

Harnessing Copra Meal as a Sustainable Protein Source: Partial Replacement of Soybean Meal in the Nile Tilapia (*Oreochromis niloticus*) Diets

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ABSTRACT

This research was carried out to evaluate the effect of copra meal (Coconut oilcake) as a partial replacement of soybean meal on the growth and survival rate of the Nile tilapia (*Oreochromis niloticus*) fingerlings. Four treatments (T1, T2, T3, and T4) were designed, each with three replicates. Copra meal was used to replace soybean meal at different inclusion levels: 0% in T1 (control), 25% replacement in T2 (7.5% copra meal in the diet), 30% replacement in T3 (9.0% copra meal in the diet), and 35% replacement in T4 (10.5% copra meal in the diet). Water quality parameters were within the acceptable range during the study period. Final weight (g), weight gain (g), percent weight gain (%), feed conversion ratio (FCR), specific growth rate (%/day), protein efficiency ratio (PER) and daily growth co-efficient (DGC) varied from 14.11 to 18.92g, 12.47 to 17.28g, 760.36 to 1053.35%, 1.34 to 1.89, 4.3 to 4.89, 2.69 to 1.88 and 0.25 to 0.35, respectively. According to the results of the current study, 35% replacing of copra meal/kg (10.5% used in diet) in place of soybean meal resulted in the best growth performance and survival rate of tilapia.

INTRODUCTION

The main sources of protein in animal feeds have been limited to fish meal and, more recently, soybean meal (Rahman *et al.*, 2025). However, considering how essential these compounds are to human nutrition and how slowly their productivity is declining, using them is becoming more difficult. Ng and Chen (2002) reported a significant

decline in soybean production, an underutilized crop in tropical regions. It is found in many human diets, together with soy pap (ogi), soy milk, and newborn formula. As a result of the pressure, it has become necessary to assess less expensive substances that are either irrelevant to or have no value for human nutrition while making fish feed. The dried form of coconut meat is called copra. To remove moisture from coconut on a large scale, the hard white meat of mature coconuts is first dried in a hot kiln. During this process, the coconut meat begins to dehydrate and becomes slightly toasted, producing a product known as copra. After being separated from the coconut's hard outer shell, the copra is further processed for various applications. Copra meal, also known as copra cake, is the residual material obtained after coconut oil extraction. This dried by-product is a valuable resource and is commonly used as a nutritious livestock feed (**Dairo FAS 2006**). Copra meal has a tremendous amount of promise to be an alternative, affordable, and sustainable source of protein for the fish feed industry, given the growing by-products created from the manufacture of coconut oil. Copra meal has a substantially higher water-binding capacity and contains comparatively high concentrations of mannans, galactomannans, arabinoxylogalactans, and cellulose. According to **Swick (1999)**, copra's protein quality is subpar in terms of both its amino acid balance and digestibility. Additionally, copra meal has a high fiber content and tannins (**Swick, 1999**), which are the main anti-nutritional components that restrict its usage. By soaking the copra meal in water, the tannins are easily removed from the copra meal. It was proposed that copra meal could offer tilapia a low-cost, high-quality source of protein and energy if we could lower the tannin content. As it also has an excessive amount of fiber, for vegetarian fish, omnivorous fish (5–15%), and carnivorous fish (5–10%), the copra meal is more profitable (**Rahman et al., 2025**). A common element in aquafeed, soybean meal, has been shown to be helpful (**Ayadi et al., 2012; Islam et al., 2020**) in fish growth but if we can use the copra meal as a substitute of soybean meal then it would decrease the use of soybean meal and ultimately lower the feeding cost. In comparison with fish meal, prospective sources of plant protein have been demonstrated to be deficient in protein and critical amino acids. With farms opening and growing all throughout the world, tilapia has emerged as aquaculture's brightest star (**Biswas et al., 2021; Hossain et al., 2021; Mahmud et al., 2021; Mou et al., 2023**). Eminently, tilapia is considered as a significant source of protein (**Baroi et al., 2019; Murshed et al., 2023**). As the second most farmed fish in the world, tilapia has significantly contributed to the expansion of aquaculture and it has the potential to maintain density (**Nasrin et al., 2021; Noor et al., 2024**) of fish to meet up the protein requirements. In Bangladesh and around the world, tilapia is an inexpensive, delicious fish (**Mahmuda et al., 2020, Rahman et al., 2021; Rahman et al., 2022**). Among its traits are disease resistance, rapid growth, and efficient feed consumption (**Lovell, 1989**). The purpose of this study is to assess how well the Nile tilapia (*Oreochromis niloticus*) fingerlings use soaked copra meal in place of soybean meal in terms of growth performance and nutritional uptake. The findings of this research

will reduce the feed cost for tilapia farmers, and it will change the economy and profit rate of the fish farmers.

MATERIALS AND METHODS

Experimental site and strategy

The current study was organized in 12 cisterns behind the Fisheries faculty's main building at Bangladesh Agriculture University (BAU), Mymensingh. The fish were raised in groundwater previously stocked. There was no aeration offered for the experimental cistern. Each cistern measured 2.5m in length, 1.5m in width, and 1.2m in depth, maintaining an effective water depth of about 1.0m throughout the study period. Twelve cisterns were used for the experiment, four different treatments (T₁, T₂, T₃, and T₄) with three replications for each. Different amounts of copra meal were replaced, such as 0% in T₁ (control), 25% in T₂ (7.5% used in diet), 30% in T₃ (9.0% used in diet), and 35% in T₄ (10.5% used in diet). In each treatment, the Nile tilapia fingerlings were dispersed at a rate of 30/m³ which was around 168 fingerlings per cistern. The water was around 4 feet deep and every day, around 30% of the water was replaced applying the syphoning method. The experiment was conducted in the cisterns for 50 days. In the beginning and final, weights of each fish cistern were recorded. The fingerling's initial weight was 1.54 ± 0.65g. Two feedings per day, at 9 am and 4 pm, were performed. Fish were mass-weighted every 10 days to keep track of their weight. Fish were gently gathered using a fine-mesh scoop net and then thoroughly wiped of excess water using blotting paper before being weighed by a portable digital balance. For every sampling, 41 fish were taken from each replication. After being weighed, the fingerlings were put in the cistern.

Collection of fish and acclimation

Before being stocked, tilapia fingerlings were obtained from a nearby hatchery, Reliance Aquafarm Trishal in Mymensingh, as they showed no clinical symptoms of any infections. Fish fry were transported in oxygen bags to prevent stress and damage. After submerging the poly bag containing the fish for a while to regulate the temperature, the fish were released into the tank for acclimatization.

Feed ingredients collection and feed formulation

The components that are typically available were used to create the basic experimental diets (Table 1). Fish meal, rice bran, wheat bran, molasses, soybean meal, and copra meal, as well as mineral and vitamin premix from a nearby store, were the ingredients chosen for this experiment. The following levels of various basal diet items' incorporation are presented, a proximate analysis of several feed components is also shown. The base diet included four grades of copra meal at levels 0, 25, 30, and 35% (copra meal was added as a partial replacement for soybean meal). The materials were ground, milled, weighed, mixed, and made into a dough of feed ingredients before being

pelleted with a meat mincer through a 0.5 mm diameter. The feed was pelletized, air-dried, and then placed in an airtight container.

Analysis method

The Department of Aquaculture, BAU's Nutrition Laboratory, examined the approximate composition of prepared feeds and individual ingredients using the modified techniques outlined below, in accordance with the Association of Official Analytical Chemists (AOAC, 2005):

Growth parameters

Fish growth was assessed using the following metrics: weight gain (g), weight gain percentage, specific growth rate (SGR), food conversion efficiency (FCE), food conversion ratio (FCR), survival rate (%), and production (kg/ha).

Weight gain (Boyd & Tucker, 1998; NRC, 2011)

Weight gain (g) = mean final weight (g) - mean initial weight (g)

Percent weight gain (%)

The percent weight gain formula was used to calculate the total increase in mean body weight over a certain amount of time.

$$\text{Percent weight gain (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

Where, W_1 = the mean initial fish weight.

W_2 = the mean final fish weight.

Specific growth rate (SGR)

The percentage increase in body weight every day over a specified time period was used to compute the particular growth rate in the immediate change in fish weight. Fish growth was measured in terms of weight by deducting the fish's original weight (at the time of release) from its ultimate weight. The following formula was used to calculate the specific growth rate, or SGR:

$$\text{Specific growth rate (\%/)} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \times 100$$

Where,

W_1 = Initial live body weight (g) at time T_1 .

W_2 = Final live body weight (g) at time T_2 .

$T_2 - T_1$ = No. of days of the experiment.

Food conversion ratio (FCR)

The following formula was used to calculate the FCR, which was expressed as the rate of food consumption to weight gain:

$$\text{FCR} = \frac{\text{Amount of dry fed (g)}}{\text{Live weight gain (g)}}$$

Food conversion efficiency (FCE)

FCE was determined by the following formula:

$$\text{FCE} = \frac{\text{Live weight gain (g)}}{\text{Amount of dry fed (g)}}$$

Protein efficiency ratio (PER)

PER was calculated using the subsequent formula.

$$\text{PER} = \frac{\text{Live weight gain (g)}}{\text{Crude Protein fed (g)}}$$

Nitrogen free extracts (NFE)

By deducting the total percentage contents of moisture, protein, fat, ash, and crude fiber from 100, one can estimate nitrogen-free extract (NFE), a soluble carbohydrate (Castell & Tiews, 1980).

$$\text{NFE (\%)} = \{100 - (\text{crude lipid} + \text{moisture} + \text{ash} + \text{crude fibre} + \text{crude protein})\}$$

Survival rate

The number of fish of each species harvested from each treatment at the end of the experiment and the data collected at the beginning of the trial were used to calculate the survival rate of fish of each species for each treatment. The following formula was used to estimate the survival rate:

$$\text{Survival rate (\%)} = \frac{\text{Total number of fish harvested}}{\text{Total number of stocked}} \times 100$$

Water quality

Throughout the 50-day experiment, water quality was carefully monitored to maintain optimal conditions for the Nile tilapia. The key parameters measured included dissolved oxygen (DO), pH, water temperature, and ammonia (NH₃/NH₄⁺).

- i. **Dissolved Oxygen (DO):** Maintained at approximately 5.2 ± 0.3 mg/L, measured using a portable DO meter (Model: XYZ, Manufacturer).
- ii. **pH:** Kept within the range of 7.2–7.8, recorded with a digital pH meter (Model: ABC, Manufacturer).
- iii. **Water Temperature:** Monitored daily and maintained at 28 ± 1°C using a thermometer.
- iv. **Ammonia (NH₃/NH₄⁺):** Levels were kept below 0.02 mg/L, determined using standard spectrophotometric methods (APHA, 2012).

Measurements were taken twice daily (at 09:00 and 16:00) to ensure stable water quality throughout the study, providing a suitable environment for the growth and survival of the fish.

Analysis of feed and feed ingredients

Using the techniques outlined by the Association of Official Analytical Chemists (AOAC, 2005), the approximate composition of prepared feeds and individual

constituents was examined in the Fish Nutrition Laboratory, Department of Aquaculture, BAU (Tables 2, 3).

Statistical analysis

The collected data were statistically analyzed by Microsoft Excel and XL-Stat (version 2013) analytical tools to perform statistical analysis ANOVA. The average and significance level were determined at $P < 0.05$ to see whether the influence of different treatments on these parameters was significant or not. The means of different treatments were composed by the Duncan multiple range test (DMRT) (**Duncan, 1955**) to test the significance of the variation between the treatment means. The graphs were made using MS Excel 2013.

Table 1. The basal diet's composition (on a dry matter basis)

Ingredient	D ₁ (%)	D ₂ (%)	D ₃ (%)	D ₄ (%)
Fish Meal	25	25	25	25
Soybean Meal	27	22.5	21	19.5
Rice Bran	23	20	20	20
Wheat Bran	20	20	20	20
Copra Meal	0	7.5	9	10.5
Molasses	4	4	4	4
Vitamin mineral Premix	1	1	1	1
Total	100	100	100	100

RESULTS AND DISCUSSION

Throughout the course of the study, fingerlings were fed experimental diets twice daily at 9 a.m. and 4 p.m. at their satiation level. In the case of T₁, after a 98% survival rate of 168 fry (164 fries survive), intake was 4373.54g of feed with an average body weight of 14.11g for each fish. In the case of T₂, after a 98% survival rate of 168 fry (164 fries survive), intake was 4496.08g of feed with an average body weight of 14.43g for each fish. On the other hand, T₃ after a 98% survival rate of 168 fry (164 fries survive) intake 4230.38g of feed with an average body weight of 18.43g for each fish. Finally, in the case of T₄, after a 98% survival rate of 168 fry (164 fries survive), intake was 4033.75g of feed with an average body weight of 18.92g per fish. The proximate composition of experimental feed and fish in terms of % moisture, % crude lipid, % crude protein, % ash, % crude fibre, were calculated at the end of the experiment following Association of Officials Analytical Chemists (**AOAC, 2005**) methods (Table 3). Growth parameters of the Nile tilapia (*Oreochromis niloticus*) fingerlings after feeding different diets replaced with copra meal, such as 0% copra meal in T₁ (control), 25% copra meal in T₂ (7.5% used in diet), 30% copra meal in T₃ (9.0% used in diet), and 35% copra meal in T₄ (10.5% used in diet), were as follows:

Growth performances of the Nile tilapia fingerlings

The growth performances of the Nile tilapia fingerlings in terms of initial weight (IW) (g), final weight (FW) (g), weight gain (WG) (g), percent weight gain (%), and specific growth rate (%/day) were calculated at the end of the experiment (Table 4).

In a column, values with the same letter or without a letter do not differ significantly, whereas those with dissimilar letters differ significantly (as per DMRT).

Water quality parameters

Throughout the experiment, different tanks' water quality characteristics, including temperature, dissolved oxygen, and pH, were measured. Temperature, dissolved oxygen, and pH values fell within the optimal ranges.

The Nile tilapia fingerling growth performance was considerably ($P < 0.05$) better in treatment 4. According to several studies, adding raw, processed, or soaked copra meal to diets of rohu (*Labeo rohita*), tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio*) does not significantly affect performance parameters when added at inclusion levels of 25 to 30%. In our study, treatment 4 had the highest mean final weight (18.92 g), while treatment 1 had the lowest mean final weight (14.11 g). The results demonstrated that using copra meal in place of soybean meal had a considerable favorable impact on FCR, SGR, and daily average growth. In the past, fermented copra meal has been used for black tiger shrimp (*Penaeus monodon*) as aqua feed to supplement fish meal's dietary protein by up to 40% without negatively affecting growth, feed efficiency, or survival (Apines-Amar *et al.*, 2015). Additionally, when utilized for a longer period of time in commercial cage culture systems, the same component can be used to substitute soybean meal in milkfish diets by up to 20% without altering performance metrics (Apines-Amar *et al.*, 2015). Copra meal has enormous potential to be an alternative, affordable, and sustainable source of protein for the fish feed industry, given the growing by-products created from the manufacture of coconut oil. Milkfish and *Chanos chanos* were fed processed copra meal, which at a 5% inclusion level significantly improved weight gain. Additionally, Apines-Amar *et al.* (2015) found that copra meal levels up to 20% did not significantly differ from the control treatment. Additionally, it was tested on the black tiger shrimp (*Penaeus monodon*) showing that, up to 40% of fermented copra meal could be added to the diet without negatively impacting growth, survival, or feed efficiency (Apines-Amar *et al.*, 2015). Growth and feed effectiveness were determined in *P. monodon* which gained weight similar to the control group when fed diets partially substituted with CM (copra meal) at any replacement amount. Shrimp development was unaffected when up to 40% of the fish meal was replaced with CM protein. Ubiquitous anti-nutrients (Thorne *et al.*, 1990), aflatoxin (Head *et al.*, 1999), a high fiber content (Dairo & Fasuyi, 2008), and a low bulk density are all characteristics of raw copra meal. Through a variety of physico-chemical processing methods, the nutrient profile of raw copra meal can be enhanced. According to several studies, adding raw, processed, or soaked copra meal to diets of rohu (*Labeo rohita*), tilapia (*Sarotherodon mosambicus*)

and carp (*Cyprinus carpio*) does not significantly affect performance parameters when added at inclusion levels of 25 to 30%. The high dietary inclusions of copra meal had no appreciable effects on the sensory qualities of the fillet. The findings of this study show that autoclaved copra meal may be added to the Nile tilapia diets up to 680g. kg⁻¹ without having any negative impacts on fish growth or meat sensory features. In the current study, the protein efficiency ratio in treatment 1 (control) was found to be 1.88 ± 0.02 , and the highest PER (2.69 ± 0.02) was recorded in treatment 4 (35% soybean meal was replaced with copra meal); nevertheless, 45% replacement is not as good as that recorded in the PER results reported by **Olude *et al.* (2008)**. It can be assumed that copra meal is a good element that could replace wheat meal in the diet of *C. carpio* fry at an ideal level of 9%. However, increasing copra meal up to a level of 12% might not be necessary to improve *C. carpio*'s growth performance. While T₄ (with 35% of the soybean meal substituted with copra meal) had the lowest FCR, T₁ (without copra) had the highest FCR value. In terms of survival rate, treatments 1, 2, 3, and 4 had survival rates of 95.31, 97.22, 97.22, and 99.44%, respectively. Treatment 1 served as the control. Treatment 4 employed the highest level of copra meal, whereas treatment 1 (the control), which used fish raised without copra meal, had a lower survival rate. In this respect, **Olude *et al.* (2008)** postulated that, the use of copra meal as a replacement for soybean meal at 15% resulted in the best survival rate (86.6%) and the lowest (76.7%) in the control group, demonstrating that it also protects fish against illnesses. In pelleted feed for *Oreochromis niloticus*, soaked copra meal may be used substituting some of the soybean meal. *Oreochromis niloticus*'s growth performance and feed utilization efficiency won't be affected if up to 30% of the soybean meal in their diet is replaced with soaked copra meal (Fig. 1). However, development was slowed when treated copra meal was supplemented only partially, at a level of 35% inclusion. The performance of the fish likewise showed similar tendencies in terms of weight gain, specific growth rate, feed conversion ratio, and feed efficiency ratio. The specific growth rate (SGR%/day) in this study was at its lowest in treatment 1 (control) with 4.3 ± 0.03 , and the greatest value was recorded in treatment 4, with the highest level of copra meal at 4.89 ± 0.01 . The elements that affect water quality are crucial for ensuring a healthy environment for aquatic creatures. The experimental tanks' water temperature during the study period ranged from 27.6 to 29.63°C. According to **Boyd (1982)**, fish can be raised in water with temperature between 26.06 and 31.97°C. Trishal and Myrnensingh's ponds were recorded with water temperatures measured by **Alam (2009)** and **Hossain (2009)** that varied from 26.9 to 32.5°C. In ponds on the BAU campus in Mymensingh, Bangladesh, **Hossain (2004)** and **Hossain (2007)** measured water temperatures that varied from 29.4 to 33.0 °C and 26.0 to 32.8°C, respectively. According to the aforementioned remark, cistern water temperatures were comparable to pond temperatures. The experiment's dissolved oxygen concentration ranged between 8.3 and 9.4mg/ L. According to **DoF (1996)**, dissolved oxygen levels for fish culture should be between 5- 8mg/ L. Dissolved oxygen levels in

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ponds at Agro-3 arm, Trishal, and Mymensingh were measured by **Alam (2009)** and **Hossain (2009)** and ranged from 5.5 to 6.5mg/ L. In ponds behind the Faculty of Fisheries on the BAU campus, **Hossain (2009)** measured dissolved oxygen levels ranging from 5.1 to 8.7 mg/L. The experiment's oxygen content fell within a range that was productive. The pH value during the study period was determined to be between 7.98 and 8.20. According to **DoF (1996)**, a pH range of 6.5 to 8.5 is ideal for fish production. The pH value of the ponds at Agro-3 Farm, Trishal, and Mymensingh was measured by **Alam (2009)** and **Hossain (2009)** to be between 7.54 and 8.3 and 7.72 and 8.03, respectively.

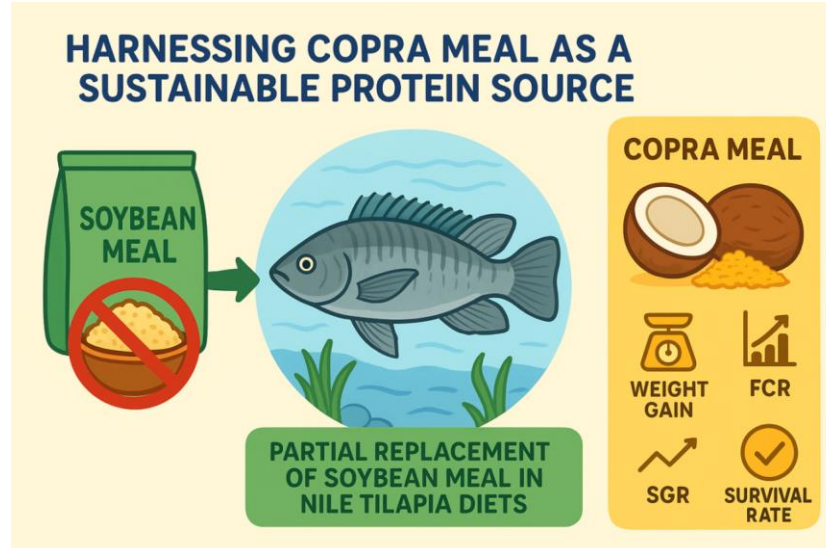


Fig. 1. Harnessing copra meal as a sustainable protein source

Table 2. Composition of various feed components

Feed ingredient	Crude protein %	Crude lipid %	Moisture %	Ash %	Crude fiber %
Fish meal	55%	12.60	8.30	15.52	2.47
Rice bran	6.41	9.23	12.84	20.27	4.76
Wheat bran	11.5	4.01	13	2.52	12.84
Soybean meal	38.67	3.81	10.30	7.22	5.29
Copra meal	20.92	8.21	35.52	4.37	15.03

Table 3. Proximate composition analysis of feed and fresh fish (moisture basis)

Name	% moisture	% crude lipid	% crude protein	% ash	% crude fibre	% carbohydrate
Diet 1	12.66	5.94	26.31	10.60	7.40	37.09
Diet 2	12.46	6.23	27.11	10.64	6.35	37.21
Diet 3	11.98	6.46	27.67	11.23	6.28	36.38
Diet 4	11.42	7.10	29.04	12.12	5.88	34.44
Fish (T ₁)	77.62	2.18	13.39	3.50	1.12	1.69
Fish (T ₂)	77.90	2.51	14.09	3.61	1.29	0.60

Fish (T ₃)	77.62	2.74	14.19	3.39	1.43	0.63
Fish (T ₄)	77.54	3.22	13.87	3.40	1.53	0.44
Table 4. The (mean $\pm$ SD) effect of different treatments on FCR , FCE,% weight gain, PER and survival rate of the Nile tilapia fingerlings reared in cisterns during the study period						
	T ₁	T ₂	T ₃	T ₄	P value	Level of sig
IW	1.64 $\pm$ 0.00	1.64 $\pm$ 0.00	1.64 $\pm$ 0.00	1.64 $\pm$ 0.00	-	ND
FW	14.11 $\pm$ 1.11 ^b	14.429 $\pm$ 1.43 ^b	18.425 $\pm$ 0.57 ^a	18.915 $\pm$ 1.02 ^a	0.021	*
%Wt. GAIN	760.365 $\pm$ 10.10 ^d	779.81 $\pm$ 0.90 ^c	1023.47 $\pm$ 10.02 ^b	1053.35 $\pm$ 10.05 ^a	0.001	**
FCR	1.89 $\pm$ 0.10 ^a	1.9 $\pm$ 0.10 ^a	1.4 $\pm$ 0.05 ^b	1.34 $\pm$ 0.20 ^b	0.001	**
SGR	4.3 $\pm$ 0.30 ^b	4.34 $\pm$ 0.20 ^b	4.83 $\pm$ 0.12 ^a	4.89 $\pm$ 0.01 ^a	0.008	**
FCE	0.526 $\pm$ 0.01 ^b	0.524 $\pm$ 0.02 ^b	0.7133 $\pm$ 0.01 ^a	0.7428 $\pm$ 0.02 ^a	0.001	**
PER	1.88 $\pm$ 0.02 ^b	1.86 $\pm$ 0.10 ^b	2.56 $\pm$ 0.10 ^a	2.69 $\pm$ 0.02 ^a	0.001	**
Survival rate	96.57 $\pm$ 0.02 ^a	93.71 $\pm$.10 ^b	97.14 $\pm$.10 ^a	98.28 $\pm$.02 ^a	0.001	**

** = Significant at 1% level of probability, * = Significant at 5% level of probability

NS = Not significant, Feed conversion ratio (FCR), Protein efficiency ratio (PER), Daily growth coefficient (DGC).

CONCLUSION

This study demonstrates that copra meal can successfully replace soybean meal in the Nile tilapia diets without negatively affecting growth or survival. Among the tested inclusion levels, 35% replacement (equivalent to 10.5% of the total diet) showed the highest growth performance and survival rate, suggesting it as an optimal inclusion level for tilapia fingerlings. Using copra meal in diets provides not only adequate nutrition but also a cost-effective alternative, which is particularly beneficial for small-scale and resource-limited farmers. The findings emphasize the potential of copra meal to improve feed efficiency, support fish health, and promote sustainable aquaculture practices. Nonetheless, further research is warranted to investigate whether higher inclusion levels could enhance growth further and to establish the maximum safe and effective replacement level. Overall, this study offers practical guidance for fish farmers and feed manufacturers, showing that copra meal is an economical, nutritionally balanced feed ingredient that can contribute to the growth of the aquaculture industry and national food security.

Statements and Declarations

Ethics approval and consent to participate: Not applicable

Consent for publication: Not applicable

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