Impact of Climate-Smart and Water-Saving Frontier Agriculture on the WEFE Nexus in Arid Mediterranean Regions

Practice Abstract

"Aquaponics with fish sludge anaerobic digestion"

Responsible Partner

אוניברסיטת בן-גוריון בנגב
جامعة بن غوريون في النقب
Ben-Gurion University of the Negev

Authors: Ze Zhu; Osnat Gillor; Amit Gross

Dissemination Level		
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PRIMA
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Introduction / Problem or challenge addressed

Aquaponics is a sustainable agricultural practice that integrates aquaculture (fish farming) and hydroponics (growing plants without soil). This symbiotic system allows for the efficient production of both fish and plants, where the fish waste provides essential nutrients for plant growth, and the plants, in turn, help purify the water for the fish. However, while aquaponics offers numerous environmental and economic benefits, it also presents challenges, particularly in the management of fish sludge (Fig. 1). If not properly managed, fish sludge can accumulate in the system, leading to poor water quality, increased risk of disease, and reduced fish and plant productivity. Disposing of fish sludge as waste is costly and poses environmental risks, including pollution and eutrophication of water bodies. Therefore, finding effective ways to manage and reuse fish sludge is crucial for the sustainability of aquaponic systems.

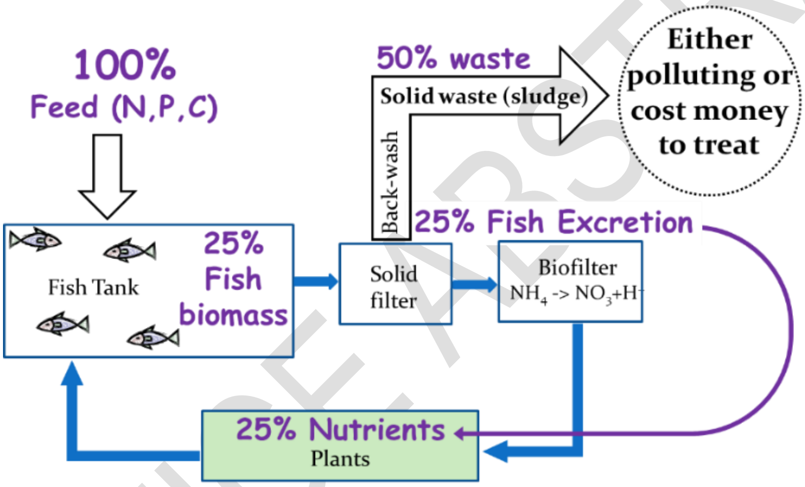

Figure 1. Typical aquaponics system components and the fate of nitrogen, phosphorous, and carbon

Several technologies have been explored for the reuse of fish sludge, focusing on converting it into valuable resources rather than disposing of it as waste. These technologies include composting, vermiculture, and anaerobic digestion. Among these, anaerobic digestion (AD) stands out as a particularly promising approach due to its dual benefits: the production of biogas (a renewable energy source) and the generation of nutrient-rich supernatant, which can be reused within the aquaponic system.

Solution / Innovation

Anaerobic digestion is a biological process that breaks down organic matter, such as fish sludge, in the absence of oxygen, producing biogas, sludge blanket and supernatant. The Upflow Anaerobic Sludge Blanket (UASB) reactor is a specific type of anaerobic digester that is highly efficient in processing waste with relatively low solid content (<1-3%), making it well-suited for treating fish sludge.

The integration of anaerobic digestion, particularly using UASB reactors, into aquaponics addresses multiple challenges simultaneously. This integration allows for the anaerobic digestion of fish sludge, converting it into biogas and nutrient-rich supernatant. Biogas can be utilized as an energy source, while the supernatant enriches the hydroponic component, reducing the need for external fertilizers and improving water use efficiency.

Implementation of UASB-aquaponics

1. Collection of Fish Sludge

Fish sludge composed of uneaten feed, fish excreta, and other organic materials, must be effectively collected to prevent accumulation in the aquaculture unit. Solid removal technologies/equipment, such as settling tanks, brushes, gauze nets, or drum filters, are employed to separate solid waste from the water.

2. UASB reactor design

UASB reactor volume: A typical reactor volume is 20-40% of the fish tank volume, ensuring sufficient retention time for sludge processing without unnecessary scaling.

Height-to-Diameter Ratio: The UASB reactor is typically designed with a height-to-diameter ratio of 4:1 to 5:1. This configuration maximizes the contact between the sludge and the active biomass, enhancing digestion.

Inlet Distribution: The sludge is introduced into the reactor through a distribution system at the bottom of UASB that ensures even dispersion across the reactor’s cross-section, preventing short-circuiting and dead zones.

Gas-Liquid-Solid Separator: A three-phase separator is included at the top of the UASB reactor to separate the produced biogas, treated supernatant, and the solid sludge blanket.

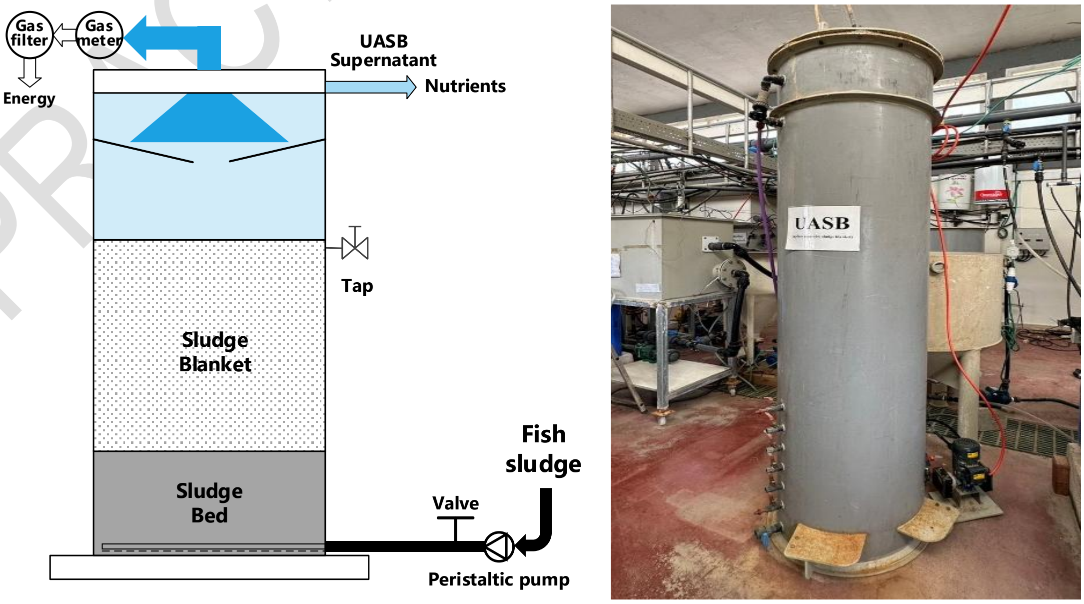

Figure 2. Diagram of the UASB design structure.

3. Introduce fish sludge into UASB

Once concentrated, the fish sludge is transferred to the UASB reactor using peristaltic pumps. These pumps are ideal for handling viscous and particulate-laden fluids like fish sludge.

4. Integration of the UASB into Aquaponics

The integration of the UASB digester into the aquaponics system involves strategically placing the digester to allow for the seamless flow of fish sludge into the reactor and the recirculation of treated supernatant back into the aquaponics system. The UASB digester is typically installed downstream of the fish tanks and solid removal units.

- Sludge Inflow: Fish sludge collected from the solid removal units is pumped into the UASB digester using peristaltic pumps.
- Effluent Recirculation: The treated supernatant from the UASB is recirculated into the hydroponic component of the aquaponics system, where it serves as a nutrient source for plant growth.
- Biogas Utilization: The biogas generated during anaerobic digestion is captured and can be used as a renewable energy source within the system.

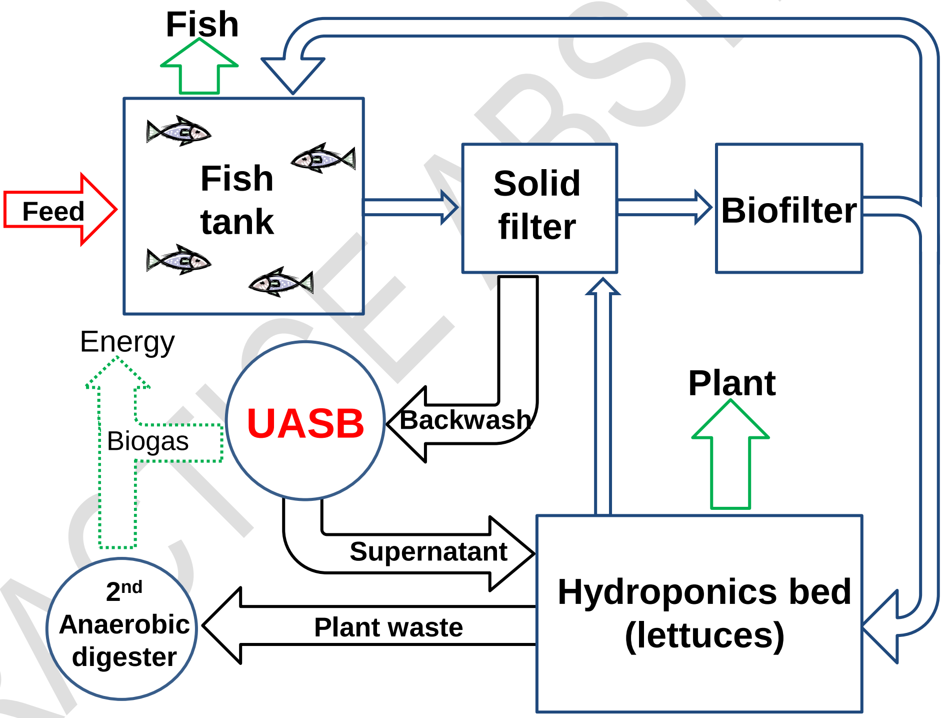

Figure 3. Schematic representation of the aquaponic system, with its fish, filtration system, and the hydroponic plant bed unit and UASB.

5. UASB Operation and Maintenance

Operating Parameters:

- Hydraulic Retention Time (HRT): Typically maintained between 4 to 20 d, depending on the sludge load and reactor design.
- Organic Loading Rate (OLR): A typical OLR for fish sludge is 1 to 2 kg COD/m^3/day.
- pH: The reactor should be maintained at a neutral pH (6.8-7.2) to ensure optimal microbial activity.
- Temperature: Good digestion occurs at >28 °C, and optimal is at 35-37 °C.

Optimal Operating Conditions and Control Measures:

- ✓ Temperature Control: Insulating the UASB reactor or using a heating system ensures the temperature remains within the optimal range.
- ✓ pH Control: Regular monitoring and adding alkaline or acidic substances can help maintain a stable pH within the reactor.
- ✓ Sludge Removal: Periodic removal of excess sludge from the reactor is necessary to prevent the loss of reactor volume and maintain efficient digestion.

6. Supernatant Pretreatment and Nutrient Characteristics

After digestion, the supernatant (liquid effluent) exiting the UASB reactor may require pretreatment before being recirculated back into the aquaponics system. The pretreatment process typically involves:

- ✓ Filtration: Removing any remaining solids that could clog the hydroponic components.
- ✓ Nutrient Balancing: Adjusting nutrient levels to meet the specific requirements of the plants in the system may involve adding trace minerals or diluting the effluent.

The supernatant from the UASB reactor is rich in essential nutrients such as nitrogen and phosphorus, making it an excellent fertilizer for plants (Table 1). The nutrient composition should be regularly monitored and adjusted to ensure optimal plant growth without causing nutrient imbalances or toxicity.

Table 1. Characteristics of dissolved nutrients of UASB supernatant from freshwater aquaponics at BGU. Data presented as mean ± SD. (Unit: mg/L)

Parameters	Supernatant of anaerobic fish sludge
pH	7.1±0.2
EC (mS/cm)	1.7±0.3
ORP (mV)	-386±8
TN	130±30
TAN	123±32
NO_3-N	0.8±0.2
NO_2-N	0.02±0.02
TP	43.3±4.5
SRP	30.1±6.6
Macro- and Micro- nutrients	
K[1]	183±11
Ca	92.2±8.4
Mg	16.4±1.4
S	4.4±2.4
Cl	158±13
Na	103±8
Fe	3.2±0.1
B	1.10±0.19
Mn	0.2±0.06

Zn	0.18±0.03
Cu	0.05±0.01
NPK ratio[2]	1:0.8:1.7

[1] An alkalinity buffer in the form of K_2CO_3 was introduced to the system periodically, which was the main K resource.

[2] N:P(P_2O_5):K(K_2O) ratio on a dry weight basis.

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