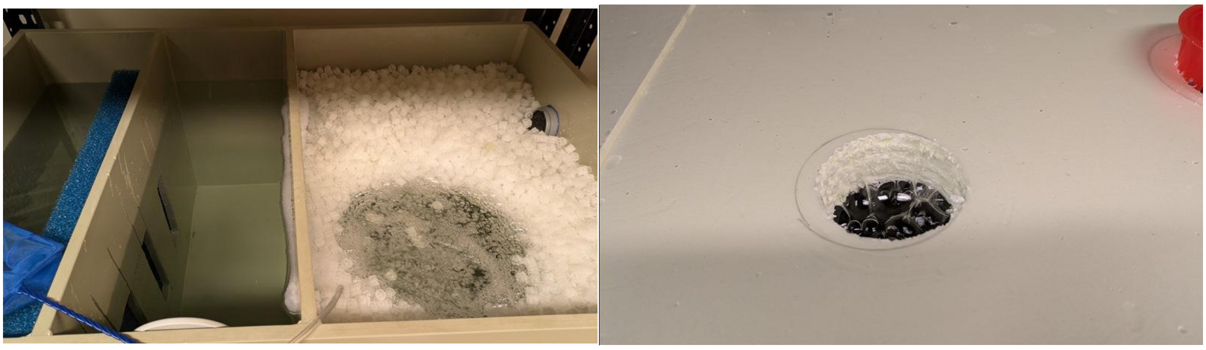

Figure 7. Water level and flow testing in aquaponics system.

Overflow systems were tested by temporarily increasing water levels to confirm that excess water was safely directed to the building drainage system. This step was particularly important given the absence of a floor-level drain in the room. Successful overflow testing confirmed the effectiveness of the system’s safety design and reduced the risk of uncontrolled flooding during operation. Aeration devices and air blowers were tested to ensure adequate air delivery to all relevant system compartments. Lighting systems were activated and tested under timer control to verify correct photoperiod settings and uniform illumination of plant growing areas. Electrical loads were monitored during testing to confirm that system operation remained within the available power limits. Throughout the testing phase, adjustments were made where necessary, including fine-tuning water levels, repositioning pipes, and securing fittings. The testing process confirmed that all individual components functioned as intended and that the integrated system operated reliably under initial operating conditions (Figure 8.). Completion of initial testing and functional checks marked the transition from construction to operational start-up, providing confidence that the demonstration unit was ready for controlled commissioning and early operation.

Figure 8. With small water pump running vertical farming system as loop inside aquaponics system. Installation and testing climate control sensors.

5.3. Start-up procedures, adjustments

Following the successful completion of initial testing and functional checks, the demonstration unit was transitioned into operational start-up. This phase focused on stabilising system operation, establishing baseline conditions, and making incremental adjustments to ensure the reliable and safe functioning of all components before introducing biological load. The start-up process began with continuous circulation of water through the system under controlled conditions. Pumps, aeration devices, and lighting systems were operated according to their planned schedules to verify long-term stability beyond short test periods. Water levels were monitored closely during the first days of operation to ensure consistent flow and to confirm that overflows and return paths functioned as intended under continuous use. During early operation, minor adjustments were made to optimise system performance. These included fine-tuning water flow rates between components, adjusting water levels in individual tanks and beds, and securing pipe connections after initial settling. Lighting height was adjusted using the hanging system to achieve uniform illumination across plant growing areas, while aeration intensity was balanced to ensure adequate oxygenation without excessive turbulence.

Figure 9. Assembled and tested aquaponics system which is ready for fish and plant introduction.

Start-up procedures also included verification of operational routines and accessibility. Maintenance access to all system components was tested in practice, ensuring that routine tasks such as inspection, cleaning, and water top-ups could be performed safely and efficiently. Electrical systems were observed under normal operation to confirm a stable power supply and correct functioning of timers and safety features. Environmental conditions within the room were monitored during early operation to confirm that temperature and humidity remained within acceptable ranges under active system conditions. While no immediate intervention was required, the availability of additional climate control equipment ensured preparedness for seasonal variation. The start-up phase was intentionally conducted gradually, allowing the system to settle and enabling early detection of unexpected behaviour. This cautious approach reduced stress on system components and created a stable foundation for subsequent biological commissioning. Completion of the start-up procedures marked the point at which the demonstration unit was considered operational and ready for further use in demonstration, education, and early-stage system observation.

Figure 10. Fish (sturgeon) introduction in aquaponics.

As part of the start-up phase, the system underwent a controlled cycling period to establish the biological filtration necessary for stable aquaponics operation. This process focused on promoting the development of nitrifying microbial communities within the biofilter units, media beds, and other surfaces in contact with circulating water. System cycling was recognised as a critical step to ensure that ammonia produced by fish metabolism could be reliably converted into less toxic nitrogen forms prior to full biological loading. During the cycling phase, water circulation, aeration, and temperature were maintained under stable conditions to support microbial activity. The system was operated continuously, allowing microorganisms to colonise filter media and internal surfaces. Particular attention was paid to maintaining adequate oxygen levels and avoiding sudden changes in operating conditions, as these factors are essential for the successful establishment of ammonia-oxidising and nitrite-oxidising bacteria. The gradual and controlled approach to cycling reduced the risk of water quality instability during later stages of operation. System cycling was carried out in parallel with careful observation and incremental adjustments. Early system behaviour informed minor operational refinements, such as flow balancing and aeration optimisation, to ensure that biological filtration capacity could develop effectively. Completion of the cycling phase provided confidence that the system was biologically prepared for subsequent operational use and further demonstration activities. Final cycling and biofilter establishment were completed only later, when the fish had been living within the system for a month (Figure 10, 11.).

Figure 11. Plant introduction in aquaponics.

6. Challenges, lessons learned and future use

6.1. Challenges and recommendations

The construction and early operation of the demonstration unit revealed several practical challenges related to space limitations, technical constraints, and system start-up dynamics. Addressing these challenges provided valuable insight into the real-world implementation of small-scale aquaponics systems and informed recommendations for future installations.

One of the primary challenges was the limited available space within the installation room. Although the room offered sufficient ceiling height, the restricted floor area constrained the size and arrangement of system components, particularly plant growing beds. This required careful layout planning and, in some cases, on-site adaptation of components to fit within the shelving system. Recommendation: when working in compact indoor spaces, component dimensions should be verified against support structures at an early stage, and modular or customizable elements should be prioritised – check 7 times before accepting the deliveries. Vertical growing solutions can significantly increase productivity, but should be introduced only after baseline system stability is achieved.

Electrical capacity represented another important constraint. The room was supplied by a single electrical circuit with a limited maximum load, which required careful balancing of lighting, pumping, and aeration demands. While this limitation did not prevent system operation, it influenced decisions regarding lighting intensity and system expansion. Recommendation: Early assessment of available electrical capacity is essential, particularly when artificial lighting is required. Where possible, separating lighting and life-support systems into independently monitored circuits improves operational flexibility and safety. Hydraulic safety was also a key consideration, especially given the absence of a floor-level drain. While the use of overflow connections to the drainage system effectively reduced flood risk, the situation highlighted the importance of conservative water management in indoor installations. Recommendation: All tanks in indoor aquaponics systems should be equipped with dedicated overflow outlets connected to a reliable drain, and routine inspection of these connections should be part of standard operation.

From an operational perspective, the system cycling phase presented challenges typical of new aquaponics installations, including the time required for biological filtration to establish. Managing expectations during this phase was important, as system performance does not immediately reflect steady-state operation. Recommendation: cycling should be approached as an integral learning phase, with gradual loading, stable environmental conditions, and continuous observation rather than rapid optimisation attempts. Finally, environmental conditions within the room, particularly low air humidity during winter, were identified as a potential constraint for plant growth. Although not critical during early operation, this factor may influence long-term performance. Recommendation: Indoor aquaponics systems should include provisions for basic climate control or mitigation strategies, even if such measures are not immediately required at start-up.

6.2. Potential applications of the Demo unit

The demonstration unit has been designed as a multifunctional platform supporting education, research, knowledge transfer, and broader societal engagement. Its transparent structure, clearly separated system components, and extensive monitoring make it particularly well-suited for use in teaching and demonstration activities. The unit provides a tangible environment in which principles of aquaponics, nutrient cycling, water reuse, and system integration can be observed directly. This makes it a valuable resource for university-level education, professional training, workshops, and guided demonstrations, where abstract theoretical concepts can be linked to real system behaviour.

In addition to its educational value, the demonstration unit offers opportunities for applied research and technical testing. While it is not intended for large-scale optimisation or intensive production experiments, the system allows for pilot-scale investigations into operational strategies, environmental control, monitoring approaches, and system responses during early operation. The integrated monitoring infrastructure enables detailed observation of system dynamics, supporting exploratory studies and methodological development in a controlled yet realistic environment. The unit also plays an important role in knowledge transfer to practitioners and stakeholders. By presenting a functional aquaponics system under real spatial and technical constraints, the demonstration unit enables informed discussion with farmers, planners, policymakers, and project stakeholders. Rather than presenting an idealised or fully optimised system, the unit highlights practical challenges, trade-offs, and decision-making processes that are essential for evaluating the feasibility of aquaponics under local conditions. This realistic perspective supports a more grounded assessment of replication potential and scalability.

From a broader societal perspective, the demonstration unit serves as a communication and awareness-raising tool for resilient food production. It illustrates how food can be produced locally using limited space, controlled resources, and biological processes, contributing to discussions on food security, sustainability, and resilience. In the context of increasing uncertainty in global food supply chains, the unit provides a concrete example of decentralised production approaches that may complement conventional systems. The modular and adaptable nature of the demonstration unit supports future development and long-term use. Planned expansions, such as the introduction of vertical growing elements, allow the system to evolve and remain relevant for new applications. This flexibility ensures that the demonstration unit can continue to serve as a living platform for learning, experimentation, and dialogue around sustainable food systems.

Beyond education and demonstration, the unit provides a valuable platform for applied research under controlled yet realistic conditions. Its compact scale and extensive monitoring infrastructure allow investigation of system dynamics, nutrient cycling behaviour, and interactions between environmental conditions and biological processes during early and stable operation. The demonstration unit is particularly suitable for exploratory and method-oriented research, such as testing monitoring approaches, evaluating system responses to operational adjustments, and assessing the performance of small-scale aquaponics configurations under indoor conditions. While not intended for long-term production optimisation, the unit supports hypothesis-driven studies and pilot experiments that can inform future system design, scaling strategies, and decision-making related to resilient local food production.