Effects of Microalgae on Growth and Nutritional Performance of Koi Carp, Cyprinus Carpio, (Linnaeus, 1758), and Leafy Vegetables Raised in Aquaponic System

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ABSTRACT

This study was carried out to assess the dietary effects of freshwater microalga, *Spirulina platensis* on the growth performance and nutrient utilisation in Koi carp, *Cyprinus carpio* fingerlings raised in aquaponic system with fluted pumpkins. Five feeds were formulated with different inclusion levels of spirulina at 0%, 20%, 30%, 40% and 50% each in diet 1, 2, 3, 4 and 5 denoted as T1(Control), T2, T3, T4 and T5 respectively to replace soybean meal respectively. One hundred and fifty Koi carp, *C. carpio* fingerlings (2.35g±0.05) were stocked in the aquaponics system and fed with commercial fish feed for 56days.The experiment were replicated with three tanks per replicate. Fish biological performance during the experiment was measured based on growth performance and nutrient utilization. The growth of the leafy vegetable was measured, and inferential statistics were done using one way analysis of variance (ANOVA) to compare the growth performance and nutrient utilization of fish at 95% level of confidence and 0.05 level of significance. The study found that the water quality, as well as the fish performance in the system were all within the recommended limits and appreciable performance respectively. ANOVA result showed a statistically significant difference among the inclusion levels of the microalgae. The result showed that were significant differences ($P<0.05$) in the growth and nutrient utilization parameters with treatment 4 with 75% spirulina inclusion having the best protein efficiency ratio, feed conversion and feed efficiency ratios. The study concluded that microalgae and Fluted pumpkins have better production performance and growth performance in aquaponic system thus, integration of Fluted Pumpkin and C. carpio in aquaponics system has the potential of adding more to the benefits of the system in terms of productivity.

Keywords: Aquaponics, A-pyramid, Vegetable, Growth performance and Microalgae.

INTRODUCTION

The aquaculture sector is driven by the private sector, Nigeria is the largest aquaculture producer in Sub-Saharan Africa and this importance is steadily increasing (FAO, 2024). The ornamental fishery though a science, has an artistic appeal, and an entrepreneurial edge (Ekpo, 2013). It is a very vast and lucrative study with a wide and interconnecting value chain (Ibim, 2019). A total of 45 exotic fish species were identified from 2,950 fish analyzed. Varieties of *Carassius auratus* (goldfish); *Pterophyllum Scalare*) ;(Angel fish) and *Tricogaster leeri* (Gourami)were the most common and found in 65%, 60% and 53% respectively of the tanks surveyed. While *Scleropages formosus* (Golden Arowana) and *Symphysodonaequi fasciatus* (Discuss fish) were the rarest species. 22.2% of the identified species are being bred locally. Only one of the fish tanks and facilities surveyed housed marine ornamental fish (Ibim, 2019). Koi carp, *Cyprinus carpio,* is a valuable ornamental fish due to its coloration, patterning and scalation. Koi carp, often simply referred to as "koi," are a species of ornamental fish that are highly prized for their vibrant colours and distinctive patterns. They come in a wide range of colours and patterns, including red, white, yellow, black, and blue. The most popular varieties include Kohaku (white body

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with red markings), Taisho Sanke (white body with red and black markings), Showa Sanshoku (black body with red and white markings), and Bekko (solid colour with black markings) (Biswas, 1995).

Microalgae are microscopic photosynthetic organisms belonging to various taxonomic groups, including cyanobacteria, chlorophytes (green algae), diatoms, dinoflagellates, and others. They are unicellular or multicellular and typically range in size from a few micrometers to a few hundred micrometers (Borowitzka, 1992). Microalgae are rich sources of proteins, essential fatty acids, vitamins, minerals, and other bioactive compounds. Species like *Chlorella, Spirulina, and Nannochloropsis* have high protein content and provide essential amino acids (Becker, 2007). Microalgae supplements, such as *Spirulina* and *Chlorella*, are consumed for their potential health benefits, including immune system support, antioxidant activity, and nutritional supplementation (Kurnia *et al*., 2019). *Spirulina* is recognized as a rich source of phycocyanin, a pigment with antioxidant and anti-inflammatory properties.

Aquaponics is the symbiotic assembly of plants and fish, where the fish releases nitrogenous metabolic end products into the water, which are further metabolized by bacteria to produce useful products which serve as nutrients for plants (Effendi *et al.,* 2015). It is a system made up of a looped arrangement of interactions between fish, vegetables and bacteria (Goddek *et al.,* 2015). It makes use of a flood drain system in a filter bed, in which the plants growing media is flooded and drained systematically, thereby permitting the plant roots to receive both water and air (Endut *et al.,*2010 ; Effendi *et al.,* 2015). The current study assessed the effects of microalga, *Spirulina* on nutritional performance and nutrigenomics in koi carp, *cyprinus carpio,* and leafy vegetables, fluted pumpkin raised in aquaponic system.

Experimental Study Site

The study was carried out at the Teaching and Research farm of the Department of Fisheries Technology Federal Polytechnic Ile-oluji, Ondo State. The dietary freshwater microalgae (*S. platensis*) was procured from Farm support, Akure, Ondo State.

Experimental System and Fish

Koi Carp, *C. carpio* juveniles were procured from a reputable farm. The fish was distributed randomly into the A-pyramid aquaponic system at ten fish per segment, with ten fish used for the proximate analysis aspect, and for the replacement of dead fish during acclimatization. Acclimatization lasted for 14 days, after which the fingerlings were not fed for 24 hours on the experimental diet (which was prepared during the acclimatization phase) to maintain a uniform stomach condition of the fish and to induce/prepare their appetite for the commencement of the feeding trial. The fish was fed to satiation with their respective diets twice daily between (8.00am-9.00am) and (4.00pm – 5.00pm) GMT for 56days. Feed was administered at 5% body weight and given bit by bit to check the rate at which the fish picks the feed. Fish performances during the experiment, growth and nutrient utilization efficiencies were monitored.

Feed Ingredients and Formulation of Experimental Diets

Five diets containing 35% crude protein was formulated for Koi Carp, *C. carpio* fingerlings in the 56 days trial experiment (Table 1) using Pearson square method. *S. platensis* was added to the formulated feed at different proportions at 0%, 20%, 30%, 40% and 50% each in diet 1, 2, 3, 4 and 5 denoted as T1(Control), T2, T3, T4 and T5 respectively to replace SBM. All dietary ingredients were first milled to small particle size. The dry ingredients were thoroughly mixed by adding hot water until a consistent dough resulted from the mix. The dough will then be pelleted using Hobart A-200 pelleting machine with 2.0mm die. After pelleting, the diet was dried immediately for a week to avoid mould formation and later broken mechanically into small sizes and packed in dry, airtight containers and labelled prior to use.

Table 1: Composition of the experimental diet in g/100g containing various inclusion level of S. platensis for Cyprinus carpio

Ingredients	**T1**	**T2**	**T3**	**T4**	**T5**
Fishmeal	17.21	17.21	17.21	17.21	17.21

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Soyabeans	17.21	12.91	8.61	4.30	0.00
Spirulina	0.00	4.30	8.61	12.91	17.21
Groundnut cake	17.21	17.21	17.21	17.21	17.21
Yellow maize	33.38	33.38	33.38	33.38	33.38
Vegetable oil	11.00	11.00	11.00	11.00	11.00
Vitamin	2.00	2.00	2.00	2.00	2.00
Starch	2.00	2.00	2.00	2.00	2.00
Total	**100**	**100**	**100**	**100**	**100**

Premix manufactured by Chemiconsult International Limited, Ikeja, Lagos, Nigeria (2023).

Assessment of Water Quality Parameters

Water quality is the most important factor affecting fish health and performance in Aquaculture production systems. Temperature, pH, Dissolved oxygen concentration, and salinity was monitored using HANNA Multi-parameters (Poland, OLNY) water checker.

Proximate and Carcass Analysis

This is the Analytical procedure for the routine description of feedstuffs. The different fractions that result are moisture (water), crude protein, ether extract, ash, crude fibre and nitrogen free extract (NFE). The chemical analysis of diets and fish carcasses to be used was performed according to the procedures of the AOAC (2019). The fat, crude protein, ash and moisture contents of the samples were determined using the standard method as described by AOAC (2019).

Experimental performance of leafy vegetable

Fluted Pumpkin seedlings was procured from Department of Crop, Soils and Pest Management (CSP) and planted one pair per row of the aquaponics troughs and will generate their nutrient from the fish feed waste and the excretory waste of the fish. The yield parameters of the leafy vegetable was initiated 4 weeks after seed germination and subsequent 2 weeks according to the specified method by Gbadamosi and Adebayo, (2021). In order to the determine the growth performance of the vegetable, growth rate was monitored by measuring the height of each vegetable in the aquaponics system troughs and counting the number of shoots and flowers (representing the early stage of fruiting). Growth of plant;

$$\text{Height of plant} = \text{Final height of plant} - \text{initial height of plant}$$

$$\text{Growth rate} = \frac{\text{Height of plant (cm)}}{\text{Culture period(days)}}$$

Growth Performance and Nutrient Utilization

The fish was weighed using an electrical weighing balance before the commencement of the experiment and fortnightly during the period of the experiment to adjust the feeding level. At the end of the experiment, individual weights of all surviving fish from all the groups were measured to obtain their final mean weight after evacuation of feed by starving for 24 hours. At the end of the feeding trials, various parameters used in evaluation of growth performance was carried out according to (Fasakin *et al*., 2003) such parameters include Weight Gain (WG), Percentage Weight Gain (PWG), Specific Growth Rate (SGR), Feed Intake (FI), Feed Conversion Ratio (FCR), Protein Intake (PI), Protein Efficiency Ratio (PER).

Statistical Analysis of Data

All data collected were checked for normality using one-way analysis of variance (ANOVA), and homogeneity of variance using Levene's test to test for significant difference in the means using Statistical Package for Social Sciences (SPSS 22.0 for windows). The means were separated using Duncan's multiple range test where there is significant difference.

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RESULTS AND DISCUSSION

Growth Performance and Nutrient Utilization of Koi Carp (Cyprinus Carpio) Fingerlings

The growth performance and nutrient utilization of koi carp fingerlings fed diets supplemented with S. platensis over 56 days showed marked differences among the treatment groups (table 2). These results suggest that incorporating *S. platensis* in koi carp diets positively influences growth performance and feed efficiency. Similar findings were reported by Sadraddin (2019), who observed significant improvements in weight gain, specific growth rate, and feed utilization in common carp (*Cyprinus carpio*) fed astaxanthin powders—an active pigment in *S. platensis* —demonstrating its growth-promoting properties. Li *et al*. (2014) also found dietary astaxanthin and *S. platensis* supplementation enhanced growth factors in large yellow croaker. The improved feed conversion and protein efficiency ratios in this study align with the enhanced nutrient utilization documented by Kurnia *et al*. (2019) in koi carp fed pigment-rich diets. It is noteworthy that the highest survival rate correlated with intermediate to high inclusion levels of *S. platensis*, consistent with benefits of carotenoid supplementation for immune function and stress resistance in fish (Chainapong and Traichaiyaporn, 2013). The growth performance and nutrient utilization data affirm the beneficial role of *S. platensis* as a functional feed ingredient for koi carp, promoting better growth, feed efficiency, and survival compared to control or lower inclusion levels.

Table 2: Growth Performance and Nutrient Utilization of Koi Carp (Cyprinus carpio) fingerlings fed with S. platensis for 56 days

Here is your data **converted into a properly aligned table format**:

TRTS	T1	T2	T3	T4	T5
IW	0.62 ± 0.01a	0.69 ± 0.01c	0.67 ± 0.02b	0.68 ± 0.02bc	0.63 ± 0.01a
FW	1.08 ± 0.01a	1.07 ± 0.01a	1.12 ± 0.02a	1.08 ± 0.05a	1.19 ± 0.02b
WG	0.47 ± 0.02b	0.38 ± 0.01a	0.45 ± 0.03b	0.39 ± 0.05a	0.56 ± 0.02c
%WG	75.86 ± 3.97b	54.82 ± 1.85a	67.58 ± 5.35b	57.58 ± 7.14a	89.44 ± 3.93c
FI	0.97 ± 0.36a	0.74 ± 0.03a	0.75 ± 0.06a	0.68 ± 0.16a	0.79 ± 0.10a
FCR	2.10 ± 0.86a	1.94 ± 0.09a	1.67 ± 0.04a	1.72 ± 0.22a	1.39 ± 0.13a
FER	0.52 ± 0.17a	0.52 ± 0.03a	0.60 ± 0.01ab	0.59 ± 0.08ab	0.72 ± 0.07b
SGR	1.13 ± 0.36a	0.72 ± 0.39a	0.78 ± 0.33a	0.82 ± 0.16a	0.88 ± 0.07a
PER	1.50 ± 0.50a	1.48 ± 0.07a	1.71 ± 0.04ab	1.68 ± 0.23ab	2.06 ± 0.21b
%SURV	90.00 ± 0.00a	90.00 ± 0.00a	90.00 ± 0.00a	90.00 ± 0.00b	90.00 ± 0.00a

Values with different superscripts on the same row indicate significant difference at $P<0.05$

IW- Initial weight, FW- Final weight, WG- Weight gain, %WG- Percentage weight gain, FCR- Feed conversion ratio, FER- Feed efficiency ratio, SGR- Specific growth rate, PER- Protein efficiency ratio, %SURV- Percentage survival.

The proximate composition trends observed in this study—isonitrogenous diets with variation in moisture, crude fat, ash and crude fibre—are consistent with previous feeding trials where protein was held constant while non-protein components were modified. Similar proximate composition tables and ranges are reported in *S. platensis* supplementation studies and in trials testing protein–lipid levels (e.g., Zhang and Wang., 2023; Li *et al*., 2014). The minor variation in ash and fibre and relatively stable NFE are also commonly reported when diets are formulated isonitrogenously. Proteins are the building blocks of amino acids and certain of them are essential in human diet for the maintenance of good living.

Table 3: Proximate Composition of Experimental Diets

Parameters	T1	T2	T3	T4	T5
Moisture	6.50 ± 1.00ab	6.87 ± 0.12ab	5.37 ± 1.12a	8.00 ± 1.25b	6.87 ± 1.16ab
Protein	34.73 ± 0.01a	35.48 ± 0.01a	34.54 ± 0.01a	35.41 ± 0.01a	35.29 ± 0.01a
Crude Fat	8.17 ± 0.90a	8.05 ± 0.26a	9.66 ± 2.35b	7.00 ± 0.27a	6.47 ± 0.00a

Fibre	2.76 ± 0.72a	2.54 ± 2.50a	2.05 ± 0.88a	2.07 ± 1.06a	2.00 ± 0.71a
Ash	8.26 ± 0.46ab	7.63 ± 1.17ab	6.17 ± 0.67a	8.11 ± 2.75b	6.00 ± 0.50a
NFE	39.53 ± 0.83a	39.43 ± 4.06a	41.86 ± 2.10a	38.77 ± 5.08a	43.36 ± 1.09a

Means (±SD) of water quality parameters obtained in the treatment tanks did not vary significantly (P>0.05)

Water Quality Parameters for 56 days feeding trial of *Cyprinus carpio* fingerlings fed with diet

The pH values across the treatments ranged from 7.85 to 8.16, which is within the optimal pH range of 6.5 to 8.5 for *Cyprinus carpio*. Stable pH levels are essential for the proper functioning of physiological processes in fish, as extreme pH levels can lead to stress or mortality (Olowosegun *et al.,* 2005).

Table 4: Water Quality Parameters for 56 days feeding trial of *Cyprinus carpio* fingerlings fed with diet

Treatments	T1		T3	T4	T5
pH	7.91 ± 0.14^{a}	7.85 ± 0.14^{a}	7.94 ± 0.14^{a}	7.96 ± 0.14^{a}	8.16 ± 0.29^{a}
Temperature	26.05 ± 0.25^{a}	26.15 ± 0.25^{a}	26.15 ± 0.25^{a}	26.12 ± 0.25^{a}	26.14 ± 0.25^{a}
DO_2	5.49 ± 0.25^{a}	5.61 ± 0.25^{a}	5.45 ± 0.25^{a}	5.54 ± 0.25^{a}	5.08 ± 0.36^{a}

Means (±SD) of water quality parameters obtained in the treatment tanks did not vary significantly (P>0.05)

Furthermore, the current research also found that Pumpkin (*Telfairia occidentalis*) has good growth performance in the experiment (Figure 1). According to Rakocy *et al*., (2017), the choice of a vegetable for an aquaponics system is based on three parameters namely, the market demand, the convenience for growing fish and vegetables in an aquaponics system, and the match between nutrient input and requirements. Hence, only a few plants have been successfully grown in aquaponics systems for example; lettuce, cucumbers, bell peppers, tomatoes, eggplant (with some extra care) and root crop such as carrot (Gbadamosi and Adebayo, 2021). The findings of the current study suggest that microalgae could affect the nutrient uptake of nutrients from plants in an aquaponics system. Consequently, this could increase the growth efficiencies of the plant.

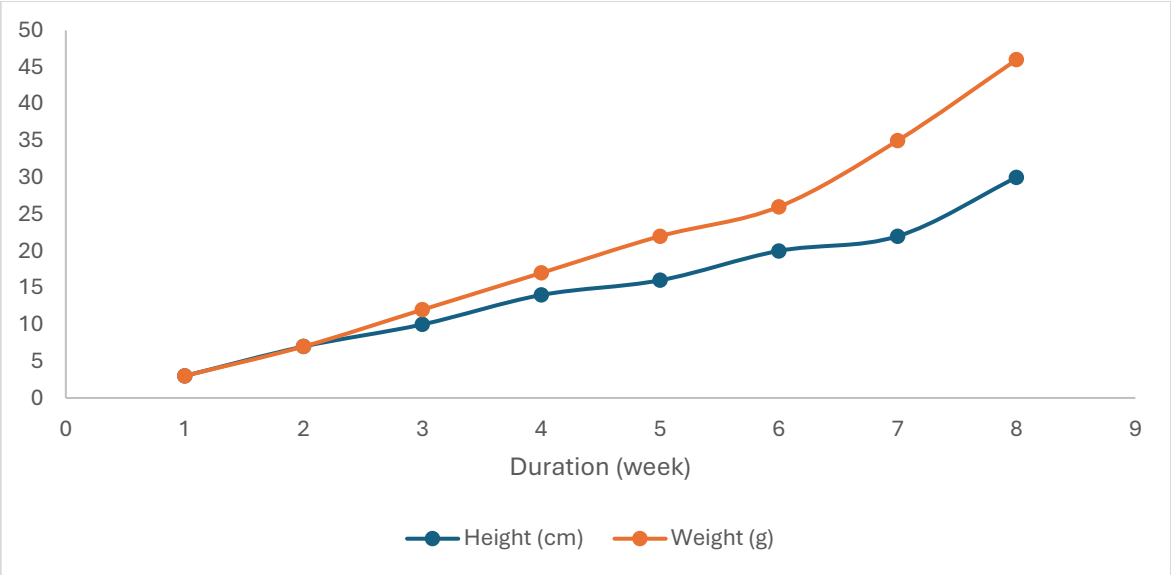

Figure 1: Height and weight of fluted pumpkin in the aquaponic system raised with the *C. Carpio*.

CONCLUSION

Fluted pumpkins and Cyprinus carpio have a good bio-production and growth performance in aquaponic system. The water quality, as well as the fish performance in the system were all within the recommended limits and appreciable performance respectively thus, Fluted Pumpkin can be cultivated in such system. A system which

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permit greater control and use of aquaculture waste and play important role in food security and economy. More so, the usage of the system also help to maximize use of land where there is no much space and conservation of water because of the recirculatory system which reused water. Also, the integration of indigenous vegetable such as Fluted Pumpkin and Cyprinus carpio in aquaponics has the potential of adding more to the benefit of this system not only in the area of pollution control, but also in terms of productivity.

Limitations of the Study:

The study focused on Koi carp (Cyprinus carpio) and leafy vegetables, which may not be representative of other fish species or vegetable types and may not have been sufficient to capture long-term effects of microalgae on growth and nutritional performance. The study was conducted in a controlled aquaponic system with a specific microalgae species, which may not be representative of other microalgae species.

Future Research should be directed towards the exploration of the effects of different microalgae species on growth and nutritional performance of Koi carp and other fish species. The conduct of longer-term studies to assess the sustainability and stability of microalgae-based aquaponic systems should also be done.

Author Contributions: The authors ATM, GOK, and OOS designed the study and performed the experiments. GOK and OOS performed the statistical analysis of the data. All authors participated in the writing of the draft and final versions of the manuscript.

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Data Availability: All datasets, on which the conclusions of the manuscript rely, are present in the results section in the manuscript.

Declarations: Ethics Approval The experimental procedures were approved by the Institutional Animal Care and Use Committee of the Federal University of Technology, Akure, Nigeria; approval number FUTA/ETH/22/91.

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