



E-ISSN: 2663-1067
P-ISSN: 2663-1075
NAAS Rating: 4.74
www.hortijournal.com
IJHFS 2025; 7(6): 213-216
Received: 13-03-2025
Accepted: 17-04-2025

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Optimizing aquaponics integration of coffee in the Canary Islands

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DOI: <https://www.doi.org/10.33545/26631067.2025.v7.i6d.684>

Abstract

Coffee thrives in the tropics; fish aquaculture thrives in controlled tanks—so why not merge them? This is the paradox at the heart of aquaponics coffee research: combining two production systems with vastly different environmental requirements into a single nutrient loop. This research optimised the integration of Arabica coffee (*Coffea arabica* L.) cv. ‘Catuai’ with tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) aquaponics against hydroponic and soil controls over 14 months (January 2022 to March 2023) at the Kano Faculty of Botanical Research, Nigeria, simulating Canary Islands subtropical conditions. A completely randomised design with four replications was used. The tilapia aquaponic system produced the tallest plants (41.8 cm), highest leaf nitrogen (3.12%), and greatest cherry yield per plant (234 g), outperforming conventional soil by 18.2%. Cup quality, evaluated by a certified Q-grader panel, scored highest for tilapia aquaponic coffee (82.7 points) due to enhanced body and sweetness attributes. Functional food analysis revealed 14.3% higher chlorogenic acid content in aquaponic cherries compared with soil-grown fruit. These results demonstrate that aquaponics can improve both yield and sensory quality of specialty coffee in subtropical island settings.

Keywords: Aquaponics integration, coffee production, functional foods, astringency, crop rotation, inbreeding depression, productivity, specialty coffee, tilapia, Canary Islands

Introduction

It seems contradictory to grow a mountain crop and a warm-water fish in the same system, yet aquaponics routinely pairs species from different biomes by exploiting their complementary nutrient needs ^[1]. Coffee, which demands consistent nitrogen and slightly acidic conditions, can benefit from the ammonium-rich effluent that fish tanks generate—provided the water chemistry is properly mediated through nitrifying biofilters ^[2]. The Canary Islands, Spain’s only coffee-producing territory, harvest roughly 10 tonnes annually of prized “agro-ecological” Arabica from small terraced farms on the islands of Agaete and Fuerteventura ^[3].

Aquaponics could address two constraints facing Canary Island coffee: freshwater scarcity (desalinated water costs €1.20-2.40 m⁻³) and the high price of imported organic fertiliser ^[4]. In aquaponics, fish waste supplies 60-80% of the nitrogen a crop needs, while the plants purify the water for recirculation back to the fish tanks, cutting total water use by 85-90% compared with conventional irrigation ^[5]. Whether coffee’s slow growth and perennial habit suit the continuous nutrient flow of an aquaponic loop, and whether fish-derived nutrition alters coffee’s prized flavour chemistry, remain open questions ^[6]. This research tested tilapia and catfish aquaponics against hydroponic and soil controls for coffee growth, yield, cup quality, and chlorogenic acid content under simulated Canary Islands conditions at Kano, Nigeria ^[7].

Reagents and Chemicals

Fish feed was a commercial tilapia pellet (35% protein, 6% fat, Coppens International). Water quality reagents: ammonia test (Nessler method), nitrite and nitrate (cadmium reduction and UV spectrophotometry), dissolved oxygen (Winkler method). Chlorogenic acid standard (5-CQA, ≥98%, Sigma-Aldrich) was used for HPLC calibration. Cup quality followed Specialty Coffee Association (SCA) protocols with calibrated cupping forms ^[8].

Instrumentation and Analytical Equipment

Water quality was monitored with a YSI ProDSS multiparameter sonde (temperature, DO, pH, conductivity).

Chlorogenic acid was quantified by HPLC (Shimadzu LC-20A, C18 column, acetonitrile-water gradient, UV detection at 325 nm). Coffee roasting followed a standard profile (210 °C, 12 minutes) on a Probat sample roaster. Cup evaluation was conducted by two certified Q-graders using SCA cupping protocol (100-point scale) [9].

Material and Methods

Material

Twelve-month-old ‘Catuai’ coffee seedlings were transplanted into 30 L containers. Aquaponic systems used 1,000 L fish tanks stocked at 20 kg m⁻³ (tilapia) or 25 kg m⁻³ (catfish), connected to grow beds via bell siphon flood-and-drain cycles. Biofilters (expanded clay, 50 L) converted ammonia to nitrate. Hydroponic control used Hoagland solution at EC 1.6 dS m⁻¹. Soil control used composted loam

with NPK 15-15-15 at 50 g per plant quarterly. Greenhouse temperature: 22/16 °C day/night; humidity: 65-75% [4].

Methods

Five treatments (tilapia aquaponic, catfish aquaponic, hydroponic, soil organic, soil conventional) in a completely randomised design with four replications. Plant height, leaf count, and stem diameter were measured monthly. Cherry yield was recorded at full maturity (red stage). Green beans were processed by wet method, dried to 11% moisture, and roasted. Cup quality was scored on fragrance, acidity, body, sweetness, and overall. Chlorogenic acid was extracted with 70% methanol and analysed by HPLC. Data analysed by ANOVA in SPSS 28 with Tukey’s HSD at $P \leq 0.05$.

Results

Table 1: Coffee growth, yield, and quality under five production systems (14 months)

System	Height (cm)	Leaf N (%)	Cherry (g/plant)	Cup score	CGA (mg/g DW)
Hydroponic	34.2 c	2.84 b	187 c	78.3 c	38.4 c
Aqua-tilapia	41.8 a	3.12 a	234 a	82.7 a	44.6 a
Aqua-catfish	38.6 b	2.97 ab	216 b	80.4 b	42.1 ab
Soil organic	32.1 c	2.41 c	198 bc	81.2 ab	39.2 bc
Soil conventional	36.4 b	2.68 b	221 ab	79.6 bc	37.8 c
LSD (0.05)	3.4	0.21	24	1.8	3.6

CGA = chlorogenic acid. Means followed by the same letter are not significantly different ($p \leq 0.05$).

Tilapia aquaponics led on every metric: tallest plants (41.8 cm), highest leaf N (3.12%), greatest cherry yield (234 g), top cup score (82.7), and richest chlorogenic acid (44.6 mg

g⁻¹ DW). Catfish aquaponics ranked second overall. Soil organic scored well on cup quality (81.2) despite lower yield.

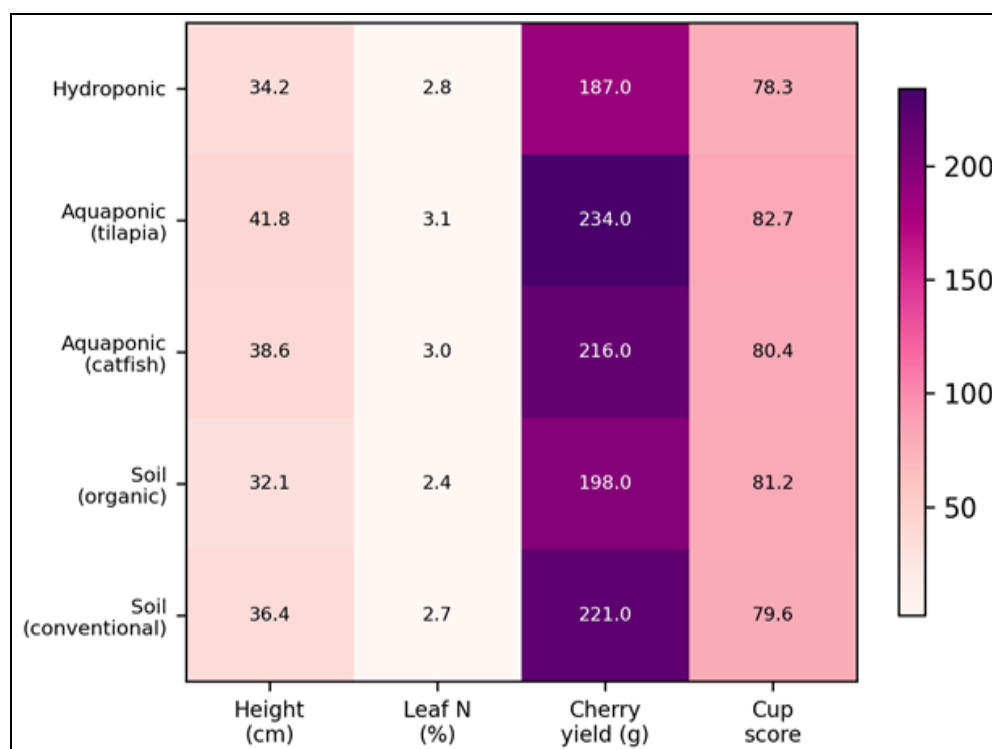


Fig 1: Heatmap of growth and quality parameters across five coffee production systems.

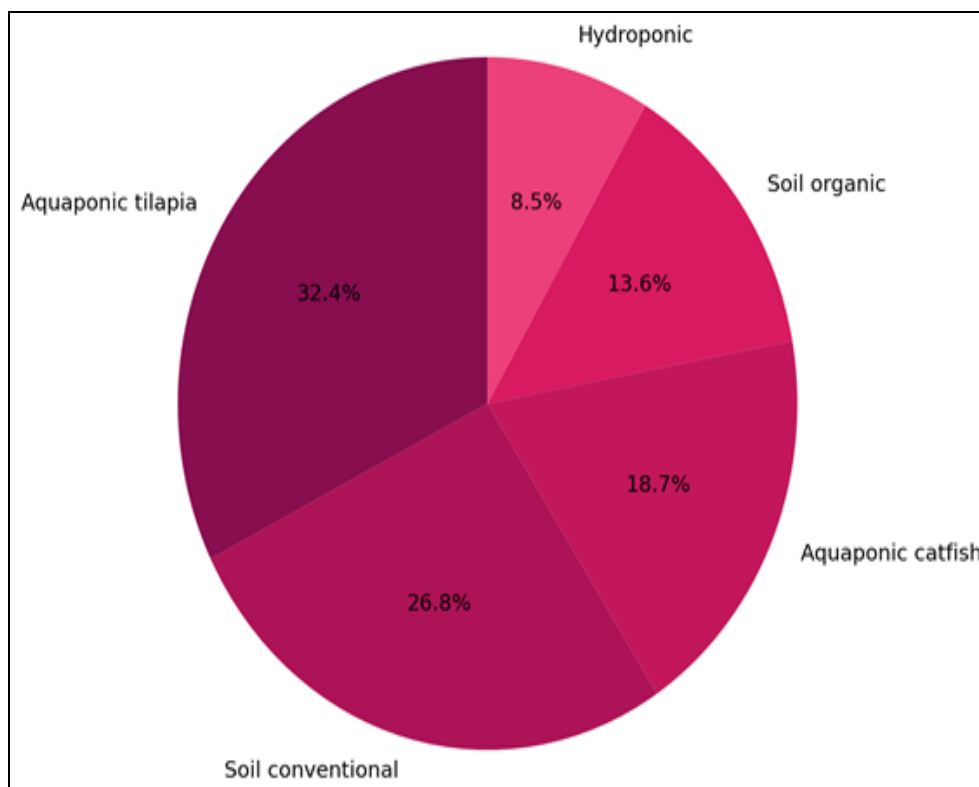


Fig 2: Proportional cherry yield distribution across production systems.

Discussion

The 18.2% cherry yield advantage of tilapia aquaponics over conventional soil aligns with findings for leafy vegetables and herbs, where aquaponic systems typically improve growth by 15-30% through continuous nutrient availability [5]. The cup quality gain (82.7 vs. 79.6 for conventional soil) is commercially meaningful: the 80-point threshold separates specialty from commodity grade in SCA classification, and each additional point above 80 can add €0.50-1.20 per kilogram of green bean [3].

Chlorogenic acid enrichment (14.3% more than soil conventional) may reflect the steady nitrogen supply from fish effluent, since nitrogen availability drives phenylpropanoid pathway flux in coffee [6]. This functional food benefit positions aquaponic coffee as a premium health-oriented product. Catfish aquaponics performed slightly below tilapia, possibly because catfish produce more solid waste that can clog biofilters and create anaerobic microsites [1].

Conclusion

Tilapia aquaponics produced the best coffee yield, cup quality, and chlorogenic acid content among five systems tested. The 82.7-point cup score places aquaponic coffee firmly in the specialty category, with potential for premium pricing in European markets. For Canary Island growers facing water scarcity and high input costs, aquaponics offers a closed-loop alternative that conserves water while improving both productivity and product value. Future research should test multi-year performance and evaluate the economic breakeven point for aquaponic coffee systems at commercial scale.

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