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The investigation of the effect of different protein content in fish food on the average weight of Lactuca Sativa under SRAPS aquaponics condition

Dingyuan Liu

Dulwich College Beijing, Beijing, 101312, China

lawrence.liu24@stu.dulwich.org

Abstract. Commercial aquaponics for crop production is a sustainable agricultural technique that functions based on the merging of three biological systems: crops, fish, and nitrifying bacteria. However, finding the right balance and factors needed for the three biological systems to achieve high and efficient crop productivity that may satisfy commercial needs still requires further study, especially aquaponics which combines aquaculture and hydroponics in a single cycle, namely the SRAPS system. In this paper, three trials of the growth of *Lactuca sativa* were done based on SRAPS conditions. The results demonstrated a visible difference between the two sets of common lettuce. The set given fish food with a high-protein content showed a larger average weight of common lettuce at harvest time compared to that of the set given a low-protein content.

Keywords: commercial aquaponics, single recirculating aquaponics system, sustainable agriculture, protein content, nutrient film technique

1. Introduction

Aquaponics is a sustainable agricultural system based on aquaculture for the propagation and harvesting of aquatic animal products, and hydroponics for propagation and harvesting using water-based media. Through the nitrification process carried out by nitrifying bacteria, the nutrient-rich fish waste product is converted by microorganisms into nutrition available to plants and pumped directly to the hydroponics unit. In the 21st century, environmental issues caused by conventional agriculture required the development of sustainable agriculture[1,2]. Aquaponics has demonstrated a possibility for food production and decreased water use in urban contexts[3,4]. In order to meet the demand of the current population, sustainable agriculture in an intensive commercial form has become the main aim. While being able to reach the demands of the population, traditional agriculture such as aquaculture may influence the environment negatively with highly nutrient-loaded water or chemical fertilizers run-off that may cause severe damage to water bodies[5]. Therefore, Recirculating Aquaculture System (RAS) and high-yield hydroponics are introduced as approaches to improve traditional agricultural methods. However, these approaches still require the deposition of wastewater into the environment after circulation, thus causing damage[6]. Therefore, aquaponics was designed to recycle the wastewater produced by the utilizing wastewater deposited as a source of nutrition for crops.

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SRAPS aquaponics system may face multiple challenges and disadvantages. Goddek et al. suggested that SRAPS has low productivity and is not yet utilized for commercial agriculture [6]. The three biological systems are all under sub-optimum conditions considering pH values (the optimum pH for nutrient availability under the aquaponics condition is 5.5-6.5, and the optimal pH range for fish and bacteria growth is 7.0-9.0.) [7,8]. To guarantee the production of nutrition, the fish must be kept under the pH level of 7.0-9.0 for proper digestion of food. However, this would limit the nutritional availability of crops and therefore artificial adjustments are needed [6,8,9,10]. In SRAPS, a single cycle requires a pH of 6.8-7.0.

This investigation aims to explore the optimal method to improve productivity and efficiency of crop growth for SRAPS aquaponics. It is hypothesized that better growth would occur due to a higher amount of nutritional supply received by the aquaculture component. Two sets of SRAPS given fish food with different protein content are compared.

2. Materials and methods

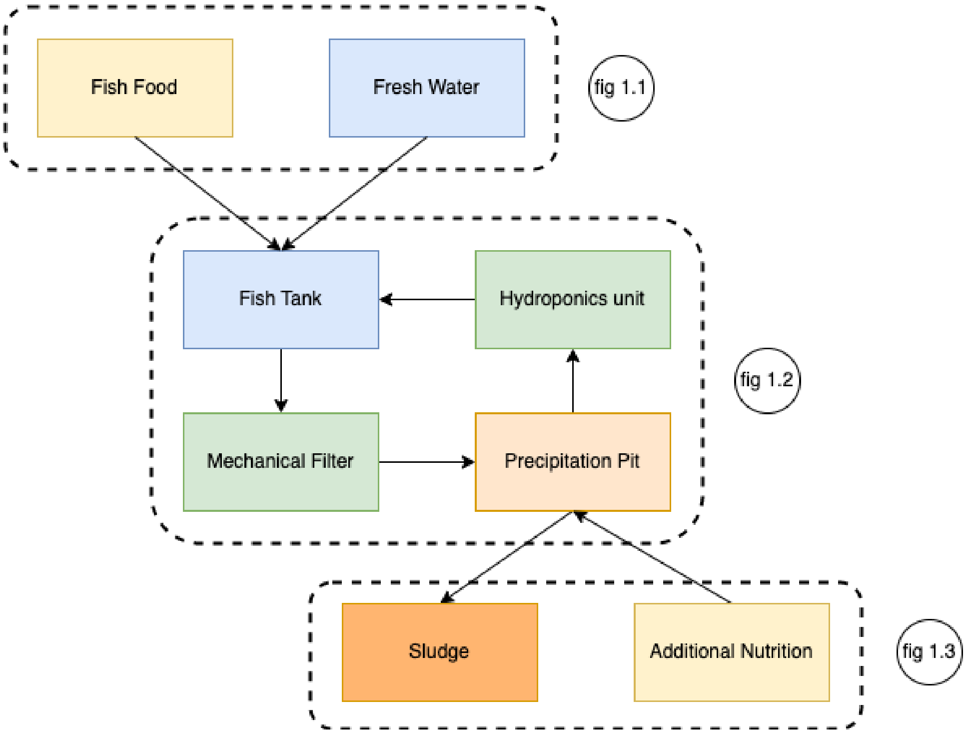

Figure.1 Schematic diagram of SRAPS system components and functions.

The diagram is split into three major sections: fig 1.1 aquaculture input, fig 1.2 the main cycle, fig 1.3 precipitation pit input and precipitation pit output.

2.1. Overview of the SRAPS system

In fig 1.1, freshwater is added and fish food is given. The water in the fish tank flows through a mechanical filter for the removal of solid materials present in the water produced in the fish tank. The water is then transported to a precipitation pit (fig 1.3), where it is temporarily near a stationary flow. Sludge is formed by the precipitation of solid materials that have passed through the mechanical filter and additional microorganism activity. The sludge is gathered in the pit and removed after reaching a certain amount. Meanwhile, additional nutrition could be added through the precipitation pit and flow directly to the crops without affecting the water conditions in the aquaculture unit. The hydroponics unit is composed of three NFT (Nutrition film technique) channels and the crops are grown in plating baskets placed in the hollow spacing. The solid-free water after filtration and precipitation flows to the NFT channel for the final process of nutrition absorption by crops and microorganisms. The nutrient-free water is pumped back into the fish tank to provide the aquaculture unit with clean water.

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2.2. Investigation setup, water treatment and lettuce cultivation

2.2.1. Basic Setup. The investigation was conducted in a Quonset greenhouse of a sustainable farm located in Shunyi district, Beijing (Kai Xin Yun Zhuang, Cloud Farm) from January 16th to May 25th. The greenhouse is located in an open field with substantial natural lighting. No artificial light source was used during the investigation. Two identical NFT SRAPS sets, each with a planting bed size of 4.8m x 1.2m x 0.3m, were applied to the investigation.

The two sets of SRAPS were placed in adjacent positions in the greenhouse to minimize environmental differences.

2.2.2. Aquaponics system. Two identical SRAPS systems were installed in the greenhouse; the aquaculture unit of the system is composed of mineralization tanks, precipitation pits, a biofilter for hosting nitrifying bacteria, a mechanical filter, and a 1000ltr IBC fish tank. Glass rings were used in the biofilter section and filter pulp was used in the mechanical filter section. The hydroponics unit was composed of three NFT channels, with two ends connected to the aquaculture unit for water recirculation. Each channel holds 12 circular pores with a diameter of 8 cm for planting basket installation, with each pore distanced 10 cm apart.

Tap water was treated with reverse osmosis to alter the pH level from 8.5 to 7.0 [11,12]. The water was recirculated in the two systems for 28 days to establish a living culture of nitrifying bacteria. The rising pH level in water was treated by submerging volcanic rock packs in aquaculture to drop the pH level, and the pH level was monitored using an API test kit. The fish culture was introduced after NO_3^-, NO_4^-, NH_3, and NH_4 levels dropped to zero in two aquaculture setups, suggesting the establishment of the nitrifying bacterium in the aquaponics set. The fish culture was left unfed for a month before being introduced to avoid digestion and excretion, which could influence the results of the investigation.

This investigation selected Common carp (*Cyprinus carpio*). A total of 25 kg (approximately 50 individuals) of common carp were introduced into each 1000-liter IBC fish tank. The species was selected for its acceptance of temperature changes across seasons compared to other fish species used in aquaponics, such as tilapia, that may not survive under a low water temperature, preventing any deaths during the investigation as it may affect the outcomes if any replacement of fish is required. Meanwhile, common carp may accept a diverse range of food sources, allowing it to be fed a variety of fish foods with varying contents. Lettuce seed was sown in a mixture of coconut fiber and humus cultivation soil. After sowing, the plant is transported into the planting basket with ceramsite medium. Nine planting baskets were placed in an NFT channel, and the plant was grown for two to three weeks until it was harvested. The investigation was repeated three times—batch 1, batch 2, and batch 3 consecutively. Each batch was grown for around two weeks and then harvested. Weight measurement for each crop was conducted right after harvest, the taproot of the crop was cut, and the weight would be measured using an electronic scale ("JinXuan" home-use kitchen scale, accuracy 0.1g) with the crop placed in the center of the scale for accurate measurement.

The two identical SRAPS systems are provided with fish food with different protein content. The high-protein fish food (Tong Wei High Protein Perch Food, protein content 48%) was fed to the SRAPS located on the east side of the greenhouse which is named the east set. The fish food with a low-protein content (self-made alfalfa grass fish food, protein content 0-10%) was fed to the SRAPS located on the west side and, therefore, named the west set. The aquaculture unit in each set contains 50 individuals with a total weight of 25 kg to produce sufficient feces. The fish was starved for a month to minimize individual differences, and when the experiment started, they were fed once a day, and each set was given 1 to 3 % of fish food according to the weight.

2.3. Statistical analysis and system monitoring

The temperature will be monitored three times a day with a probe thermometer, at 7:00 a.m., 12:00 p.m., and 5:00 p.m., and recorded with no manual control of the internal temperature of the greenhouse. The whole investigation was separated into three growth periods, which is defined by the time from sowing to harvesting of each batch. During the batch 1 growth period (From Jan 14th to Mar 19th), the internal temperature of the greenhouse is in the range of 15- 18 degrees from the lowest and highest temperature gathered between 8:00 am and 4:00 pm. The temperature increased during the batch 2 growth period (Mar 1st to Apr 3rd) to a range between 20-22 degrees. During the batch growth period (March 8th to Apr 25th), the temperature increased to a range between 22-25 degrees. Conditions of the aquaculture unit are monitored with the API freshwater test kit and compared with colorimetric cards. NO_3^-, NO_4^-, NH_3, NH_4, and pH values are measured with water samples gathered from the fish tank in an aquaculture unit. The data were processed using SPSS.

Table 1. The water condition of aquaponics sets during the investigation.

		pH	NH_3/NH_4^+	NO_3^-	NO_2^-
2022/3/1	East	6.4to6.6	0to0.25	5to10	0to0.25
	West	6.8	0to0.25	0to5	0to0.25
2022/3/2	East	6.6to6.8	0.25	5to10	0
	West	6.8	1	0to5	0
2022/3/3	East	7	1	20	0
	West	7	0.25to0.5	5	0
2022/3/4	East	6.8	2	40	0
	West	6.8	0.25to0.5	5to10	0
2022/3/6	East	6.8	2	40	0
	West	6.8to7	0.25	5to10	0
2022/3/7	East	6.8	1	20to40	0
	West	7	0.25to0.5	5to10	0
2022/3/8	East	6.8	1	20to40	0
	West	7	0.25to0.5	5to10	0
2022/3/9	East	6.8	0.25	20to40	0
	West	7	0.25	5to10	0
2022/3/10	East	7	0.25	20to40	0
	West	7	0.25	5to10	0
2022/3/11	East	7	0.25	20to40	0
	West	7	0.25	5to10	0
2022/3/13	East	6.8	0.25	20to40	0
	West	7	0.25	5to10	0
2022/3/14	East	6.8	0.25	20to40	0
	West	7	0.25	5to10	0
2022/3/15	East	6.8	0.5	20to40	0
	West	7	0-0.25	0to5	0
2022/3/16	East	6.8	0.5	40to80	0
	West	7	0to0.25	0to5	0
2022/3/18	East	6.8	0.5	40	0
	West	7	0.to0.25	0to5	0
2022/3/19	East	6.6	0.5to1	10to20	0
	West	7to7.2	0.25	0	0

Table 1. (continued).

		pH	NH_3/NH_4^+	NO_3^-	NO_2^-
2022/3/22	East	6.8	1	20	0
	West	7	0to0.25	0to5	0
2022/3/23	East	6.8	1	20	0
	West	7	0to0.25	0to5	0

2022/3/24	East	6.8	1	20	0
	West	7	0to0.25	0to5	0
2022/3/25	East	6.7	1	20to40	0
	West	7	0to0.25	0to5	0
2022/3/26	East	6.7	0.5	20	0
	West	7	0to0.25	0to5	0
2022/3/28	East	6.8	0.5	20	0
	West	7	0to0.25	0to5	0
2022/3/30	East	6.8	1	20	0
	West	7	0to0.25	0to5	0
2022/4/3	East	6.8	1	20	0
	West	7	0to0.25	0to5	0

Table 1 shows the level of pH, NH_3/NH_4^+, NO_3^-, and NO_2^- of the west and east set in the investigation. The first changes of NO_3^- occurred in Feb, marking the start of the differentiation of nutrition of the two sets.

3. Results and discussions

3.1. Effects of the nutrient level difference in two sets on crop growth

In this paper, an experiment was designed to explore the relationship between the weight of the crop and the protein content fed to carp in the SRAPS aquaponics system, so as to validate the possibility of increasing the growth and yield of SRAPS plants by varying the protein content of the fish food.

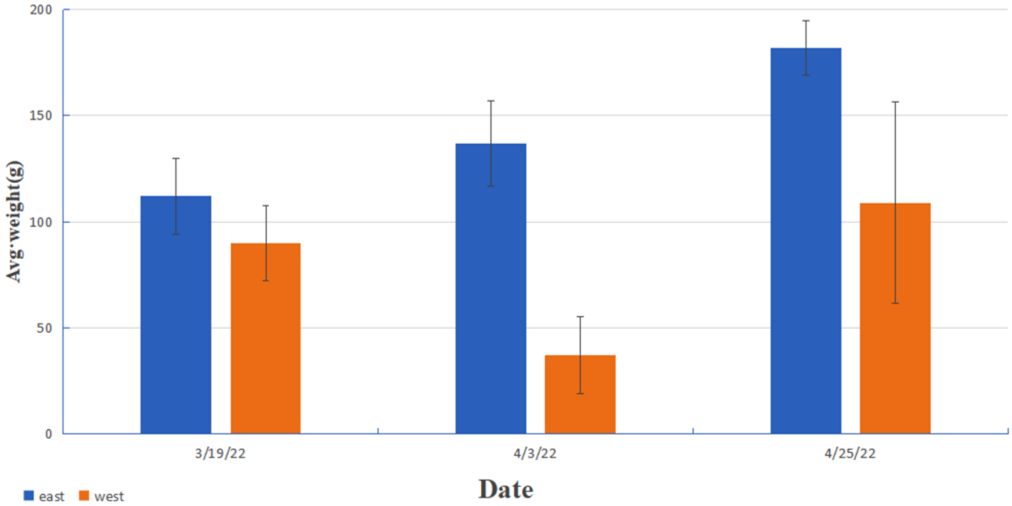

Figure 2. Effects of nutrient levels difference in two sets on L savita. L yield.

The graph plotted the date of harvest and harvested average weight of the two sets in each batch. According to Fig 2, the average weight of two sets of plants harvested has three features:

1) The east set has shown significantly higher yield than the west set in all three batches.

2) There is a consistently increasing trend in the east set.

3) The west set has a dip in batch 2.

The results of three batches demonstrated a consistent difference between the west set and the east set. In all three batches, the east set produced larger and heavier crops than the west set. During the experiment, the changes of NO_3^- occurred on Feb-26th, from both two sets of 5-10 to the east set remaining the same while the west set changing to 0-5 (see table 1) caused by the production of fish feces.

However, in the west set that received a limited number of proteins, NO_3^- produced is quickly consumed.

This result supported the assumption that an aquaponics system with fish food input of different protein content would affect the growth and yield of crops. Under identical conditions, crops that received fish food with a high-protein content demonstrated a larger weight compared to those that received fish food with a low-protein content.

Table 2. Time composition of growth period of L. sativa.

Batch	Sowing	Transplant	Harvest	Growth Period
1	01/14/22	03/05/22	03/19/22	64days
2	03/01/22	03/19/22	04/03/22	34days
3	03/08/22	04/03/22	04/25/22	48days

Table 2 shows the growth period from sowing to the harvest of batches 1-3. According to the dates and the number of days in Table 2, it can be found that batch 1 has the longest growth period and batch 2 has the shortest.

3.2. Effect of the growth period and temperature on crop growth

3.2.1. Comparison between batches of west and east. In the comparison between the west set and east set in three batches, batch 1 has demonstrated the smallest difference while batch 2 has demonstrated the biggest. In batch 1, the low temperature limited the growth of crops, especially in the east, which received fish food with a higher protein content, producing a small difference. In batch 2, the optimal temperature for lettuce growth allowed the east set to develop faster with the higher protein content of fish food compared to the west set. The short growth period limited the production of the west set as the batch was harvested before the west set could reach a higher yield, enlarging the difference. Batch 3 had a high temperature compared to batch 1 (16- 18 vs 22-25), allowing the faster growth of the east set, however, the difference was shortened by the longer growth period compared to batch 2 (48 days vs 34 days) where it allowed the west set to reach higher productivity.

3.2.2. Analysis of difference compared in sets. The three east sets have shown a consistent trend of increase in weight across the investigation as shown in Figure 2. Batch 1 produced relatively a low weight due to the low internal temperature (all shown in table 1, 16-18 degrees) which limited crop growth. Batch 2 has shown a higher weight compared to batch 1 and a lower weight compared to batch 3. The result in batch 2 is caused by a higher temperature compared to batch 1 which benefited crop growth (20-22 degrees) but did not reach a higher weight due to its short growth period (34 days). Batch 3 has the highest weight in the east set due to a higher temperature compared with batch 1 (22-25 degrees) and a longer growth period compared to batch 2(48 vs 34 days). In batch 3, the relatively high temperature compared to batch 1 and receiving a larger amount of time caused it to have the highest weight yielded in the three batches of the east set. However, the west batch has demonstrated a different trend in crop growth and yield compared to the east batch. Batch 2 has shown a significant decrease in weight compared to batch 1 and batch 3 due to the short growth period. Batch 1 and batch 3 both experienced a longer growth period compared to batch 2, which allowed a higher yield of crops. The longer growth period of batch 1 compared to batch 3 (64 days vs 48 days) allowed batch 1 to shorten the difference from batch 3 in the growth and yield of crops. However, the growth and yield of crops in batch 1 did not exceed batch 3 due to a higher temperature batch 3 crops are grown under (16- 18 degrees vs 22-25 degrees).

In the east batch 2, a similar number of crops is produced compared to batch 3, however, it has a shorter growth period of a difference of about 15 days. Concerning this result, it can be concluded that the growing period and temperature are two determining factors that have a direct influence on the growth and yield of crops under aquaponics conditions and that finding an optimal combination between them can produce high yields in a relatively short period.

4. Conclusion

As a sustainable agricultural approach, aquaponics can be a solution to many upcoming environmental and socio-ecological problems. In order to take aquaponics to the next level, commercial-scale yields should be considered. This investigation possesses a value towards economically beneficial production of crops, which can be derived from the results. By purposefully inputting fish food with a high-protein content, altering temperature and growth period could impact the production of crops, and an optimal combination with high-protein content fish food would produce a high yield. While receiving a high-protein content fish food, the fish would probably also show a gain in weight. The gain in weight of fish would not be discussed since this research lasts for a relatively short period. However, it may also contribute to an increase in profit in commercial aquaponics if it is under a longer period. Batch 2 is used as a reference as batch 1 and batch 3 are not conducted under preferable temperatures and growth periods, which affected the production of lettuce. In batch 2, the average weight of crop yield in the east set exceeds the west set by 3.7 times. In the future, more advanced aquaponics systems (DRAPS) can be studied and more extensive research on the components of aquaponics systems can be conducted.

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