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Research Article

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Isolation and Identification of Cultivable Bacteria in an Aquaponic System with Koi Carp and Parsley *(Petroselinum crispum)*: Implications for Water Quality and System Health

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Abstract Aquaponic integrates aquaculture and hydroponic plant cultivation into a sustainable food production system. Understanding the microbial profile, particularly the cultivable bacterial species in such systems, is critical for maintaining the health of both aquatic animals and plants. In this study, water samples were collected from a recirculating aquaponic system containing koi carp (*Cyprinus carpio* var. *koi*) and parsley (*Petroselinum crispum*), as well as from a separate aquaculture tank. Samples were taken from the sump (AP-S), the fish tank within the aquaponic system (AP-FT), and the standalone aquaculture tank (AC). After serial dilutions, the samples were inoculated on Tryptic Soy Agar (TSA) and incubated at 22 °C for 24–48 hours. Isolated colonies were analyzed based on their morphological, physiological, and biochemical characteristics, and further identified using the API 20E system. The bacterial species isolated from the aquaponic system included *Bacillus spp., Aeromonas hydrophila, Shewanella putrefaciens,* and *Flavobacterium* spp., *Micrococcus luteus, Pseudomonas* sp., *Serratia* spp. In contrast, the aquaculture tank yielded dominantly *A. hydrophila, A. caviae,* and *A. sobria.* The absence of *A. caviae* and *A. sobria* in the aquaponic system suggests that *Bacillus* spp. may exert an inhibitory effect against opportunistic pathogens such as *A. caviae,* and *A. sobria.* These findings provide valuable insight into the microbial ecology of aquaponic systems and highlight the importance of microbial monitoring for sustainable and healthy production environments. Furthermore, the presence of additional genera such as *Pseudomonas*, *Serratia* and *Micrococcus* highlights the need for broader microbial monitoring beyond typical aquaculture pathogens.

Keywords Aquaponic · cultivable bacteria · koi carp · parsley · water quality · *Bacillus* · *Aeromonas*

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INTRODUCTION

Aquaponic is a sustainable food production method that integrates recirculating aquaculture with hydroponic plant cultivation in a closed-loop system. In this setup, nutrient-rich water from fish tanks is filtered through plant grow beds, allowing for mutual biological support between fish and plants. These systems have garnered significant attention in recent years for their efficient resource utilization, minimal environmental impact, and suitability for urban and water-limited regions (Somerville et al., 2014; Goddek et al., 2016; Schmautz et al., 2017; Tunçelli et al., 2024).

At the heart of aquaponic systems lies a diverse microbial community that bridges the gap between aquaculture and hydroponics. Microorganisms, particularly bacteria, play a central role in nutrient transformation—especially through nitrification—by converting toxic ammonia excreted by fish into plant-available nitrate via *Nitrosomonas* and *Nitrobacter* species (Eck et al., 2021; Somerville et al., 2014). The establishment of these bacteria is essential during the startup phase, as an insufficient nitrifying community can result in harmful ammonia and nitrite accumulation, leading to fish mortality or impaired plant growth (Badiola et al., 2012; Tunçelli and Memiş, 2024).

Microbial diversity and abundance in aquaponic systems are highly variable and depend on system design, water quality, and the interactions between fish, plants, and microbes. A stable microbial environment supports productivity, while imbalances may allow opportunistic pathogens to proliferate (Kasozi et al., 2019; Joyce et al., 2019). In this context, using native beneficial bacteria and optimizing system conditions is increasingly emphasized in recent research (Tunçelli et al., 2023a). Furthermore, lighting and system layout have been shown to affect both plant growth and microbial dynamics (Tunçelli et al., 2023b), highlighting the need for integrative design strategies.

Several fish pathogens, such as *Aeromonas hydrophila*, *Vibrio* spp., and *Pseudomonas aeruginosa*, have been identified in aquaponic environments (Fischer et al., 2021). However, the ecological role of other bacteria—such as *Acidovorax, Sphingobium, Flavobacterium*, and *Pseudomonas*—in plant growth, disease suppression, or microbial balance remains underexplored (Sirakov et al., 2016). On the other hand, there is growing evidence that beneficial rhizobacteria such as *Pseudomonas*, *Bacillus*, *Serratia*, and *Enterobacter* species contribute to plant development by enhancing nutrient availability, suppressing plant pathogens, and forming biofilms on plant roots (Chabot et al., 1993; Nadeem et al., 2014; Lareen et al., 2016; Bartelme et al., 2018).

Bacillus spp., in particular, are of special interest due to their dual benefits: they not only support plant growth but are also widely recognized as probiotics in aquaculture. These bacteria have been shown to improve fish immunity, inhibit the growth of harmful microorganisms, and maintain microbial balance within aquaponic systems (Gatesoupe, 1999; Shafi et al., 2017; Kasozi et al., 2021). Furthermore, *Bacillus subtilis, B. megaterium, Serratia marcescens*, and *Micrococcus luteus* have been isolated from aquaponic systems and may serve beneficial roles for both fish and plants (Sheema & Dorai, 2017). Some commercial hydroponic probiotics already include these strains, supporting their practical relevance. Studies on aquaponic lettuce production have also demonstrated that systems managed with microbial care can result in high food safety and improved product quality (Tunçelli et al., 2023a).

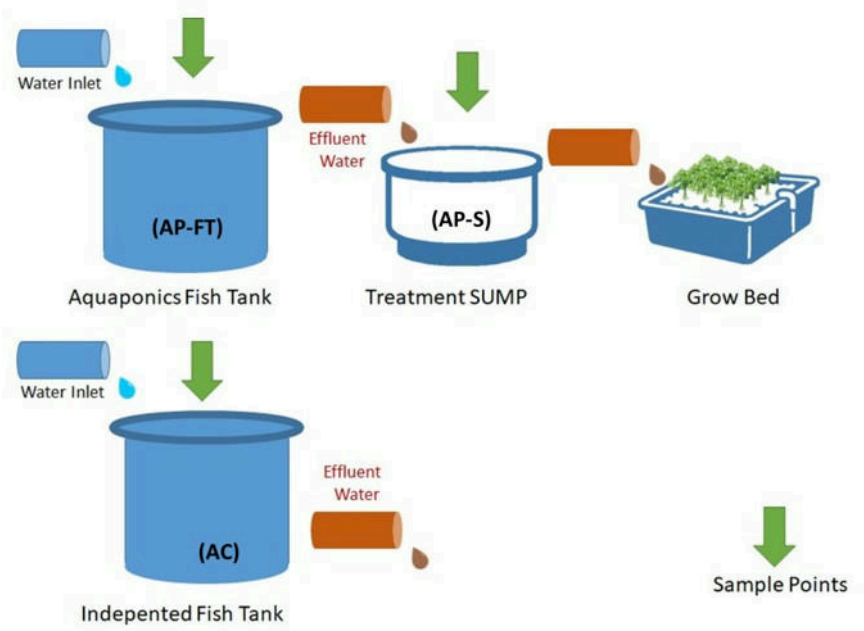
Although the relationship between bacteria and health outcomes in aquaponic systems requires further investigation, some studies suggest that properly functioning aquaponic may reduce the prevalence of pathogenic bacteria. For example, *A. hydrophila* was detected in catfish-based aquaponic systems without evidence of disease (Chitmanat et al., 2015), and *Flavobacterium columnare* outbreaks in yellow perch were only observed following system malfunction and nitrite accumulation (Bartelme et al., 2019). Similarly, Aeromonas levels were reported to be low in tilapia-lettuce systems with healthy fish (Schmautz et al., 2017).

Importantly, microbial populations can vary across different compartments of aquaponic systems—including fish tanks, drum filters, biofilters, and hydroponic beds—due to differences in oxygen levels, organic matter, and nutrient flow (Schmautz et al., 2017). As such, compartment-specific microbial monitoring is crucial for optimizing system performance and preventing pathogen outbreaks.

Given these complexities, a deeper understanding of cultivable bacteria in aquaponic systems is essential. Culture-based methods, despite the popularity of molecular tools, remain indispensable for isolating and identifying metabolically active bacterial species that directly influence system dynamics and organism health.

The aim of this study was to isolate and identify cultivable bacteria present in the water of an aquaponic system containing koi carp (*Cyprinus carpio* var. *koi*) and parsley (*Petroselinum crispum*), and to compare them with those found in a separate aquaculture tank system. The findings contribute to our understanding of microbial ecology in aquaponic and inform strategies for improving system stability and health management.

Figure 1.
The schematized representation of the locations where water samples are collected



MATERIALS AND METHODS

Fish, Aquaponic and Aquaculture System Setup

The experiment was conducted using a recirculating aquaponic system that incorporated parsley (*Petroselinum crispum*) and koi carp (*Cyprinus carpio* var. *koi*). The plant cultivation was carried out in three rectangular fiberglass grow beds (dimensions: 220 × 50 × 25 cm; volume: 200 L each). A separate aquaculture tank (AC) was also included to serve as a comparative system without plants (Figure1).

The aquaponic system used in this study was designed as a Deep Water Culture (DWC) system with three interconnected fiberglass grow beds (220 × 50 × 25 cm; 200 L each). Water circulation was maintained using a CATPOWER 662 submersible pump (flow rate: 1500 L/h) and continuous aeration was provided by an Aquaticlife PG-370 blower (airflow: 60 m³/h). Lighting was supplied by two 200W full-spectrum COB LED grow lights per tank, delivering an estimated PPFD of ~200–250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at plant level. Water temperature was maintained at 22 ± 1 °C, pH around 7.0, and dissolved oxygen between 6.5–7.5 mg/L. No external fertilizers or mineral supplements were added; nutrients were solely derived from fish waste. Parsley was not harvested during the experimental period.

The aquaponic fish tank (AP-FT), sump (AP-S), and aquaculture tank (AC) were all operated under similar environmental conditions. Throughout the 45-day experimental period, koi carp were fed once daily at 2% of their estimated body weight using commercial juvenile trout pellets (Ozpekler Yem, Türkiye), containing 45% crude protein, 20% crude fat, and 9% ash on a dry matter basis. Feed was administered manually and uneaten feed was removed after 15 minutes to avoid excess nutrient accumulation in the system. No fish were handled, measured, or subjected to invasive procedures during the study. Fish were not disturbed or manipulated in any way, and no biometric data (e.g., weight, length) were recorded.

Following a 45-day system operation period, water samples were collected from AP-FT, AP-S, and AC. Samples were taken in sterile, dark 500 mL glass bottles and immediately transported under refrigerated conditions for microbiological analysis.

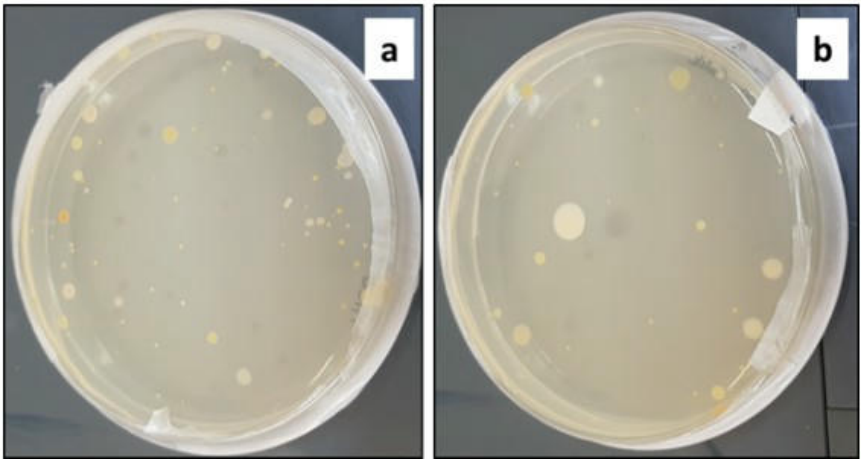
All experiments in this study were carried out in accordance with the "Regulation on the Welfare and Protection of Aquatic Vertebrates Used for Scientific Purpose" from the Republic of Turkey Ministry of Agriculture and Forestry (30751).

Microbiological Analysis of Water Samples

The collected water samples (AP-S, AP-FT, and AC) were subjected to serial dilution (1:9, 1:99, and 1:999) using sterile distilled water. From each dilution, 200 µL was spread-plated onto Tryptic Soy Agar (TSA) using sterile drigalski spatulas in three repetitions. Plates were incubated at 22 °C for 24–48 hours.

After incubation, colonies were examined based on morphology (color, shape, margin) and subsequently sub-cultured for pure isolation. Each isolate was subjected to a series of conventional bacteriological identification tests including:

Figure 2.
Bacterial colonies from AP-FT (a) and AP-S (b) sample on TSA after 48 h incubation (1:99 dilution)



-Morphological and physiological characterization: Gram staining, motility (hanging drop method), cytochrome oxidase, and catalase tests.

-Biochemical tests: Oxidation/fermentation (O/F), indole production, Methyl Red (MR), Voges-Proskauer (VP), nitrate reduction, citrate utilization, esculin hydrolysis, gelatin liquefaction, amylase production, urease, β-galactosidase (ONPG), and sugar fermentation tests including arabinose, maltose, mannitol, mannose, xylose, sucrose, inositol, rhamnose, galactose, lactose, sorbitol and usage amino acids such as arginine dihydrolase, ornithine decarboxylase, lysine decarboxylase (Koneman et al., 1992; Holt et al., 1994; Austin and Austin, 2012).

Identification of bacterial isolates was also confirmed using the API 20E rapid identification system for Gram negative bacteria (bioMérieux, France), and results were interpreted via the APIweb™ software platform (Buller, 2004)

RESULTS AND DISCUSSION

Across all samples, a total of ten cultivable bacterial genera were identified. These included *Bacillus* spp., *Aeromonas hydrophila*, *A. caviae*, *A. sobria*, *Shewanella putrefaciens*, *Flavobacterium* sp., *Pseudomonas* spp., *Micrococcus luteus*, Vibrio sp, *Staphylococcus* sp. and *Serratia* spp. This broad microbial diversity reflects the complex microbiome dynamics within aquaponic and aquaculture systems.

General Observations

Water samples collected from the aquaponic system—specifically from the sump (AP-S) and the fish tank (AP-FT)—as well as from the separate aquaculture tank (AC), yielde bacterial colonies with diverse morphologies after incubation on TSA medium. The samples from the aquaponic system (AP-S and AP-FT) exhibited nine distinct colony morphologies, while samples from the aquaculture tank displayed seven unique colony structure.

Colonies from each sample were characterized based on morphology, Gram staining, and biochemical profiling. 38 representative isolates from AP-S and AP-FT, and 30 isolates from AC, were subjected to detailed identification. The results indicated the presence of both Gram-positive and Gram-negative bacteria, with variability in biochemical traits across sampling points.

Bacterial Identification from Aquaponic System (AP-S and AP-FT)

After incubation, the bacterial colonies were divided into different types according to the colony characteristics of shape, size and color, and total 38 bacteria (n=38) were isolated. It was determined that there were no differences in bacterial species between AP-S and AP-FT. These isolates showed consistent colony morphologies between sump and tank samples, suggesting similar bacterial populations in different zones of the aquaponic system (Figure 2a, 2b).

Based on morphological, physiological, and biochemical analyses, *Bacillus* sp. (n=5), *Aeromonas hydrophila* (n=8), *Shewanella putrefaciens* (n=6), *Flavobacterium* sp. (n=4), *Serratia* spp. (n= 5), *Pseudomonas* spp. (n=4) and *Micrococcus luteus* (n=6) were identified in samples from the aquaponic system (AP-FT and AP-S). Table 1 and 2 summarizes the detailed biochemical profiles and differential traits used for identification.

It has been reported that the dominant bacterial species in aquaponic system water are *Aeromonas* spp., *Pseudomonas* spp. and *Staphylococcus* spp. (Chitmanat et al., 2015). In this study, it was noted that the dominant species among cultivable bacteria was *Aeromonas*, and *Staphylococcus* species detected in aquaculture water was not detected

Table 1.
Biochemical and morphological characteristics of bacterial isolates from aquaponics system water (AP-FT, S) and aquaculture water (AC)

Characteristic	*Bacillus* sp.		*Aeromonas hydrophila*			*Shewanella putrefaciens*			*Flavobacterium* sp.	
Sample origin	AP-FT (n=3)	AP-S (n=2)	AP-FT (n=4)	AP-S (n=4)	AC (n=5)	AP-FT (n=3)	AP-S (n=3)	AC (n=4)	AP-FT (n=2)	AP-S (n=2)
Gram stain	+	+	-	-	-	-	-	-	-	-
Motility	-	-	+	+	+	+	+	+	K	K
Cytochrome oxidase	+	+	+	+	+	+	+	+	+	+
Catalase	+	+	+	+	+	+	+	+	+	+
O/F test	F	F	F	F	F	-	-	-	O	O
Methyl Red (MR)	+	+	-	-	-	-	-	-	-	-
Voges-Proskauer (VP)	+	+	+	+	+	-	-	-	-	-
Indole production	-	-	+	+	+	-	-	-	-	-
Nitrate reduction	+	+	+	+	+	-	-	-	-	-
ONPG	-	-	+	+	+	-	-	-	-	-
O/129-150	ND	ND	R	R	R	ND	ND	ND	ND	ND
Citrate utilization	-	-	+	+	+	-	-	-	-	-
Urease	-	-	-	-	-	-	-	-	-	-
Triple Sugar Iron (TSI)	-	-	-	-	-	+	+	+	-	-
Gelatinase	+	+	+	+	+	+	+	+	-	-
Esculin hydrolysis	-	-	+	+	+	-	-	-	-	-
Starch hydrolysis	-	-	-	-	-	-	-	-	-	-
Arginine dihydrolase	+	+	+	+	+	-	-	-	-	-
Ornithine decarboxylase	-	-	-	-	-	+	+	+	-	-
Lysine decarboxylase	-	-	+	+	+	-	-	-	-	-
Lactose fermentation	-	-	-	-	-	-	-	-	-	-
Sucrose fermentation	-	-	+	+	+	-	-	-	-	-
Xylose fermentation	-	-	-	-	-	-	-	-	-	-
Rhamnose fermentation	-	-	-	-	-	-	-	-	-	-
Galactose fermentation	-	-	+	+	+	-	-	-	-	-
Mannitol fermentation	-	-	-	-	-	-	-	-	-	-
Mannose fermentation	-	-	+	+	+	-	-	-	-	-
Maltose fermentation	+	+	+	+	+	-	-	-	-	-
Arabinose fermentation	-	-	-	-	-	-	-	-	-	-
Sorbitol fermentation	-	-	-	-	-	-	-	-	-	-
Inositol fermentation	-	-	-	-	-	-	-	-	-	-
API 20E	200700416		724712457			050200441			000000402	

+: Positive reaction, –: Negative reaction, AP-FT: Fish tank water, AP-S: Sump water, K: Swarming motility, O/F: Oxidation/Fermentation test, R: Resistance, ND; Not detected

in aquaponic water. This suggests that a situation has developed within the system that will inhibit the existence of *Staphylococcus* species such as *S. aureus*, *S. epidermidis*, and *S. saprophyticus* that causes infection in humans and fish.

Table 2.
Biochemical and morphological characteristics of additional isolates from aquaponics system water (AP-FT, S) and aquaculture water (AC).

Characteristic	*M. luteus*		*Pseudomonas spp*			*Serratia* spp.		*Vibrio sp.*	*Staphylococcus sp.*
Sample origin	AP-FT (n=3)	AP-S (n=3)	AP-FT (n=2)	AP-S (n=2)	AC (n=4)	AP-FT (n=3)	AP-S (n=2)	AC (n=4)	AC (n=3)
Gram stain	+	+	-	-	-	-	-	-	+
Motility	-	-	+	+	+	+	+	+	-
Cytochrome oxidase	+	+	+	+	+	-	-	+	+
Catalase	+	+	+	+	+	+	+	+	+
O/F test	O	O	O	O	O	F	F	F	F
Methyl Red (MR)	+	+	-	-	-	V	V	-	ND
Voges-Proskauer (VP)	-	-	-	+	-	-	-	-	ND
Indole production	-	-	-	-	-	-	-	+	ND
Nitrate reduction	-	-	-	+	V	+	+	+	ND
β-galactosidase (ONPG)	-	-	-	-	-	+	+	+	ND
O/129-150	ND	ND	ND	ND	ND	ND	ND	S	ND
Citrate utilization	-	-	+	+	+	+	+	V	ND
Urease	+	+	-	-	-	v	v	-	ND
Triple Sugar Iron (TSI)	-	-	-	-	-	-	-	-	ND
Gelatinase	ND	ND	+	-	V	+	+	-	ND
Esculin hydrolysis	ND	ND	-	-	-	V	V	-	ND
Starch hydrolysis	-	-	-	-	-	-	-	+	ND
Arginine dihydrolase	-	+	+	+	+	-	-	-	ND
Ornithine decarboxylase	-	-	-	-	-	+	+	+	ND
Lysine decarboxylase	-	-	-	-	-	+	+	+	ND
Lactose fermentation	ND	ND	-	-	-	-	-	-	ND
Sucrose fermentation	+	-	-	+	-	+	+	+	ND
Xylose fermentation	ND	ND	+	+	+	v	v	-	ND
Rhamnose fermentation	-	-	-	-	-	v	v	-	ND
Galactose fermentation	-	-	ND	ND	+	+	+	ND	ND
Mannitol fermentation	-	-	+	+	+	+	+	+	ND
Mannose fermentation	-	-	+	+	+	+	+	+	ND
Maltose fermentation	-	-	+	+	+	+	+	+	ND
Arabinose fermentation	-	-	+	+	+	+	+	-	ND
Sorbitol fermentation	-	-	-	+	+	+	+	-	ND
Inositol fermentation	-	-	-	-	-	+	+	-	ND
API 20E	001402402		220706643			531676257		534412757	-

+: Positive reaction, –: Negative reaction, AP-FT: Fish tank water, AP-S : Sump water, O/F: Oxidation/Fermentation test, V: variable reaction, t: tetrads, S : sensitive, nd: not detected

Micrococcus spp. are widely distributed and are a common bacterial species in terrestrial and aquatic ecosystems (Dinev et al., 2023). *Micrococcus luteus*, belonging to the *Micrococcus* genus, has been reported to cause infection as an opportunistic pathogen (Pękala et al., 2018; Akayli et al., 2020) and to be used in fish health as a probiotic (Abd El-

Rhman et al., 2009; Akaylı et al., 2016). The isolation of this bacterium in the aquaponic system has been reported in previous studies (Chitmanat et al., 2015). In this study, it was similarly isolated from the aquaponic system water, but not from the aquaculture water.

The identification of *Shewanella putrefaciens* and *Flavobacterium* spp. in the aquaponic system aligns with previous literature. *S. putrefaciens* is a facultative anaerobic bacterium frequently isolated from aquatic environments and has been implicated in disease outbreaks in rainbow trout and European sea bass (Korun et al., 2009). While *Flavobacterium* species is a component of normal aquatic microbiota, certain species within this genus may act as opportunistic pathogens under stress conditions.

Interestingly, tanks where *Bacillus* sp. were detected exhibited enhanced parsley growth and healthy root development. While direct causal relationships remain to be confirmed, previous studies suggest that *Bacillus* species can improve nutrient uptake, promote root elongation, and enhance overall plant vigor—potentially linking microbial balance to improved plant performance (Tsotetsi et al., 2022).

Water quality parameters—particularly neutral pH (~7.0), sufficient dissolved oxygen, and increased nitrate levels observed at the end of the grow-out period—likely supported a stable microbial community. These conditions are optimal for nitrifying bacteria as well as beneficial taxa such as *Bacillus* spp., potentially suppressing the proliferation of opportunistic pathogens like *A. sobria* and *A. caviae*.

Beneficial bacteria for plants form biofilms on the roots. The dominance of *Pseudomonas* species in aquaponic system water indicates that it is an important species in terms of biocontrol (Sirakov et al., 2016). However, for aquaponic systems, these types of bacteria need to be evaluated in terms of plant, human and fish health. In particular, there are reports that many *Pseudomonas* species cause diseases in both fish (Urku, 2021; Ürkü et al., 2024b) and plants (Höfte and Vos, 2006).

As a result of the development of the microflora of an aquaponic system, an environment that suppresses microbial pathogens is formed thanks to natural antibiotic compounds secreted by beneficial microorganisms-probiotics (Dinev et al., 2023). Therefore, application of biological control with antagonistic microorganisms against pathogens is a promising alternative. It has been reported that the genera *Pseudomonas* and *Bacillus*, which are among the most important groups of Rhizobacteria, are used as plant biocontrol agents for different crops (Suslow et al. 1982; Schippers et al., 1987). It has been reported that using a strain isolated from the system that provides the characteristics of being a biological agent will contribute to increasing fish growth and plant benefit and increase the amount of production (Sirakov et al., 2016; Yousuf et al., 2023).

Bacterial Identification from Aquaculture Tank (AC)

Gram-negative rod-shaped bacteria dominated in aquaculture tank (AC). Five cultivable bacterial genera were identified from AC water sample (Table 1,2). *A. hydrophila* (n=5), *A. caviae* (n=5), *A. sobria* (n=5), *Shewanella putrefaciens* (n=4), *Vibrio* sp. (n=4), *Staphylococcus* sp. (n=3) and *Pseudomonas* spp.(n=4) were the common bacteria with *Aeromonas* species being the most dominant.

The differentiation between *A. hydrophila, A. caviae,* and *A. sobria* was confirmed through biochemical tests according to Buller (2004) and API-complementary tests. Additionally, API 20E profile numbers of the isolates are given as detailed in Table 3. Notably, *A. caviae* and *A. sobria* were not detected in the aquaponic system, but were exclusive to the aquaculture tank.

A. hydrophila is facultatively anaerobic bacterium that distressed fish with septicemia and causes a disease known as Motile Aeromonas Septicemia (MAS), which affects the aquatic environment. *Aeromonas* species, bacterial species of zoonotic importance, can be commonly found in a variety of estuaries, seaweed, sea grass, used water, drinking water and also food (Austin & Austin, 2012; Semwal et al., 2023).

Table 3.
Biochemical traits used for distinguishing A. hydrophila, A. caviae, and A. sobria from aquaculture tank (AC) water samples

Characteristic	*A. hydrophila* (n=5)	*A. caviae* (n=5)	*A. sobria* (n=5)
Lysine decarboxylase	+	-	+
Voges-Proskauer (VP)	+	-	-
Arabinose fermentation	+	+	-
Triple Sugar Iron (TSI)	-	-	+
Esculin hydrolysis	+	+	-
API profil number	724712457	324612657	764612457

Aquatic microorganisms not only affect the water quality but are also associated with the fish physiological status, diseases and postharvest quality (Al-Harbi and Uddin, 2005). Therefore, the bacterial flora reflects the aquatic environment (Shewan and Hobbs 1967). It has been reported that the dominant bacterial species in carp aquaculture water are *Aeromonas*

spp. and *Shewanella putrefaciens* (Al-Harbi and Uddin, 2008). This composition is considered to be consistent with both the natural intestinal flora of the fish and the surrounding water environment. In this study, *Aeromonas* spp. (*A. hydrophila, A. caviae*, and *A. sobria*) detected with high prevalence were accepted as the dominant species in standalone aquaculture tank.

Notably, *A. caviae* and *A. sobria*—despite being present in the aquaculture tank—were absent from the aquaponic system. Instead, only the aquaponic water samples yielded *Bacillus sp.*, which are Gram-positive, spore-forming bacteria known for their antimicrobial metabolite production and potential probiotic roles. Several strains of *Bacillus* have been reported to inhibit pathogenic bacteria and enhance host immunity, supporting their value in biological disease control (Keysami et al., 2007; Aly et al., 2008). This suggests a possible competitive exclusion or inhibitory mechanism mediated by *Bacillus* sp.

API 20E

Although API 20E test results provided identifications for most isolates (e.g., *A. hydrophila* – 98.8%, *S. putrefaciens* – 99.9%), the API system yielded conflicting results for some Gram-positive isolates. Specifically, *Bacillus* sp., identified as Gram-positive rods morphologically, were misclassified as *A. salmonicida* (93.9%), a known Gram-negative species. In addition, according to API 20E results, it was determined that the bacteria causing gliding movement (n=4) was *Chryseobacterium indologenes* (37%). Additionally, *Vibrio* sp. isolated from aquaculture water was identified as *Vibrio parahaemolyticus* (77.4%) with API profile number 534412757. These inconsistencies underscore the limitations of using API kits—designed primarily for clinical samples—in aquatic environmental studies.

The traditional bacteriological method, which includes morphological, physiological and biochemical tests, is known to be the gold standard for identification of bacterial species. However, it has negative features in terms of time, cost and workload (Austin, 2019). API kits are the most used for the identification of fish pathogenic bacteria (Urku et al., 2024a). A limitation was identified in the accurate identification of environmental isolates of the API kit used in this study. Similarly, Chitmanat et al. (2015) reported that the API 20E strip kit was inadequate in identifying bacteria such as *Aeromonas hydrophila, Pseudomonas fluorescens, Plesiomonas shigelloides, Escherichia coli, Acinetobacter baumannii, Salmonella* sp., *Staphylococcus* sp., and *Micrococcus* sp. isolated from aquaponic systems.

Overall, the microbial diversity observed in the aquaponic system was different from that in the isolated aquaculture tank. This highlights the ecological complexity of integrated systems and suggests that the combined biological activity of plants, fish, and microbial communities may contribute to a more balanced and possibly protective microbial environment.

CONCLUSION

This study demonstrates the presence and diversity of cultivable bacteria in aquaponic and aquaculture water systems and underlines their potential impact on system health and sustainability. The identification of opportunistic pathogens such as *A. hydrophila, A. caviae,* and *A. sobria* in the aquaculture tank emphasizes the risk of bacterial infections in fish-only systems. In contrast, the aquaponic system, which included both fish and plants, showed a distinct bacterial profile that notably included *Bacillus* sp.- a genus widely associated with probiotic properties in aquaculture.

The absence of *A. caviae* and *A. sobria* in the aquaponic system, along with the presence of *Bacillus* sp., suggests a possible antagonistic or inhibitory effect that may contribute to pathogen suppression. These findings support the hypothesis that aquaponic systems may offer inherent microbial benefits through ecological balance and biological competition. In our next study, we plan to investigate the probiotic properties of *Bacillus* sp. strains as well as its effects against *A. caviae* and *A. sobria.*

In conclusion, monitoring and managing the bacterial communities within aquaponic systems is essential for promoting the health of aquatic animals and plants. Further research is recommended to explore the functional roles of beneficial bacteria and their potential use as natural biocontrol agents in integrated aquaponic environments.

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