

Development and Evaluation of Vegetable and Fish Wastes Silage (VFWS) Additive to Nile Tilapia (*Oreochromis niloticus*) Feeds

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Abstract— Nile tilapia fingerlings fed varying levels of vegetable and fish waste silage (VFWS), following a completely randomized design (CRD) were studied to determine the optimum level of replacement to the commercial diet on growth parameters, and economic benefits. In the experiment, a total of 120 fingerlings with an initial mean weight of 8.89 g were used. They were divided into four (4) groups based on their dietary needs: Treatment 1 (T1) was the pure commercial feeds, 100% CF; Treatment 2 (T2) 10% VFWS and 90% CF; Treatment 3 (T3) 15% VFWS and 85% CF; and Treatment 4 (T4) 20% VFWS and 80% CF with three (3) replications each. The results showed that there were no significant differences between any of the treatments in terms of growth parameters indicating comparable performance of the treated diets with the control. Moreover, T3 has the tendency to increase the survival rate, which suggests an apparent acceptability of the VFWS. Finally, the results proved a promising utilization of VFWS as a replacement of commercial aqua diets for Nile Tilapia fingerlings at the early growth stage.

Keywords— Vegetable fish waste silage; feed utilization; growth; fish meal; Nile tilapia.

I. INTRODUCTION

Fish, particularly tilapia, is a staple food in Filipino cuisine. It is the primary source of dietary protein, vitamins, micronutrients, and minerals (Pandey and Upadhyay, 2022). Not only do they provide essential proteins but are also a valuable commodity traded worldwide and serve as a means of income for fish-producing countries, including the Philippines. Besides producing a large quantity of fish, aquaculture operations also help alleviate food insecurity, a major issue among the country's poorest regions and agricultural households.

A record of 214 MT was produced globally in fisheries and aquaculture in 2020, including 178 MT of fish and 36 MT of algae (SOFIA, 2022). This growth largely accounts for the advancement of aquaculture within Asia. Much of aquaculture's success depends on feed quality and availability. Good quality feed, however, tends to be more expensive, partly because some feed ingredients used are imported, which increases production costs whether it is for poultry, swine, or aquaculture. Around 60-70% of the entire cost of operating a fish farm is spent on feed (Mukta, Khan, Mian & Juice, 2019). One way to reduce feed costs in fish farming is by utilizing alternative feed ingredients. These can include waste materials that are readily available. Fish waste and vegetable wastes, in particular, have the potential to be used as raw material for producing feed additives, thereby decreasing reliance on imported feed ingredients.

Likewise, the aquaculture industry's growth is often accompanied by a significant volume of waste, if not properly managed it can lead to environmental pollution and loss of biodiversity. Fish waste is generated in large quantities from processing plants and wet markets. The average daily production of fish waste in Philippine wet markets was found to be 70.3 kg, with no significant differences across locations (De Ungria et al., 2023). However, vegetable wastes, on the other hand, account for 40 to 50% of postharvest losses of fruits and vegetables and 42% of its vegetable production losses was due to spoiling, resulting in landfill problems (Sanchez et al., 2019). Despite this, the vegetable waste is a rich source of nutrients. It contains between 2.11% and 2.71% protein, 1.08% fat, and 14- 15% fiber. It also has a high-water content, ranging from 89% to 90% which is a good source of calcium and other minerals (Andriani & Pratama, 2022).

Somehow, these kinds of waste materials can be processed and further enhanced through fermentation. This process increases the bioavailability of nutrients, improves the palatability of the feed. Fermenting vegetable and fish waste is expected to improve the quality of feed additives, increase digestibility, and develop flavors and aromas suitable for fish (Adriani, Lili, Zidni, Wiyatna, & Risiana., 2020). Feed additives are substances added to animal feed to enhance its nutritional value, improve the animal health and productivity, or make the feed more appealing (Olagnju et al., 2023). Nutrition is known to have a considerable effect on the reproductive performance and gonadal development of fish (Gioacchini, Olivotto, Ashouri, & Carnevali., 2023). The addition of feed additives was found to improve growth but the nutritional impact of reducing the protein digestibility and amino acid balance in this feed heavily affected the overall performance, particularly feed conversion ratio (FCR) and survival rate (Towers, 2015).

Including this fermented vegetable and fish waste silage into tilapia feeds provides for a more sustainable and profitable aquaculture sector. This aligns with the principles of circular economy, which minimizes waste and reuses resources. Some studies have explored the use of single waste materials, but the combination of assorted vegetable leftovers and fish viscera waste and its optimal inclusion levels as supplementary fish feed additives has not yet been thoroughly investigated. Finding ways for sustainable feed production is essential particularly cost saving strategies considering the unabated increase of the price of commercial aqua diets. Therefore, the utilization of vegetable and fish viscera wastes when processed by fermentation procedures to make it safe and palatable for inclusion to commercial aqua diets is very timely. Finally, these nutritional strategies can further mitigate the adverse effect of climate change at the same time addressing economic problems of the fisherfolks in the country.

Fermentation improves the nutritional content and may also positively influence fish growth, health, and overall production efficiency. This study developed a sustainable, cost-effective, and environmentally responsible feed additive using fermented dietary vegetable-fish waste silage additive into Nile tilapia feeds. Additionally, incorporating waste products aligns with circular economy principles and sustainable aquaculture. The findings could benefit the fisherfolks, as it enhanced their understanding of alternative feed sources and their practical applications to improve the nutritional quality and palatability of the feed, resulting in better growth, feed conversion ratio, making fish farming more efficient and reduced overall feed costs.

The study focused on developing and analyzing the nutritional composition of fermented dietary vegetable and fish waste silage (VFWS) as a potential feed additive for Nile tilapia. It evaluated the effectiveness of silage-based feeds on the growth performance, feed conversion ratios and weight gain. Additionally, the study examined the economic benefits of using VFWS compared to traditional feed additives. However the study was limited to a specific period, which might have restricted the understanding of long-term effects of silage-based feeds on Nile tilapia. Some of the parameters, such water quality parameters were not analyzed due to the limitation of resources, time, and situation.

II. METHODOLOGY

2.1 Study Area:

The study was conducted at Central Luzon State University (CLSU), which is situated on a 658-hectare land in Science City of Muñoz, Nueva Ecija, Philippines. Specifically, the research area was located at the CLSU BINHI Conservation Park. The campus location is identified by coordinates 15.7327°N latitude and 120.9310°E longitude, and it stands approximately 79 meters

above sea level. The campus is surrounded by rice fields, orchards, and features several bodies of water such as ponds, and streams.



FIGURE 1: Aerial image of CLSU BINHI Conservation Park. (Source: Google Earth Pro; Photo was taken by Fenny Aleluya)

2.2 Experimental Set-up and Units:

The study utilized twelve aquaria to simulate feeding trials for Nile tilapia (*Oreochromis niloticus*) fingerlings. Each aquarium was a half-cylinder made from a 200-liter plastic barrel drum, measuring 58 x 58 x 91 cm. The aquaria had maintained an equal amount of water at a depth of 29 cm. Before the experiment, all aquariums underwent thorough cleaning using a water-soluble degreaser for disinfection, thus preventing fish mortality. The 120 Nile tilapia (*Oreochromis niloticus*) fingerlings used in the study were obtained from the Bureau of Fisheries and Aquatic Resources-National Freshwater Technology Center (BFAR-NFTC), CLSU Compound, Science City of Muñoz, Nueva Ecija. A total of one hundred twenty (120) Nile tilapia fingerlings with a mean initial weight of 8.89 g were used in the experiment and were allocated in four dietary treatments with ten (10) fingerlings per replicate and conditioned for one week before the feeding trial began. Throughout the week, they were fed commercial fry mash.

2.3 Preparation of Vegetable and Fish Waste Silage:

Vegetable wastes such as leaves stems, and/ peels were collected from New Market inside the CLSU Campus. The visceral organs of any fish (e.g., liver, spleen, and intestines) were collected from the wet market in Science City of Muñoz, Nueva Ecija. These materials were thoroughly washed with clean water to remove dirt and minced into small pieces using an electronic shredder. The shredded vegetable and fish wastes were mixed in a ratio of 1:1 (w/w) by weight. The mixture was mixed with 24 g of an odor-erasing composting microbial powder premix per 3 kg vegetable and fish waste silage (VFWS). The commercial powder premix contains beneficial microorganisms, and nitrogen-fixing bacteria, that facilitate the fermentation process. The mixture was transferred to a 3.5-liter plastic container for 14 days in a dry, cool place. The vegetable and fish waste silage were stirred 3 times a day from day 1-7 and twice a day from day 8-14. After fermentation, the fermented silage was mixed with the commercial aqua diets at varying replacement levels and considered as formulated treated diets.

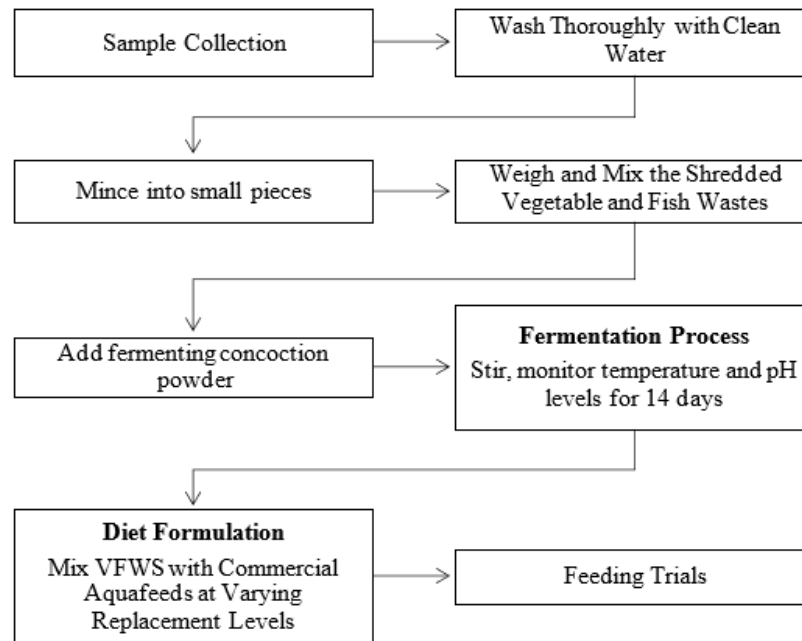


Figure 2: Flowchart diagram on the development of the fermented dietary VFWS to Nile tilapia (Barroga, 2000; Anizah et al., 2021)

2.4 Treatment Assignments:

The study followed a completely randomized design with four (4) dietary treatments, each with three (3) replicates. The treatments consisted of three (3) different levels of VFWS inclusion in the diet: Treatment I (100% Commercial Feeds) with a 26% crude protein level, Treatment II (10% Vegetable and Fish Waste Silage + 90% Commercial Feeds), Treatment III (15% Vegetable and Fish Waste Silage + 85% Commercial Feeds), and Treatment IV (20% Vegetable and Fish Waste Silage + 80% Commercial Feeds). The VFWS was mixed manually and thoroughly with the commercial surfer pre-starter mash and was prepared every three (3) days to ensure its freshness. A three-day (3) adjustment period was observed to establish palatability, acceptability and voluntary feed intake of the fish.

2.5 Proximate Analysis:

The complete proximate analysis of the experimental diets was done in the Feed Chemical Analysis Laboratory, Regional Field Office III, City of San Fernando, Pampanga. Results were standardized as percentage on a dry matter basis for accurate comparison. Methods included oven-drying for moisture content, the Kjeldahl method for crude protein analysis, furnace-ignition for ash, and ANKOM™ filter bag technology for crude fat and crude fiber measurements.

2.6 Feeding Guide and Management Procedure:

The fingerlings were fed three (3) times a day at 9:00 a.m., 12:00 p.m., and 4:00 p.m. for 30 days. The amount of feed given was 5% of their body weight. The initial and final body weights of the fish were recorded before and after the feeding trials commenced. Dead fish were monitored daily, and the feeding rate was adjusted based on the growth and behavior of the fish. The aquaria were cleaned daily by siphoning water and excess feed with a 4-mm diameter plastic tube. Half of the water volume was replaced every day, and the attached algae in the aquaria were removed every two days.

2.7 Growth Performance Parameters:

After the 30th day of feeding trials, the growth parameters of the Nile tilapia fingerlings were analyzed. The specific growth rate (SGR), feed conversion ratio (FCR), survival rate (SR), and absolute growth rate (AGR) were determined and calculated using the following formula (Campang and Vera Cruz, 2018).

$$SGR = \frac{\ln WF - \ln W_0}{t_f - t_0} \times 100 \quad (1)$$

Where:

$\ln W_f$ = natural log of final weight

$\ln W_0$ = natural log of initial weight

t_f = final time in days

t_0 = initial time in days

$$FCR = \frac{\text{Total feed consumed (g)}}{\text{Total weight gain (g)}} \times 100 \quad (2)$$

$$SR (\%) = \left(\frac{S_f}{S_0} \right) \times 100 \quad (3)$$

Where:

S_f = total number of fingerlings survived S_0 = total number of fingerlings stocked

$$AGR = \frac{W_f - W_0}{t} \quad (4)$$

where:

W_f = final weight

W_0 = initial weight

t = number of days

2.8 Statistical Analysis:

Data on feed conversion ratio, specific growth rate, absolute growth rate, and survival rate were statistically tabulated and analyzed using One-way ANOVA for Completely Randomized Design (CRD). STAR software version 2.0.1 was used to compare the treatment means using the Tukey HSD test.

III. RESULTS AND DISCUSSION

3.1 Description and Characteristics of Vegetable and Fish Waste Silage:

The physical properties of silage such as odor, color, and appearance, are commonly used to determine if the silage is suitable to feed Nile tilapia fingerlings. Over the 14-day fermentation period, the vegetable and fish waste silage were assessed based on these parameters. Initially, from Day 1 to Day 5, the silage emitted a very strong and offensive fishy odor due to the rapid breakdown of fish proteins and fats. During this phase, the VFWS had a wet and heterogeneous mixture of chopped vegetable and fish viscera, presenting a slurry-like consistency with varied colors contribute by the different components of the raw materials used. By Day 6, the fermented VFWS produced oil, visible on its surface, a result of the continuous breakdown of fish fats. The presence of proteins and oils from the fish can make the silage sticky to the touch. However, the unpleasant odor became less offensive from day 6, and the appearance became more consistent as the components further decomposed. The color started to become more uniform, indicating ongoing fermentation process. From Day 7 to Day 14 the fermented VFWS became odorless. By Day 14, the silage had transformed into a semi-liquid with a uniform dark brown color due to the oxidation of organic matter and the mixing of different vegetable and fish components. These changes demonstrate the effectiveness of the fermentation process in stabilizing and homogenizing the waste materials, resulting in an odorless product suitable as feed additive to Nile tilapia.

3.2 14-Day pH Measurements:

Figure 3 shows the pH levels of fermented vegetable and fish waste silage over 14 days, with a standard pH of 6 as reference. Initially, the pH drops quickly from 4.9 on day 1 to 4.5 by day 3, indicating that the fermentation process effectively lowers the pH, although not into the optimal range of 2-4. Over the following days, the pH fluctuates slightly between 4.5 to 5.2, but consistently stays below 6, demonstrating ongoing acid production and effective preservation. From day 9 onwards, the pH stabilizes between 4.5 and 4.9, indicating a stable phase of fermentation with balanced acid production and consumption. Maintaining a lower pH, ideally between 2 and 4, is crucial for silage. This lower pH range inhibits the growth of pathogens and spoilage organisms, ensuring the silage safe and stable over time (Libonatti, Agüería, & Breccia., 2023). Additionally, the acidic environment helps preserve the nutritional value of the silage by slowing down the degradation processes. The fermentation process, driven by lactic acid bacteria converting sugars into lactic acid, effectively reduces the pH and indicates successful preservation efforts.

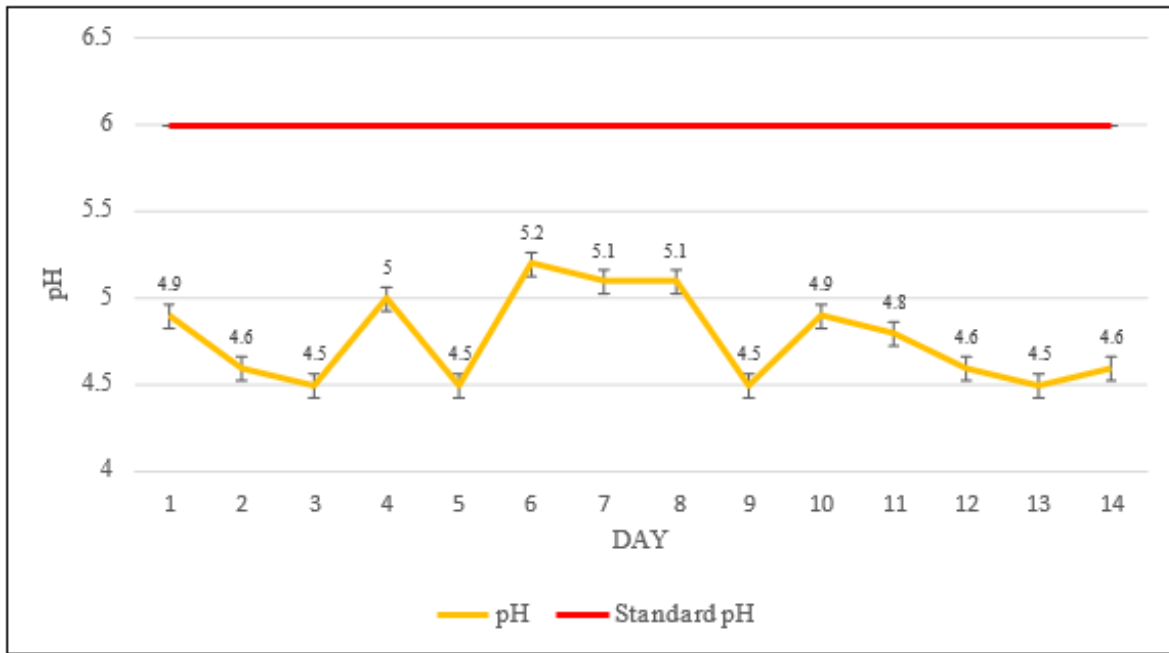


FIGURE 3: Mean pH levels of fermented VFWS for two (2) weeks

3.3 14-Day Temperature Measurements:

The 14-day temperature observation of fermented vegetable and fish waste silage shows in figure 4. Initially, at 26°C on Day 1, temperatures remain within the optimal range for silage fermentation. Notable increase in temperature on Day 5,6, and 9 to 28.3°C, 28.6°C, and 30.6°C, respectively, may have accelerated fermentation, promoting faster acidification and nutrient preservation. This conform with the study of Li et al. (2019), the temperature during ensiling is approximately 28°C particularly in tropical areas. Despite minor decrease in temperature on Day 4, 7 and 11, the overall temperature range remains acceptable to efficient fermentation suggest an effective process, preserving the nutritional integrity of the silage throughout the observation period. The temperature in the present study agreed with the observation of Peñarubia (2020) who recommended of 25°C to 40°C for ideal fermentation environment.

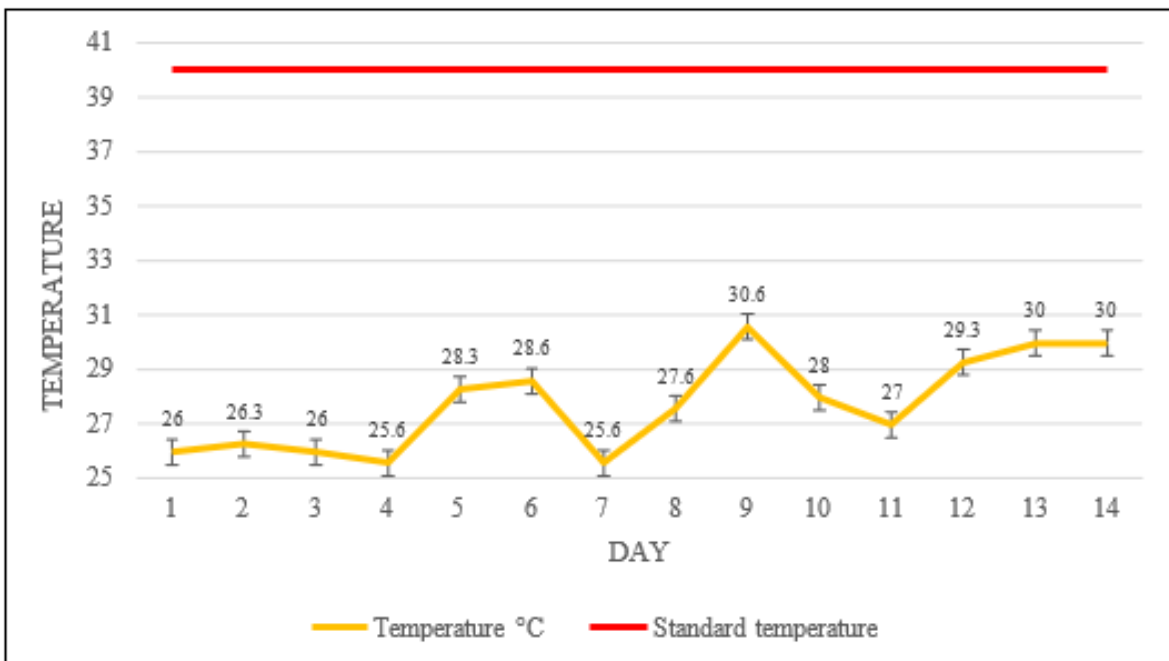


FIGURE 4: Mean temperature levels of fermented VFWS for two (2) weeks

3.4 Chemical Composition of Experimental Diets:

TABLE 1
COMPARATIVE CHEMICAL ANALYSIS OF THE TREATMENT DIETS, % DM

Parameter							
Treatment	CF (%)	VFWS (%)	Crude Protein	Crude Fat	Crude Fiber	Ash	Moisture
I	100	0	26.5 ± 0.3	6.3 ± 0.4	7.3 ± 0.9	12.8 ± 0.5	8.3 ± 0.1
II	90	10	23.8 ± 0.8	5.8 ± 0.7	6.6 ± 0.6	12.2 ± 0.1	14.1 ± 0.3
III	85	15	21.1 ± 0.1	6.0 ± 0.6	6.1 ± 0.3	11.4 ± 0.3	19.2 ± 0.9
IV	80	20	20.9 ± 0.6	5.5 ± 0.7	6.0 ± 0.9	11.4 ± 0.5	20.3 ± 0.5

The comparative analysis of the different treatment diets and its corresponding parameters: crude protein, crude fat, ash, and moisture was shown in Table 1. Treatment I, representing the control group (100% Commercial Feeds), exhibits the highest levels of crude fiber (7.3%) and crude protein (26.5%), while the introduction of vegetable and fish waste silage (VFWS) in Treatments II, III, and IV results in a gradual decrease in both parameters. Interestingly, the inclusion of VFWS leads to an increase in ash content across treatments, suggesting a higher mineral content in the substrate. Moreover, moisture content shows a consistent increase with the addition of VFWS, indicating its higher moisture content compared to the original feed. It is interesting to note that while there was a decreasing nutrient content as replacement level by VFWS increases to 20%, a comparable growth rate and tendency to increase in survival rate was still evident when a feeding trial was done to Tilapia during their early growth stage. This suggest that there might be valuable nutrients present in the VFWS which served as an offsetting effect on possible nutrients that were sacrificed from the commercial diet.

3.5 Growth Performance of Nile tilapia:

3.5.1 Survival Rate:

TABLE 2
SURVIVAL RATE OF NILE TILAPIA FINGERLINGS FED WITH VARYING LEVELS OF VFWS AFTER 30-DAYS OF FEEDING

Treatment	Survival Rate (%)			Mean (± SE)
	R1	R2	R3	
I	80	80	50	70± 10.00 ^{ns}
II	60	100	40	66.67± 17.64 ^{ns}
III	80	90	70	80± 5.77 ^{ns}
IV	50	60	70	60± 5.77 ^{ns}
<i>P-value</i>				0.6436 ^{ns}

*Significant at P<0.05

^{ns} Not significant

Table 2 shows the average survival rates for each of the different treatments. Across treatments, there was no statistically significant difference (P>0.05) in the mean survival rates. With a mean value of 80%, Treatment III had the highest percentage survival rate, indicating that the amount of silage incorporated in this treatment was most favorable for the fingerlings. TI (Control) and TII had comparable survival rates with a mean value of 70% and 66.67%, respectively, suggesting these silage levels were similarly effective. Treatment IV had the lowest survival rate with a mean value of 60%, which might imply that the silage incorporation level in this treatment was less optimal for the survival of fingerlings.

These findings conform with Asefa, Melaku & Tsige (2021) that incorporating fish silage into the diets of Nile tilapia fries has no significant difference in terms of survival rate with 83.3%, which confirm the viability of fish waste silage as a sustainable feed additive that promotes growth and survival without compromising feed efficiency, indicate that a 20% inclusion of fish silage is ideal for early-stage Nile tilapia.

3.5.2 Specific Growth Rate:

TABLE 3
SPECIFIC GROWTH RATE OF NILE TILAPIA FINGERLINGS FED WITH VARYING LEVELS OF VFWS AFTER 30-DAYS OF FEEDING

Treatment	Specific Growth Rate (%)			Mean (\pm SE)
	R1	R2	R3	
I	0.1	0.8	0.9	0.60 \pm 0.25 ^{ns}
II	0.3	0.2	1.2	0.57 \pm 0.32 ^{ns}
III	0.1	0.6	0.8	0.50 \pm 0.21 ^{ns}
IV	0.5	0.1	0.2	0.27 \pm 0.12 ^{ns}
<i>P-value</i>				0.7525

*Significant at $P < 0.05$

^{ns} Not significant

Specific growth rates of Nile tilapia fingerlings given with diets supplemented with varying levels of VFWS are shown in Table 3. The results showed no significant difference among the treatments, respectively. Though statistically not significant, Nile tilapia fed with TI had a numerically higher SGR of 0.6%, indicating that the growth rate of the fingerlings was most optimal under this treatment. Treatment II also showed a relatively high SGR with 0.5667%, closely following Treatment I. Treatment III had a moderate SGR with 0.5%, which was slightly lower than Treatments I and II. Treatment IV had the lowest SGR with 0.2667%, suggesting that the level of silage in this treatment was less effective in promoting growth. Similarly, in the study of Soltan & El-Laithy (2008), found that replacing up to 30% of dietary protein made from fish waste, tomato, and potato by-products (FTPS) as a protein source in Nile tilapia diets had no significant effect on final body weight, body length, weight gain, and specific growth rate of Nile tilapia.

3.5.3 Absolute Growth Rate:

TABLE 4
ABSOLUTE GROWTH RATE OF NILE TILAPIA FINGERLINGS FED WITH VARYING LEVELS OF VFWS AFTER 30-DAYS OF FEEDING

Treatment	Absolute Growth Rate (g/d)			Mean (\pm SE)
	R1	R2	R3	
I	0.01	0.07	0.08	0.05 \pm 0.02 ^{ns}
II	0.02	0.02	0.1	0.04 \pm 0.03 ^{ns}
III	0.01	0.05	0.08	0.04 \pm 0.02 ^{ns}
IV	0.06	0.01	0.01	0.02 \pm 0.0 ^{ns}
<i>P-value</i>				0.8357

*Significant at $P < 0.05$

^{ns} Not significant

Data on absolute growth rate (AGR) are shown in Table 4. The fingerlings fed with commercial feeds (TI) showed the highest AGR with 0.0533 g/day, indicating the best growth performance in terms of weight gain per day. Treatments II and III had identical AGR (0.0467 g/day), which were slightly lower than Treatment I. Treatment IV had the lowest AGR (0.0267 g/day), indicating the least favorable weight gain. The *P-value* of 0.8357 suggests that the differences in AGR among the treatments are not statistically significant. This indicates that replacing with VFWS from 10 to 20% level of substitution can still be comparable to the pure commercial diet. Ahmad et al. (2020) found that replacing 50% of soybean meal with tilapia viscera silage did not affect the percent weight gain, average weight gain, specific growth rate, and feed conversion of Nile tilapia. This suggests that tilapia diets containing fermented silage can partially replace FM without adverse effects on tilapia growth performance and feed intake.

3.6 Feed Conversion Ratio:

The FCR values of Nile tilapia fingerlings fed with supplemented diets with varying levels of VFWS are presented in Table 5. Treatment II had the best FCR of 2.00, meaning the fish were most efficient in converting feed into body mass under this treatment, followed by treatment I with an FCR of 2.67. Treatment III had a numerically higher value of 3.33, indicating less efficiency compared to Treatment I and II. Treatment IV had the highest FCR of 4.17, suggesting the least efficiency in feed conversion. This is similar to Anizah, Manaf & Halaliyah (2021), the FCR of fermented fish waste with 40% protein level ranging from 1.78 to 2.85 for all dietary treatments. Finally, no significant differences ($P>0.05$) were observed in the mean feed conversion ratio among all the diets given to Nile tilapia fingerlings indicating a significant feed savings to be achieved by fisherfolks that can be maximized due to a level of up to 20% replacement of the commercial diet. This corresponds to the findings of Srour (2009), who did not find any significant changes ($P>0.05$) in the feed conversion ratio between the FWSHP and the control group.

TABLE 5
FEED CONVERSION RATIO OF NILE TILAPIA FINGERLINGS FED WITH VARYING LEVELS OF VFWS AFTER 30-DAYS OF FEEDING

Treatment	Feed Conversion Ratio			Mean (\pm SE)
	R1	R2	R3	
I	6	1	1	2.67 \pm 1.67 ^{ns}
II	3	2	1	2 \pm 0.58 ^{ns}
III	8	1	1	3.33 \pm 2.3 ^{ns}
IV	1.6	7	3.9	4.1 \pm 1.56 ^{ns}
<i>P-value</i>				0.8163 ^{ns}

*Significant at $P<0.05$

^{ns} Not significant

3.7 Total Weight Gain of Nile tilapia fingerlings:

TABLE 6
MEAN WEIGHT OF NILE TILAPIA FINGERLINGS BEFORE AND AFTER BEING FED WITH DIETS CONTAINING VARYING LEVELS OF VFWS

Treatment	Initial Weight (g)	Final Weight (g)	Weight Gain (g)
I	8.90 ^{ns} (\pm 0.59)	10.59 ^{ns} (\pm 0.15)	1.69 ^{ns} (\pm 0.69)
II	7.30* (\pm 0.51)	8.62* (\pm 0.24)	1.31 ^{ns} (\pm 0.72)
III	9.27 ^{ns} (\pm 0.82)	10.67* (\pm 0.53)	1.39 ^{ns} (\pm 0.63)
IV	10.07* (\pm 0.29)	10.87* (\pm 0.64)	0.80 ^{ns} (\pm 0.43)
<i>Mean</i>	8.89 (\pm 0.039)	10.19 (\pm 0.33)	1.30 (\pm 0.06)
<i>P-value</i>	0.0544	0.0229	0.7951

*Significant at $P<0.05$

ns Not significant

The initial and final weight of Nile tilapia fingerlings fed with different inclusion of VFWS in the fish diet for 30 days are presented in Table 6. For the initial weight, a numerically higher value was recorded in Nile tilapia fed with T4 with 10.07g among the treatments. For final weight at 30 days, Nile tilapia fingerlings fed with T4 showed a higher value of 10.87g compared to other treatments. The table compare the initial and final weights of Nile tilapia fingerlings across different treatment. For initial weights, T2 (7.30 \pm 0.51) and T4 (10.07 \pm 0.29) shows a significant difference ($p<0.05$). In final weights, significant differences are observed between T2 (8.62 \pm 0.24) and both T3 (10.67 \pm 0.53), and T4 (10.87 \pm 0.64), suggesting that the treatment in T2 significantly affects the growth performance of the fingerlings compared to T3 and T4. However, no significant differences were found between other treatments. For the weight gain, a numerically higher value was recorded in Nile tilapia

fingerlings fed with T2 compared to T4, which had the lowest weight gain. T1 and T3 showed a similar weight gains, with T1 yielding the highest weight gain but statistically insignificant ($P>0.05$) during all feeding period across different treatments.

TABLE 7
EFFECT OF DIETARY TREATMENTS ON INITIAL AND FINAL WEIGHT OF NILE TILAPIA FINGERLINGS

	T-Statistics	P-Value
Initial and Final Weight (g)	-7.02	0.0059*

**Significant at 5% level*

Table 7 shows the results of a paired sample t-test comparing the initial and final weights of the fingerlings. The weight of Nile tilapia increased significantly for each treatment group during the 30-day feeding period. A statistically significant difference ($P<0.05$) between the initial and final weights is shown by the t-test findings ($t(3) = -7.02$, $p = 0.0059$). This implies that the fermented silage diet could be a beneficial feed additive option for Nile tilapia farming, potentially offering a sustainable and cost-effective feeding strategy. This suggests that the diet of fermented vegetable and fish waste silage is effective in promoting weight gain in these fish. These results correspond with Noaman et al. (2015) findings, showing that a 75% inclusion of fermented soybean in Nile tilapia fingerlings' diets led to a significant increase in their final weights.

3.8 Economic Analysis of Partial Substitution of Commercial Aquafeed by VFWS:

Table 8 shows the economic benefit of utilizing VFWS at varying replacement levels in the commercial aqua diet. Considering the prohibitive price of the aquafeeds at Php 43.00/kg. Nowadays, maximum inclusion of environment friendly agro by-products particularly undergoing sustainable post-harvest processing such as fermentation of vegetable leftovers and fish viscera is indispensable. The VFWS in the present experiment proved to be acceptable to tilapia in the early growth stage as shown by comparable growth rate and tendency to increase their survival rate. The savings on feed cost generated as replacement levels increased from 10%, 15%, and 20% was Php 310.00, Php 465.00, Php 620.00, respectively. The percentage reduction rates from the commercial diet from 7.21%, 10.81%, and 14.42%, respectively was also documented. At the commercial level for a fisherfolk consuming 10 tons of aquafeed per month equivalent to 11,111 Nile tilapia growers feeding at 14.42% savings for 20% substitution of VFWS to the commercial diet, could result in saving of Php 62,000 per month or Php 744,000 per year. Therefore, the economic benefit of utilizing VFWS is immense and promising. The incorporation of VFWS for Nile tilapia diets results in a significant decrease in feed expenses. This conforms to the results of Soltan & El-Laithy (2008) that up to 22.43% in feed costs per kilogram by including fish silage containing tomato and potato by-products. Similarly with the study of Soltan et al. (2017) achieved a 15.59% reduction in feeding costs by substituting 50% of the Nile tilapia diet with fermented fish by-product silage.

TABLE 8
ECONOMIC BENEFIT OF VFWS AT VARYING REPLACEMENT LEVELS OF CF DIET

	Cost/100kg CF (Php)	Cost/kg VFWS (Php)	Total Cost (Php)	Savings (Php)	Percentage Reduction
T1 (100% CF)	4,300	-	4,300	-	-
T2 (90% CF + 10% VFWS)	3,870	120.00*	3,990	310	7.21%
T3 (85% CF + 15% VFWS)	3,655	180	3,835	465	10.81%
T4 (80% CF + 20% VFWS)	3,440	240	3,680	620	14.42%

**Transportation cost, labor month/day, equipment*

3.9 Comparative Cost of Feeding Commercial Feeds and Vegetable and Fish Waste Silage:

TABLE 9
COMPARATIVE COST AND RETURN ANALYSIS OF 1,000 HEAD TILAPIA GROW-OUT FED WITH PURE COMMERCIAL AQUA DIET AND 85% CF AND 15% VFWS

100% Commercial Feeds		85% CF and 15% VFWS	
Revenue			
Sales of Tilapia	₱27,000.00	₱27,000.00	
Production Expenses			
Cost of Fingerlings	₱1,000.00	₱1,000.00	
Total Cost of Feeds	₱8,397.9	₱7,138.215	
Total Expenses	₱9,397.9	₱8,138.215	
Net Income	₱17,602.1	₱18,861.785	

**Fingerling cost, cost of CF, feed composition for 85% CF and 15% VFWS, market price of tilapia, feed conversion ratio*

Incorporating 15% VFWS into an 85% CF increases profitability compared to using 100% CF alone as shown in Table 9. Both feeding practices generated the same revenue ₱27,000.00, based on 80% survival rate. However, the production expenses varied due to the feed costs. For 100% CF, the total feed costs were ₱8,397.9, whereas ₱7,138.215 was the total cost for the 85% CF and 15% VFWS. The total expenses were lower, leading to a higher net income of ₱18,861.785 for the 85% CF and 15% VFWS, compared to ₱17,602.1 for 100% CF. After four (4) months of feeding, using 85% CF and 15% VFWS saved ₱1,259.685 compared to using pure CF, while maintaining the same feed conversion ratio (1.085), indicating that the substitution does not compromise feed efficiency. The findings show that substituting a portion of commercial feed with VFWS not only reduces feed costs but also enhances profitability without compromising the growth and market value of the fish. Additionally, the use of VFWS promotes sustainability by utilizing waste products effectively, thus reducing environmental impact. This feeding strategy offers a practical and scalable solution to optimize the feed costs and improve financial income for tilapia farmers while supporting sustainable farming practices.

IV. SUMMARY

Nile tilapia (*Oreochromis niloticus*) is a valuable freshwater fish species that requires high-quality protein sources in its diet. The need for sustainable protein sources in aquaculture has intensified, driven by the need to reduce reliance on fish meal (FM) as the primary protein component in aquafeeds. Cost constraints further necessitate strategic utilization of alternative protein sources. Therefore, alternative protein sources from vegetable and fish wastes are explored in this study. The study was conducted to determine the effectiveness of incorporating fermented dietary vegetable and fish waste silage into the aquafeeds. The growth performance of the fingerlings was observed over a 30-day feeding trial with varying levels of silage incorporation. Growth parameters measured included survival rate (SR), specific growth rate (SGR), absolute growth rate (AGR), and feed conversion ratio (FCR).

The results showed that there were no significant differences among treatments for all growth parameters. Despite this, T3 with 15% inclusion level of VFWS achieved the highest SR at 80%. T1 which is control, showed the highest SGR and AGR values of 0.6% and 0.0533 g/d respectively. T2 had the most efficient feed utilization, indicated by the lowest FCR. On the other hand, the results of the initial and final weights of the fingerlings indicate a statistically significant difference ($P < 0.05$) between initial and final weight over the 30-day feeding period. Therefore, incorporating up 20% of VFWS does not significantly impact the growth parameters of Nile tilapia fingerlings.

V. CONCLUSION

Growth parameters of Nile tilapia fingerlings were not significantly different between treatments when fermented vegetable and fish waste silage was added to their meals. Still, T1 increased specific growth rates, T2 optimized feed conversion ratio, and T3 with a 15% inclusion level of VFWS in commercial feed increased fingerling survival rates. These findings suggest that silage is a potential feed additive for Nile tilapia. Further research could explore the long-term impacts of utilizing the VFWS to

improve the sustainability and cost-effectiveness of tilapia farming.

VI. RECOMMENDATIONS

For future experiments, the following recommendations are made:

- 1) Pelletize the fermented vegetable and fish waste silage to improve feed handling, storage and uniformity in the diets provided to the fish;
- 2) Conduct feeding trials in fishponds for actual practices to better understand and improve feeding practices;
- 3) Expand the study to include different fish species to generalize the applicability of VFWS in aquafeeds;
- 4) Test the Hepatosomatic Index (HSI) and the Stomach Somatic Index (SSI) to assess the health impacts of VFWS on fish growth; and,
- 5) Perform comprehensive water quality assessments to ensure optimal experimental conditions.

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