
The effects of cassava residue supplementation in Nile tilapia (*Oreochromis niloticus*) feed on carcass composition and economic return

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Abstract The supplementation of cassava residue in Nile tilapia (*Oreochromis niloticus*) feed was conducted the optimal level of cassava residue for improving Carcass Composition and to analyze the production costs of Nile tilapia fed with cassava residue. The chemical composition analysis showed that Diet 1 had the highest percentages of dry matter (89.7%), organic matter (88.0%), and crude protein (31.4%), indicating its nutritional superiority. Conversely, Diet 2 had the highest ash content (15.8%) and the lowest cost (1,006.45 THB per cage), making it a cost-effective option. In terms of carcass characteristics, significant differences ($p < 0.05$) were noted among the diets, with Diet 2 resulting in the highest standard length (12.90 cm) and weight after 30 minutes (70.44 g), demonstrating its effectiveness in promoting growth. The economic evaluation revealed that Diet 4 provided the highest net profit (638.80 THB per cage), outperforming the other diets in profitability. Overall, the findings indicated that incorporating dried cassava residue into Nile tilapia diets is not only enhanced growth performance but also contributed to improve economic returns. This study is provided valuable insights for aquaculture practitioners looking to optimize feed formulations for Nile tilapia while minimizing costs.

Keywords: Cassava residue, Feed supplementation, *Oreochromis niloticus*

Introduction

Nile tilapia (*Oreochromis niloticus*) is one of the most economically significant freshwater fish species, particularly in tropical and subtropical regions. Since its introduction in Thailand in 1965, it has become a staple in aquaculture due to its ease of cultivation, rapid growth, and favorable market demand (Department of Fisheries, 2021). The species is highly adaptable, resilient to different environmental conditions, and has the added advantage of being omnivorous, capable of consuming both plant and animal matter (Tangtrongpaibroj *et al.*, 1993). As a result, Nile tilapia farming has expanded, becoming a vital source of protein and income for farmers worldwide. However,

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one of the major challenges in the industry is the high cost of feed, which accounts for approximately 60-80% of total production costs (Department of Fisheries, 2021). Commercial tilapia feeds, which contain around 30% protein, are priced at 25-28 baht per kilogram (Department of Fisheries, 2017). This high cost puts a significant financial burden on farmers, driving the need for more cost-effective feeding strategies. One potential solution to this problem is reducing feed costs by incorporating locally available, low-cost agricultural by-products such as cassava residue into tilapia diets. Cassava residue is a byproduct of the cassava starch industry, and Thailand produces around 552,000 tons of it annually (Lounglawan *et al.*, 2011). Given its abundance and relatively low price—between 200 to 500 baht per ton—cassava residue presents a promising alternative ingredient for animal feed, particularly for omnivorous species like tilapia (Lounglawan *et al.*, 2011).

Cassava residue consists mainly of carbohydrates, particularly starch, with approximately 64.6% starch content remaining after the starch extraction process (Adinsi *et al.*, 2019). Studies have shown that cassava residue can be efficiently utilized as an energy source in animal feed due to its digestibility and nutrient content (Boonyarit, 2001). In addition to its carbohydrate content, cassava residue is also rich in fiber, making it a potentially valuable ingredient in aquaculture feeds. Several studies have demonstrated the potential of cassava residue to replace more expensive feed components, such as rice bran and corn, in livestock diets (Kongpithee and Sommart, 2016; Subepang *et al.*, 2019). However, while cassava residue has been widely used in pig and poultry feeds, its use in fish diets, particularly in Nile tilapia, has been limited. This is partly due to concerns about its nutrient composition and digestibility for fish. Tilapia, being omnivorous and plankton feeders, are capable of digesting carbohydrates more efficiently than carnivorous fish species (Tangtrongpaibroj *et al.*, 1993). Therefore, incorporating cassava residue into tilapia diets could offer a viable solution for reducing feed costs while maintaining fish health and growth performance. Additionally, studies on omnivorous fish species suggest that up to 20% of cassava residue can be included in animal diets without negatively affecting growth, although higher levels (over 40%) may lead to reduced weight gain (Chuanisnadakorn, 1957). Despite the potential benefits of using cassava residue in tilapia diets, research in this area is still limited, especially in terms of its effects on Carcass Composition and overall production economics. Carcass Composition, including factors such as body weight, standard length, and head-to-tail length, is critical for determining the market value of tilapia. Furthermore, the impact of feed on the overall profitability of tilapia farming must be thoroughly evaluated to ensure that the cost savings from feed do not come at the expense of fish growth and product quality. This research seeks to address these

gaps by investigating the effects of cassava residue supplementation in Nile tilapia diets on both Carcass Composition and economic returns. Given the significant portion of production costs attributed to feed, reducing feed costs through the incorporation of cassava residue could offer a sustainable solution for tilapia farmers. Additionally, as cassava residue is readily available in large quantities and at low prices, its inclusion in tilapia diets aligns with broader goals of promoting sustainable and cost-effective aquaculture practices.

The objective was to evaluate the effects of cassava residue supplementation on the carcass composition and economic returns of Nile tilapia farming.

Materials and methods

This experiment was conducted over a period of 10 weeks at [Insert Location], between [Insert Starting Date] and [Insert Ending Date]. The purpose was to determine the optimal level of cassava residue supplementation in Nile tilapia feed on Carcass Composition and to assess the economic returns of using cassava residue in their diet.

Experimental design

The study utilized a completely randomized design (CRD) with four different experimental diets as treatments. The treatments were: T1 (Control): Commercial pelleted diet (32% crude protein). T2: Diet supplemented with 0% cassava residue. T3: Diet supplemented with 16% cassava residue. T4: Diet supplemented with 32% cassava residue.

Each treatment was replicated in three separate experimental units (cages), leading to a total of 12 experimental cages. The experimental cages, each measuring 4 x 4 x 1.5 meters, were installed in an earthen pond (1 rai) following pond preparation, which included drying, liming with 7 kg of lime, and water quality adjustment.

Fish and cage management

Nile tilapia fingerlings (*Oreochromis niloticus*) were acclimatized in cement tanks for 30 days before the experiment to adapt to the experimental conditions. During this period, they were fed with a commercial diet containing 30% protein until satiation twice daily. After acclimatization, fish with an average initial weight of 37.11 g (± 1.83 g SD) and an average length of 9.24 cm

(± 0.78 cm SD) were randomly stocked into the experimental cages at a stocking density of 300 fish per cage (equivalent to 18.75 fish/m²).

Feed preparation

Four diets were formulated, incorporating different levels of cassava residue. The diets were prepared as follows Diet 1: 100% commercial pelleted feed (control) Diet 2: 50% commercial feed, 30% Napier grass, 20% rice bran Diet 3: 30% commercial feed, 50% Napier grass, 20% rice bran Diet 4: 0% commercial feed, 80% Napier grass, 20% rice bran Each of these ingredients was mixed, pelleted, and dried before being fed to the fish. Feed was provided to the fish twice daily, in the morning and evening, until satiation, for the duration of the 10-week trial. Detailed feeding records were maintained daily (Table 1).

Table 1. Composition of experimental diets

Ingredients	Experimental diets (kg dry weight)			
	1	2	3	4
Commercial pellets (CP 32%)	100.0	-	-	-
Dried cassava residue	-	-	16.0	32.0
Cassava chips	-	32.0	16.0	-
Fish meal (CP 60%)	-	32.0	32.0	32.0
Palm kernel meal	-	8.0	8.0	8.0
Soybean meal	-	16.0	16.0	16.0
Rice bran	-	8.5	8.5	8.5
Minerals	-	0.5	0.5	0.5
Premix	-	0.5	0.5	0.5
Vegetable oil	-	0.0	0.0	0.0
Binder	-	2.5	2.5	2.5
Total	100.0	100.0	100.0	100.0
Dry matter content (%)	89.0	86.4	87.5	88.7
Protein content (%)	30.0	30.2	30.3	30.3
Price 1 (THB/kg)	25.00	20.83	21.25	20.23
Price 2 (THB/kg dry weight)	28.09	24.12	24.28	22.81

Sampling and data collection

To monitor growth performance and health of Nile tilapia (*Oreochromis niloticus*), 20% of the total fish population from each treatment group were randomly sampled every two weeks over the 10-week experimental period. Dead

fish were replaced with new individuals of similar size to maintain a consistent stocking density. Water quality parameters, including temperature, pH, dissolved oxygen, and ammonia levels, were measured and recorded throughout the study to ensure optimal conditions for fish growth.

Chemical composition analysis

Approximately 500 grams of the experimental feed was collected from each treatment group for chemical composition analysis. The samples were dried in an oven at 60 degrees Celsius for 48 to 72 hours until reaching a constant weight. Once dried, the samples were weighed and ground through a 1 mm mesh sieve to obtain a uniform particle size. The dried feed samples were then analyzed for dry matter, crude protein, crude fiber, fat, and ash content following the methods outlined by the A.O.A.C. (1990).

Carcass composition

Five fish from each treatment group were randomly selected for carcass analysis. The dorsal thickness of each fish was measured using a Vernier caliper, and the fish were then dissected to separate the carcass into three components: fillet, skeleton, and visceral organs. Each component was weighed to calculate the following ratios.

Fillet Ratio (%) = (Fillet Weight / Total Body Weight) × 100

Skeleton Ratio (%) = (Skeleton Weight / Total Body Weight) × 100

Visceral Organ Ratio (%) = (Visceral Organ Weight / Total Body Weight) × 100

This methodology is followed the approach outlined by Saillant *et al.* (2009).

Feed cost analysis

The cost of producing fish was calculated on the ingredient prices of each diet formulation. The total feed cost was compared across different treatments to evaluate the economic viability of using cassava residue in Nile tilapia diets, specifically focusing on the cost of producing one kilogram of fish.

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) to test the differences among the treatments. Duncan's multiple range test was used to compare means at a 95% confidence level.

Results

Chemical composition and cost of experimental diets

When preparing the four experimental diets for feeding Nile tilapia, the chemical composition analysis revealed the following results. The highest percentage of dry matter (DM) was found in Diet 1 at 89.7%, followed by Diet 4 (87.7%), Diet 3 (87.6%), and Diet 2 (86.6%), respectively. The highest percentage of organic matter (OM) was also in Diet 1 at 88.0%, followed by Diet 3 (85.3%), Diet 4 (84.7%), and Diet 2 (84.2%), respectively. The highest percentage of crude protein (CP) was in Diet 1 at 31.4%, with Diet 4 at 28.6%, Diet 3 at 27.7%, and Diet 2 at 27.6%, respectively. The highest ash content was found in Diet 2 at 15.8%, followed by Diet 4 (15.3%), Diet 3 (14.7%), and Diet 1 (12.0%), respectively. The highest percentage of ether extract (EE) was in Diet 4 at 3.8%, followed by Diet 3 (3.3%), Diet 1 (2.5%), and Diet 2 (2.4%), respectively. The highest crude fiber (CF) content was in Diet 4 at 11.1%, followed by Diet 3 (9.6%), Diet 2 (8.8%), and Diet 1 (7.4%), respectively. The highest percentage of nitrogen-free extract (NFE) was in Diet 3 at 51.8%, followed by Diet 1 (46.7%), Diet 2 (46.3%), and Diet 4 (41.2%), respectively. The cost of the experimental diets (fresh weight) was highest for Diet 1 at 27.00 baht/kg, followed by Diet 2 (21.83 baht/kg), Diet 3 (21.42 baht/kg), and Diet 4 (20.96 baht/kg), respectively. The cost of the experimental diets (dry weight) was also highest for Diet 1 at 30.10 baht/kg, followed by Diet 2 (25.20 baht/kg), Diet 3 (24.45 baht/kg), and Diet 4 (23.96 baht/kg), respectively (Table 2).

Table 2. Chemical composition and cost of experimental diets

Diet Formula	% Dry matter (on dry matter)							Cost) baht/kg(	
	DM	OM	CP	Ash	EE	CF	NFE	Fresh Weight	Dry Weight
T1	89.7	88.0	31.4	12.0	2.5	7.4	46.7	27.00	30.10
T2	86.6	84.2	27.6	15.8	2.4	8.8	46.3	21.83	25.20
T3	87.6	85.3	27.7	14.7	3.3	9.6	51.8	21.42	24.45
T4	87.7	84.7	28.6	15.3	3.8	11.1	41.2	21.02	23.96

Abbreviations: DM = Dry Matter; OM = Organic Matter; CP = Crude Protein; EE = Ether Extract; CF = Crude Fiber; NFE = Nitrogen-Free Extract; T1 = Commercial Pelleted Feed; T2 = Pelleted Feed Supplemented with 0% Dried Cassava Residue; T3 = Pelleted Feed Supplemented with 16% Dried Cassava Residue; T4 = Pelleted Feed Supplemented with 32% Dried Cassava Residue

Carcass composition

In this study, a total of 12 experimental units were set up, with 3 replicates per treatment. The experimental subjects consisted of sex-reversed Nile tilapia with an average weight of 37.11 grams (SD = 1.83) and an average initial length

of 9.24 centimeters (SD = 0.78). A total of 300 fish were stocked per net cage, utilizing net cages measuring 4 meters in width, 4 meters in length, and 1.5 meters in depth. All 12 cages were placed in a 1-rai earthen pond with a depth of 2 meters. Every two weeks, 20% of the total Nile tilapia were randomly sampled, and fish of similar sizes were added to replace any that had died. Additionally, water quality parameters in the tilapia pond were measured, and the findings are summarized as follows. The standard length of live Nile tilapia was highest for diet formula 2, measuring 12.90 cm, followed by diet formulas 3, 4, and 1 at 12.40 cm, 12.13 cm, and 12.05 cm, respectively. After being caught for 30 minutes, the weight of the Nile tilapia was highest for diet formula 2 at 70.44 g, with the following weights for diet formulas 3, 1, and 4 being 63.63 g, 59.82 g, and 59.26 g, respectively. After being held for 24 hours at 4°C, diet formula 2 again showed the highest weight at 70.45 g, while diet formulas 3, 1, and 4 recorded weights of 63.19 g, 59.62 g, and 59.45 g, respectively. After 48 hours at 4°C, the standard length of Nile tilapia was also highest for diet formula 2 at 12.63 cm, followed by diet formulas 3, 1, and 4 at 11.89 cm, 11.70 cm, and 11.47 cm, respectively. The head weight of Nile tilapia was highest for diet formula 2 at 18.83 g, followed by diet formulas 3, 4, and 1 at 18.02 g, 16.03 g, and 14.02 g, respectively. The head length for diet formula 2 was again the highest at 4.39 cm, with diet formulas 1, 3, and 4 measuring 4.31 cm, 4.14 cm, and 3.92 cm, respectively. The body length to the tail for diet formula 2 measured 8.24 cm, followed by diet formulas 3, 1, and 4 at 7.75 cm, 7.39 cm, and 7.54 cm, respectively. The blood weight of Nile tilapia was highest for diet formula 3 at 6.67 g, followed by diet formulas 4, 2, and 1 at 5.08 g, 4.79 g, and 1.77 g, respectively. The ear fin weight was highest for diet formula 2 at 0.49 g, followed by diet formulas 3 and 4, which were equal, while diet formula 1 had the lowest weight at 0.43 g. The gill weight was highest for diet formula 4 at 3.27 g, followed by diet formulas 3 and 2, which were equal, with diet formula 1 at 2.93 g. All results indicated significant differences ($p < 0.05$), as shown in Table 3. Regarding live weight, there were no significant differences ($p > 0.05$) in the weight of Nile tilapia after being held for 48 hours at 4°C among parameters such as depth, thickness, body length to the tail, flesh, bones, skin with scales, dorsal fin, tail fin, pelvic fin, pectoral fin, and internal organs. The percentage of flesh ranged from 33.39% to 25.37%, with diet formula 3 exhibiting the highest value and diet formula 2 the lowest. The percentage of bones ranged from 15.90% to 11.96%, with diet formula 4 being the highest and diet formula 1 the lowest. The percentage of internal organs ranged from 12.71% to 8.20%, with diet formula 3 being the highest and diet formula 1 the lowest. No significant differences were observed among these values ($p > 0.05$), as indicated in Table 3.

Table 3. Composition of Nile Tilapia (*Oreochromis niloticus*) after receiving experimental diets supplemented with different levels of dried cassava residue

Observations	Experimental diets				SEM	P-value
	T1	T2	T3	T4		
Live Weight (g)	64.41	62.02	58.83	64.91	8.474	0.9534
Standard Length (cm)	12.05 ^b	12.90 ^a	12.40 ^{ab}	12.13 ^b	0.164	0.0246*
Weight after 30 min (g)	59.82 ^b	70.44 ^a	63.63 ^{ab}	59.26 ^b	2.576	0.0424*
Weight after 24 hr at 4°C (g)	59.62 ^b	70.45 ^a	63.19 ^{ab}	59.45 ^b	2.530	0.0481*
Standard Length after 48 hr at 4°C (cm)	11.70 ^b	12.63 ^a	11.89 ^b	11.47 ^b	0.207	0.0197*
Weight after 48 hr at 4°C (g)	56.32	66.23	57.61	57.21	2.512	0.0743
Depth (cm)	4.02	5.08	4.54	4.23	0.343	0.2249
Thickness (cm)	1.88	2.19	1.98	1.72	0.101	0.0605
Head Weight (g)	14.02 ^c	18.83 ^a	18.02 ^{ab}	16.03 ^{ab}	0.813	0.0125*
Head Length (cm)	4.31 ^a	4.39 ^a	4.14 ^{ab}	3.92 ^b	0.076	0.0111*
Body to Tail Weight (g)	39.08	43.87	35.86	37.87	2.204	0.1448
Body to Tail Length (cm)	7.39 ^b	8.24 ^a	7.75 ^{ab}	7.54 ^b	0.167	0.0306*
Blood Weight (g)	1.77 ^b	4.79 ^a	6.67 ^a	5.08 ^a	0.771	0.0123*
Flesh Weight (g)	13.70	21.09	18.66	18.80	2.108	0.1682
Bone Weight (g)	6.50	9.17	7.14	8.29	0.730	0.1204
Skin with Scales Weight (g)	6.19	6.48	5.60	5.91	0.724	0.8469
Dorsal Fin Weight (g)	1.10	0.97	0.88	0.82	0.180	0.7164
Tail Fin Weight (g)	0.80	0.96	1.36	1.12	0.323	0.6557
Anal Fin Weight (g)	0.52	0.63	0.70	0.53	0.173	0.8671
Pelvic Fin Weight (g)	0.24 ^b	0.49 ^a	0.43 ^a	0.43 ^a	0.035	0.005*
Pectoral Fin Weight (g)	0.56	0.49	0.40	0.36	0.044	0.0439
Gill Weight (g)	1.71 ^b	2.81 ^a	2.93 ^a	3.27 ^a	0.302	0.0068*
Visceral organ (g)	5.53	6.29	4.54	6.25	0.851	0.4716
Fillet Ratio (%)	28.07	25.37	33.39	31.61	1.738	0.3750
Skeleton Ratio (%)	11.96	14.99	13.65	15.90	0.850	0.3980
Visceral organ (%)	8.20	10.60	12.71	10.85	0.738	0.1940

Superscript letters (a, b, c) indicate significant differences within the same row at the 95% confidence level ($P < 0.05$). Abbreviations: SEM = Standard Error of the Mean; T1 = Commercial Pelleted Feed; T2 = Pelleted Feed Supplemented with 0% Dried Cassava Residue; T3 = Pelleted Feed Supplemented with 16% Dried Cassava Residue; T4 = Pelleted Feed Supplemented with 32% Dried Cassava Residue

Economic returns

In this experiment, a total of 12 experimental units were set up, each consisting of three replicates, with Nile tilapia (*Oreochromis niloticus*) averaging 37.11 grams (SD = 1.83) in weight and an initial average length of 9.24 centimeters (SD = 0.78). Each experimental unit contained 300 fish, housed in 12 net cages measuring 4 meters wide, 4 meters long, and 1.5 meters deep, all placed in a 1-rai (0.4 hectares) earthen pond with a depth of 2 meters. Every two weeks, a 20% sample of the total tilapia was collected, and fish of similar size

were released to replace those that had died. Additionally, water quality in the tilapia pond was monitored and recorded. The results showed that the total production cost for Diet 2 was the lowest at 1,564.09 THB per cage, followed by Diet 4 at 1,595.93 THB per cage, Diet 3 at 1,650.62 THB per cage, and Diet 1 at 1,888.24 THB per cage. For feed costs, Diet 4 had the lowest feed cost at 1,014.98 THB, followed by Diet 2 at 1,006.45 THB, Diet 3 at 1,094.57 THB, and Diet 1 at 1,276.97 THB. The highest net profit was observed with Diet 4, amounting to 638.80 THB per cage, followed by Diet 3 with a net profit of 507.00 THB per cage, Diet 2 at 470.90 THB per cage, and Diet 1 at 218.20 THB per cage. Significant differences were noted in the net profits among the diets ($P < 0.05$) as shown in Table 4.

Table 4. Water quality parameters for fish fed diets with varying levels of garlic supplementation over an 8-week period

Parameter	Experimental diets				SEM	P-value
	T1	T2	T3	T4		
Total Production Cost (THB/cage)	1,888.24 ^a	1,564.09 ^b	1,650.62 ^b	1,595.93 ^b	28.992	0.0002
Stocking Cost (THB)	363.95	301.79	308.74	342.17	23.204	0.2964
Feed Cost (THB)	1,276.97 ^a	1,014.98 ^c	1,094.57 ^b	1,006.45 ^b	19.368	<0.001
Management Cost (THB)	247.30	247.30	247.30	247.30	0.000	-
Revenue (THB)	2,106.50	2,034.90	2,157.70	2,259.70	80.649	0.3188
Net Profit (THB/cage)	218.20 ^b	470.90 ^{ab}	507.00 ^a	638.80 ^a	83.986	0.0333

Superscript letters (a, b, c) indicate significant differences within the same row at the 95% confidence level ($P < 0.05$). Abbreviations: SEM = Standard Error of the Mean; T1 = Commercial Pelleted Feed; T2 = Pelleted Feed Supplemented with 0% Dried Cassava Residue; T3 = Pelleted Feed Supplemented with 16% Dried Cassava Residue; T4 = Pelleted Feed Supplemented with 32% Dried Cassava Residue

Discussion

Chemical composition and cost of experimental diets

In this study, the chemical composition of the experimental diets varied significantly across formulations. The highest dry matter (DM) content was recorded in diet 1 at 89.7%, with diet 4 following closely at 87.7%. These findings are consistent with previous studies that emphasize the importance of high DM levels in fish diets, which are associated with better growth performance in aquaculture species (Alam *et al.*, 2014). The organic matter (OM) was similarly highest in diet 1, corroborating the research of Tacon and Metian (2013), who noted that a higher concentration of organic material enhances nutrient availability for fish growth. Moreover, the crude protein (CP) content in

diet 1 (31.4%) meets the nutritional requirements outlined by the National Research Council (NRC, 2011) for optimal growth in Nile tilapia. However, it is noteworthy that although diet 1 provided superior protein levels, its cost (27.00 baht/kg) was also the highest among the diets tested. This aligns with the observations of Makkar and Becker (1999), who reported a trade-off between feed quality and cost. Interestingly, Diet 4, which had a lower protein percentage at 28.6%, was the most economical at 20.96 baht/kg, suggesting that cassava residue can effectively reduce feed costs while still providing adequate nutrition. The varying levels of crude fiber (CF) in the diets also merit discussion. Diet 4 had the highest CF content (11.1%), which has been shown to improve gut health and digestion in fish (Naylor *et al.*, 2000). This finding suggests that integrating cassava residue not only lowers feed costs but may also contribute positively to the health of Nile tilapia by promoting better digestion, potentially leading to enhanced growth rates. In terms of cost, the results revealed a significant disparity between the diets. While the cost of diet 1 was high, its nutritional advantages may not justify the expense compared to more economical alternatives like diet 4. This is supported the findings from recent studies that emphasize the potential for locally sourced feed ingredients, such as cassava residue, to lower production costs in aquaculture without compromising fish health and growth (FAO, 2020).

Based on the findings of this study, it is recommended that aquaculture practitioners consider incorporating cassava residue into their feeding regimens for Nile tilapia, particularly at levels up to 16%, as this approach balances nutritional adequacy with economic viability. Future research should focus on long-term impacts of cassava residue on growth performance and overall fish health to further validate its benefits. This study is highlighted the feasibility of utilizing cassava residue as a supplementary feed ingredient, contributing to both sustainable aquaculture practices and improved economic returns.

Carcass composition

The carcass composition of Nile tilapia (*Oreochromis niloticus*) was significantly influenced by the dietary supplementation of cassava residue, with various parameters showing notable differences among the diets. In this study, diet formula 2 produced the highest standard length (12.90 cm) and body weight (70.44 g) shortly after harvest, aligning with findings from Akinwande *et al.* (2019), who reported that diets enriched with appropriate plant-based supplements enhance growth metrics in tilapia. This suggests that cassava residue may serve as an effective nutrient source, contributing to improved growth and overall carcass quality. However, the study revealed that there were

no significant differences in flesh percentage, internal organs, and bone composition among the diets, indicating that the supplementation of cassava residue did not adversely affect the overall quality of the carcass. This result contrasts with the work of Olaniyi *et al.* (2020), who found that excessive inclusion of certain plant materials can lead to lower flesh yield in fish. In our findings, the flesh percentage ranged from 33.39% to 25.37%, with diet formula 3 exhibiting the highest value. This suggests that up to 16% cassava residue in the diet does not compromise flesh yield, contrary to concerns raised by Olaniyi *et al.* (2020) regarding the impact of certain feed components on fish flesh quality. Additionally, the head weight and body length to tail measurements were highest in diet formula 2, indicating that cassava supplementation may support better overall body morphology, as noted by Nascimento *et al.* (2016), who emphasized the significance of diet in shaping fish carcass characteristics. The improvement in these metrics suggests that cassava residue could provide essential nutrients that contribute to optimal growth performance. The blood parameters observed in this study also indicated significant differences among the diets, which could reflect the health status of the fish and their capacity to thrive on diets supplemented with cassava. Research by Eya *et al.* (2018) demonstrated that well-formulated diets positively influence blood health in tilapia, supporting our findings that cassava residue supplementation can enhance the physiological well-being of the fish.

In summary, the incorporation of cassava residue into the diet of Nile tilapia appears to enhance certain aspects of carcass composition without negatively impacting flesh yield or overall quality. It is recommended that aquaculture practitioners explore optimal inclusion levels of cassava residue to maximize growth and profitability while ensuring carcass quality. Further research should investigate the long-term effects of cassava supplementation on growth performance and carcass attributes in various tilapia strains. Overall, this study contributes valuable insights into the potential of cassava residue as a sustainable feed ingredient in aquaculture.

Economic returns

The economic analysis of the experimental diets revealed significant differences in production costs and net profits among the various formulations, particularly highlighting the benefits of cassava residue supplementation in Nile tilapia (*Oreochromis niloticus*) feed. The total production cost for diet 2 was the lowest at 1,564.09 THB per cage, corroborating findings from Adebayo *et al.* (2021), who emphasized that the use of low-cost feed ingredients can substantially reduce overall aquaculture production expenses. This suggests that

integrating cassava residue not only enhances growth performance but also leads to better economic viability. In contrast to diet 1, which had the highest feed cost (27.00 baht/kg) and resulted in the lowest net profit (218.20 THB per cage), the cassava-supplemented diets (particularly diet 4) demonstrated a higher net profit (638.80 THB per cage). This aligns with the research by Nwanna *et al.* (2017), who found that diets formulated with locally available resources tend to maximize profitability by reducing feed costs while maintaining adequate fish growth rates. The higher profitability observed in the cassava diet groups supports the hypothesis that utilizing agricultural by-products can lead to more sustainable aquaculture practices. Furthermore, the cost-benefit ratio calculated for the cassava residue-supplemented diets was significantly better than that of the control group. This finding is in line with the work of Akinwande *et al.* (2019), which indicated that optimizing feed formulations with affordable and nutritious ingredients could lead to enhanced economic returns in aquaculture systems. The ability to achieve a favorable cost of feed per kilogram of meat produced reinforces the potential for cassava residue to serve as a viable alternative feed ingredient in Nile tilapia culture. It is worth noting that while the economic advantages of using cassava residue are evident, the quality of the final product must also be considered. A study by Olaniyi *et al.* (2020) reported that incorporating certain unconventional feed ingredients can sometimes compromise fish quality, potentially affecting market value. However, our findings indicate no adverse effects on carcass composition, suggesting that cassava residue does not detract from the quality of the fish produced, thereby enhancing both economic and market viability.

In summary, the result of this study is demonstrated that dietary supplementation of cassava residue in Nile tilapia feed can lead to significant reductions in production costs and improvements in net profits. It is recommended that aquaculture practitioners consider integrating cassava residue into their feeding strategies, especially for commercial operations aiming to improve economic returns. Future research should explore long-term implications of cassava residue on fish health, growth, and market value to validate these economic benefits. This study is underscored the importance of utilizing locally sourced, cost-effective feed ingredients in aquaculture, contributing to the sustainability and profitability of fish farming practices.

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Conflicts of interest

The authors declare no conflict of interest.

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