Colegio de Postgraduados

Aquaponics production of white radish microgreens (*Raphanus sativus* var. Daikon) as an option for Tilapia Resource-limited aquaculture farmers

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ABSTRACT

Objetive: to evaluate the production of white radish microgreens (*Raphanus sativus* var. Daikon) in on-demand coupled aquaponics systems without climate control.

Design/Methodology/Approach: three treatments with three replicates each were established production of white radish microgreens with no substrate. In treatment H, a 50% commercial hydroponic solution was used, in treatment D distilled water was used, and in treatment T we used water derived from the tilapia culture.

Results: the production of radish microgreens in semi-open systems without climatic control was similar in the treatments with water derived from tilapia culture and the 50% hydroponic solution.

Limitations/Implications of the study: it is necessary to test this type of microgreens culture with a greater number of species and under different conditions, as well as testing restrictions or sanitary remediation. The production obtained presented significant biological contamination issues, so radish microgreens were not suitable for human consumption.

Findings/Conclusions: it was possible to use the water from a tilapia farm in aquaponics systems coupled on-demand for the hydroponic production of white radish microgreens. However, there was no difference between aquaponics and the production obtained with hydroponic fertilizers.

Keywords: functional-foods production, circular economy, AREL — Resource-limited aquaculture-farmers.

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INTRODUCTION

Aquaponics is a food production technology, growing interest in recent years. In this technology, aquaculture and hydroponics are symbolically integrated, so fish and plants are grown on shared resources (Tokunaga *et al.*, 2015). In economic terms for some cases of aquaponics production, the plant component is usually responsible for the majority of income (Quagrainie *et al.*, 2018). Because in these on-demand coupled systems plant yield is measured by unit (or kg), and it depends on plant density (plants per m^2), production period (weeks), and unit value ($, currency), Bailey and Ferrarezi (2017) proposed using "$ m^{-2} per week" as a unit that groups those factors together and provides a common

Photo by Jessica Lewis at Pexels

point for comparison between two very different cultures. This becomes useful because an alternative crop with high economic value and short cultivation time can be a reasonable option for the production of plants in aquaponics systems.

Microgreens are short-cycle vegetables (7 to 21 days) that are harvested without roots when cotyledon leaves are fully developed, still turgid, and the first true leaves are present (Lee *et al.*, 2004; Kyriacou *et al.*, 2016). Due to their phytochemical compound content, these vegetables are considered functional foods (Kyriacou *et al.*, 2019), which are foods and food components that can provide benefits beyond basic nutrition (IFIC, 2011). Therefore, microgreens culture can be a good option for non-commercial and small-scale aquaponics, as it is the case with Resource-limited Aquaculture farmers —AREL.

Because microgreens are plants in their early life stage, their nutrient needs are lower because the seed content is the nutrient needed for that stage. This can be explored in aquaponics systems, as it has been suggested that plants with lower nutritional requirements are better suited for cultivation within them (Kloas *et al.*, 2015; Yep y Zheng, 2019).

According with reported by García-Sifuentes *et al.* (2024), radish production in aquaponics systems is a topic of interest for micro- and small-scale tilapia producers in the states of Guerrero and Oaxaca. The production of radish microgreens in decoupled aquaponics systems that use water from tilapia production systems may represent a first approach to radish production for these producers. In this case, without the need to implement complete coupled aquaponics systems, aiming to produce functional foods with high nutritional and economic values. The objective of the study was to evaluate the aquaponics production of white radish microgreens as a productive alternative.

MATERIALS AND METHODS

An experiment was established for the aquaponics production of white radish microgreens. Three treatments were established, each one with three replicates. In each treatment the solution for the growth of the microgreens was different. Treatment (D) was distilled water; (H) was a 50% commercial hydroponic solution, and (T) was water derived from a semi-intensive open-air tilapia culture (Table 1).

For treatment T, a share of the aquaculture water (10 L) was taken and after allowing the algae to settle for 48 h in refrigeration, only the supernatant was used without the microalgae sediments. The three solutions remained refrigerated at 4 °C until they were used.

The hydroponics solution was prepared with distilled water as base and a commercial hydroponic fertilizer; with a calibrated composition to obtain 10% N, 8% P, 18% K,

Table 1. pH and electrical conductivity values (mS cm^{-2}) in treatments D: distilled water, H: 50% hydroponic solution and T: water from tilapia culture.

Treatment	pH	Electrical conductivity (mS cm^{-2})	N-NO_3 (mg L^{-1})
H	6.75	0.88	75 (mg L^{-1}, N)
D	8.20	0.01	0.12
T	8.43	1.15	4.34

mS cm^{-2}: SI equivalent unit, milisiemens per square centimeter.

Table 2. Concentration (mg L^{-1}) of macro- and microelements of the hydroponic solution at 50% concentration, according to the guaranteed composition of the commercial fertilizer.

Macroelement	Concentration (mg L^{-1})	Microelement	Concentration (mg L^{-1})
N	75.00	Fe	0.75
P	60.00	B	0.015
K	135.00	Zn	0.075
S	18.75	Cu	0.0015
Mg	13.50	Mn	0.015
Ca	44.25		

2.50% S, 1.80% Mg, 5.90% Ca, 0.10% Fe, 0.002% B, 0.010% Zn, 0.0002% Cu and 0.002% Mn. From this, a dilution to 50% of the concentration indicated for edible vegetables was prepared (Table 2).

Trial condition

For microgreens culture we used hydroponics trays, (Bisphenol A) BPA-free, with measurements of 0.33×0.25×0.03 (length×width×depth, cm). The trays consist of three parts, the first one (bottom) is used to contain the solution for growth; the second (middle) is a grid on which the seeds are placed to allow the roots to develop towards the lower tray, where the solution for growth is contained.

The third (upper) part is a temporary tray that is placed on the seeds during the first days of growth, in order to generate pressure on them and facilitate the roots to grow into the right direction; otherwise they are not directed towards the lower tray. These trays can be used with or without substrate in the middle part with grid; for this trial, only the grid was used, with no substrate (Figure 1).

Microgreens production was implemented in two stages, both without climatic control, in semi-open systems. During the experimental period, in both stages, the maximum and minimum ambient temperature and humidity were recorded with a thermohygrometer (Thermopro™ TP359S, Canada).

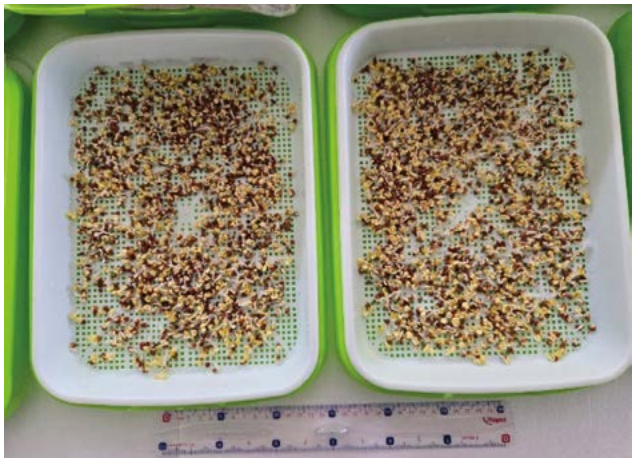

Figure 1. Hydroponics trays for microgreens production with no substrate.

The first stage, with a duration of 5 days, corresponds to germination and the blackout (dark phase). This was done in the growth area of fish larvae and fry, which is an open and roofed area. During that stage, temperatures were 25.5 °C average minimum and 34 °C average maximum; while the minimum relative humidity was 47% and the maximum, 93%.

The second stage, which corresponds to the photosynthesis phase, was done in a shade house with anti-aphid mesh walls and monofilament mesh shade roof, for 30% radiation reduction with UV light stabilizer (Textiles Agrícolas, Mexico). During this stage, temperatures were 25.5 °C average minimum and 46.7 °C average maximum. The extremes of relative humidity were 44% minimum and 88% maximum.

Seed pretreatment

Special Daikon (white radish) seeds were acquired for microgreens production (De mi Siembra, Hidalgo, Mexico). For each tray, 15 g of seeds were weighed, which corresponds to a density of 176 g m^{-2} as it is recommended by specialized producers (Johnny's Selected Seeds, Maine, USA) of seeds for microgreens. The seeds were hydrated for 6 hours in distilled water and then distributed in each of the growing trays. After their distribution on each tray they were covered with the upper tray and a weight of 3 kg was placed on them to exert pressure on them and force the roots to go to the lower part of the tray.

For 3 days the seeds were sprinkled with distilled water twice a day. On days 4 and 5, the dark phase took place, which is a period in which first sprouts remain without light to force the elongation of the stems. On the fourth day, the weight was removed and after randomly assigning the treatments, 120 mL of solution corresponding to each treatment was added to the lower tray. On day 5, 50 mL of extra solution were added to each of the replicates according to their treatment.

From day-6 to day-9, the microgreens were installed in the shade house and the amount of water added daily was recorded. On ninth day, when the first true leaves began to sprout, the experiment was completed. The microgreens were harvested and for each treatment, fresh weight and average dry weight of microgreens (g), and fresh weight and average dry weight of roots (g) were recorded. The length of 10 microgreens per replicate was randomly measured to obtain the average length per treatment (mm). With the data obtained, the productivity (g m^{-2}) of radish microgreens was calculated, also was the seed yield (g g^{-1}), microgreens sprouted per seed.

Statistical analyses

A completely randomized experimental design was used. For all variables, after checking the assumptions of normality and homoscedasticity in the results, data were analyzed with analysis of variance and the means contrasted with the Tukey's test ($p \leq 0.05$). STATISTICA® 12.0 (StatSoft Inc., 2013) was used for the analyses.

RESULTS AND DISCUSSION

On day six, when the microgreens were installed in the shade house, insect larvae were detected in some of the replicates. The solution was removed from all of them and 120

mL of the solution corresponding to each treatment (distilled water, hydroponic solution at 50% concentration, or water derived from tilapia culture) were added. This process had to be carried out daily, because from day seven onwards insect larvae were present in all the trays and the solutions presented brown color and bad smell. However, we decided to continue with the experiment to record the effects of the treatments, and to test if the presence of larvae would cause the death of the white radish microgreens.

Fresh weight, dry weight, overall productivity of the microgreens, and seed yield of white radish were similar ($p \leq 0.05$) in the H and T treatments and lower in D (Table 3, Figure 2).

The microgreens produced in the treatments with hydroponic solution at 50% concentration, and those in the water derived from the tilapia culture were similar in size and apparent vigor, while in treatment D the production was lower. This is consistent with what was reported by Murphy *et al.* (2010) and Murphy and Pill (2010), who indicated that a higher concentration of nitrates improves shoot yield.

However, even though the concentrations of N-NO_3 were different in the solutions of the H and T treatments, the productive variables evaluated were statistically similar. It has been reported that microgreens production may be higher in aquaponics systems than in

Table 3. White radish microgreens produced with treatments, D: distilled water, H: commercial hydroponics solution at 50% concentration, and T: water derived from Tilapia culture.

Variable	Treatment		
	D	H	T
Microgreens fresh weight (g)	8.77±1.23 [a]	44.84±16.81 [b]	43.65±11.63 [b]
Discarded fresh weight (g)	83.87±6.92 [a]	83.72±15.95 [a]	88.57±7.01 [a]
Microgreens dry weight (g)	0.87±0.27 [a]	3.94±1.29 [b]	4.47±1.39 [b]
Discarded dry weight (g)	10.23±0.34 [a]	8.52±1.04 [a]	8.85±1.46 [a]
Shoots height (mm)	59.36±6.34 [a]	71.66±1.43 [a]	71.09±6.37 [a]
Productivity (g m^{-2})	106.30±14.89 [a]	543.56±203.72 [b]	529.09±140.91 [b]
Seed yield (g g^{-1}, microgreens per seed)	0.58±0.08 [a]	2.99±1.12 [b]	2.91±0.78 [b]

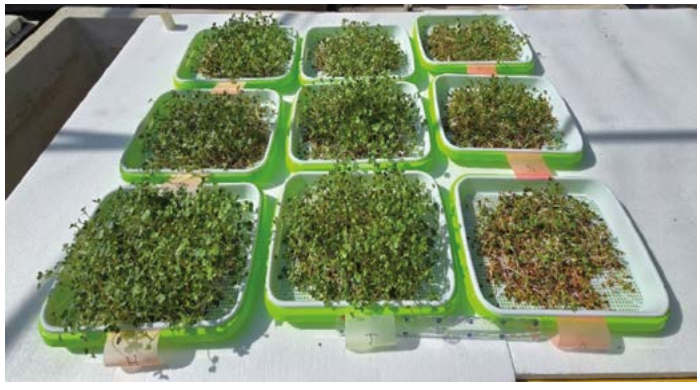

Figure 2. White radish microgreens produced with H, T and D treatments. In columns (from left to right), H: commercial hydroponics solution at 50% concentration, T: water derived from tilapia farming, and D: distilled water.

traditional systems (Guerreiro *et al.*, 2024), but it was not demonstrated in this study. In addition, insect larvae were present in the three treatments; For this reason, it is considered that the use of any tested solution did not represent a greater risk or an advantage in regard to the proliferation of insect larvae.

For AREL producers interested in reusing water from aquaculture farming, the production of microgreens of different species (in this case radish) in aquaponics systems coupled on-demand may represent a viable option to produce functional foods, either for their own consumption or for sale. However, this type of farming requires cost-efficient investment and know-how, because it uses water from aquaculture farming, of which only replacement water can be used. Moreover, the structure for coupled farming can be built with local materials.

These characteristics make coupled systems be seen as ideal for AREL producers, who generally have limited access to financing, formal education and technical training. It is these producers that a low-cost aquaponics system can benefit (Adeleke *et al.*, 2022; Flores Nava *et al.*, 2013). The sale of microgreens could support food security for AREL tilapia farmers. However, an additional economic benefit would depend on the presence or developing of appropriate markets.

The presence of insect larvae during the production of radish microgreens made it impossible to use them for human consumption. Tests are needed to prevent microgreens contamination. In addition, it is advisable to perform tests with a greater number of plant species, as well as to characterize the quality and safety of those microgreens to be used as food for human consumption.

CONCLUSIONS

The production of radish microgreens in aquaponics systems coupled on-demand was similar to that obtained with the 50% commercial hydroponic solution, but higher than that obtained with distilled water. A productive alternative cannot be generalized due to the conditions of this test. More research and sanitary control are needed.

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