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EFFECT OF RAW *MOMORDICA CHARANTIA* (BITTER MELON) SEED MEAL ON GROWTH PERFORMANCE AND HAEMATOLOGICAL PROFILE OF *COPTODON GUINEENSIS* FINGERLINGS

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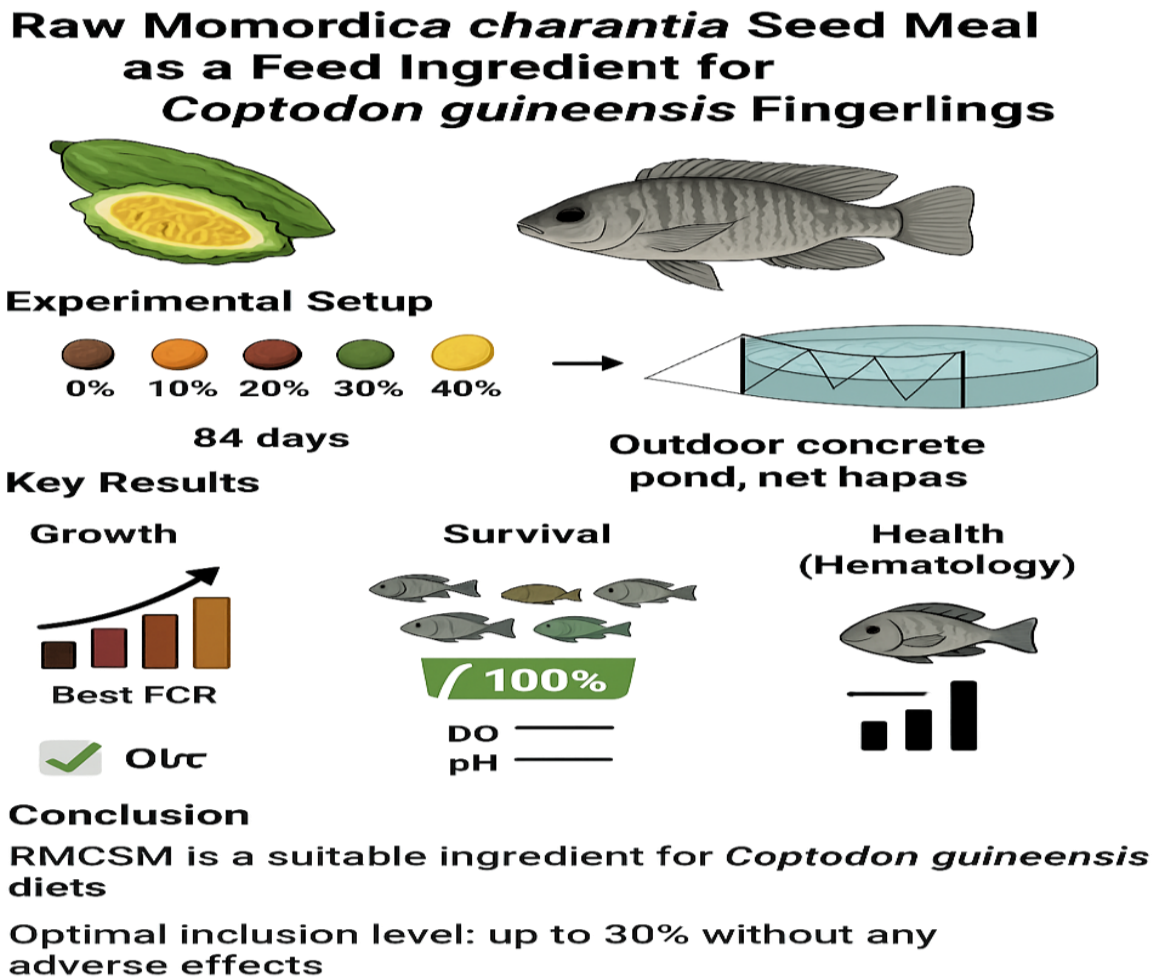
Abstract

This study investigates the use of Raw *Momordica charantia* (Bitter melon) seed meal (RMCSM) in practical diets for *Coptodon guineensis* fingerlings. Fish (initial mean weight 1.47±0.3 g) were fed five isonitrogenous (35%) and isolipidic (10.5%) diets containing varying inclusion levels of RMCMS and designated as D1 (0 %), D2 (10%), D3 (20%) D4 (30%) and D5 (40%) for 84 days. 15 fish per hapa were stocked in fifteen net hapa (0.5×0.5×1m) suspended in outdoor concrete ponds (8mx5mx1.5m) with the aid of kuralon twine tied to plastic poles. The concrete ponds were filled to 5/6 of its volume (40m^3) with filtered and dechlorinated tap water. The fish were fed at 5% body weight twice times daily. Each treatment was randomly allocated to three hapa. The result of the growth performance showed that fish fed D4 had the highest final weight (FWM), percentage weight gain (WG), feed conversion ratio (FCR) while lowest was observed in D2. Survival rate values for D4 recorded (100%) while the lowest is observed D3 (80%). The nutrient utilization exhibit that no significant different among the treatment mean ($P<0.05$) for protein efficiency ratio and protein retention and apparent net protein utilization. There was significant difference in all the haematological indices measured among all the fish fed the experimental diets. However, there was improvement from the initial value recorded at the beginning of the experiment. Water quality paraameters (mean DO and pH) measured were within the recommended range for experimental fish survival. This study showed that RMCMS meal would be a potential suitable ingredient for C*optodon guineensis* and can be included in a diet up to 30% without any adverse effect.

Keywords: *Momordica charantia, Growth performance, Haematology, Tilapia guineensis, RMCSM.*

Graphical Abstract



1.0 INTRODUCTION

Tilapia is acknowledged globally as one of the most important internationally traded fish [1] and [2]. It is ranked the second most cultured freshwater finfish in the world. Currently, farmed tilapia represents more than 75 % of world tilapia production [3] and this contribution has been exponentially growing in recent years. [4], described tilapias as the most important aquaculture species of the 21st century. Several factors have contributed to the rapid global growth of tilapia [5]. Coptodon guineensis, or the Guinean tilapia, is a euryhaline cichlid fish native to West African coastal basins [6]. Unlike many other commercially farmed tilapia species that are limited to freshwater, C. guineensis is highly tolerant of varying salinities and can thrive in freshwater, brackish water, and even seawater [7]. This adaptability makes it a promising candidate for aquaculture in coastal and estuarine regions, where many other commercially important species (O. niloticus) cannot be cultured [8,9]. The major challenge in aquaculture is the high cost of conventional fish feed, which often accounts for a significant portion of the total production cost. The primary protein source in most commercial fish feed is fishmeal, which is becoming highly expensive and unsustainable due to declining global fish stocks FAO [9,10]. However, according to [11] there is continuous investigation into other substitutes, locally available, and cost-effective feed ingredients to partially or completely replace or reduce the reliance on fishmeal. Plant-based protein sources are viable avenue, and the seeds of various plants, often considered waste, are being examine for their nutritional value [12]. Thus this shift is not without its challenges such ant-nutritional factors in plant seeds content variety of natural occurring compound that can interfere with nutrient absorption and metabolism in fish which may lead to negative effect on growth and overall health of the fish [13]. *Momordica charantia* (bitter melon) known as Karela is an extremely bitter vegetable, is a tropical and subtropical vine of the family cucurbitaceous widely grown in Nigeria, south Asia, China and the Caribbean. This plant is widely cultivated for its medicinal and nutritional properties. While the fruit

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is known for its bitter taste and is used in traditional medicine for treating diabetes and other ailments [13,14]. However, recent research has revealed that bitter melon seeds are a rich source of nutrients [14]. Therefore, the objective was to investigate the growth performance and haematological profiles of *Coptodon guineensis* fed varying inclusion levels of raw *Momordica charantia* seed meal diet.

2.0 MATERIALS AND METHODS

2.1 Study location

The study was conducted at the Water Resources, Aquaculture and Fisheries Technology departmental Fish Farm, Federal University of Technology, Bosso Campus, Minna, Niger State, Nigeria. It is located at latitude 9° 40' N and longitude 6° 30' E in the Southern Guinea Savannah region of Nigeria [15]

2.2 Collection and processing of *Momordica charantia* seed (MCS)

Momordica charantia (bitter melon) seeds were obtained from Borgu Local Government Area of Niger State, Nigeria, between May and December of every year for two years. The seeds were collected by harvesting the ripe fruits, gathered in one place and allowed to ferment for three days to facilitate pulp decomposition and seed removal. The seeds were then manually collected, washed and sun-dried as reported by [16].

2.3 Biochemical analysis

The major dietary ingredients (Raw *Momordica charantia* seed meal, fishmeal, soybean meal, maize meal). Proximate composition analysis was conducted according to Association of Official Analytical Chemists [17] procedures on dry matter basis. Moisture Content was determined by drying samples at 105±2°C until a constant weight was obtained. Dried samples were used for determination of crude fat, protein and Ash contents. Crude fat was measured by solvent extraction method in a soxhlet system where n-hexane was used as solvent. Crude protein content was calculated by using nitrogen content obtained by Kjeldahl method. A conversion factor of 6.25 was used for calculation of protein content (17). The compositions is as displayed in Table 1.

Table 1: Proximate Compositions of the Major Feed Ingredients

Ingredients	RMCSM	Soybean meal	Maize meal	Fishmeal
Crude protein (%)	21.99	44.08	10.42	63.74
Lipid (%)	18.38	19.32	5.13	11.72
Moisture content (%)	7.45	2.47	7.68	7.44
Ash content (%)	7.26	4.66	2.09	10.31
Crude fibre (%)	24.32	7.10	3.45	0.00
Nitrogen free extract (%)	20.60	22.37	71.23	6.79

2.4 Experimental diets

Based on the nutritional requirements of tilapia [18], five isonitrogenous and isolipid diets were formulated at 35 % protein and 9.5 % lipids, containing 0 -40% Raw *Momordica charantia* seed meal at varying levels of inclusion designated as D1-0%, D2-10%, D3-20%, D4-30% and D5-40% respectively. All the ingredients were weighed using a sensitive weighing scale (model: Atom A-110 Electronic compact scale) separately milled and mixed with warm water to form consistent dough, which was then pelleted, sun-dried, packed in polyethylene bags and stored at room temperature. The gross composition of the experimental diet is as presented in Table 2.

Table 2: Formulation (g/100 g diet) of the experimental diets with varying inclusion levels of raw *Momordica charantia* seed meal (RCMSM).

Ingredient	D1 (0%)	D2 (10%)	D3 (20%)	D4 (30%)	D5 (40%)
RCMSM	0.00	10.00	20.00	30.00	40.00
Yellow Maize	7.00	7.00	7.00	7.00	7.00
Fishmeal	25.00	25.00	25.00	25.00	25.00
Soybean Meal	41.60	36.60	31.63	26.63	21.64
Dextrinized Starch	0.22	0.22	0.22	0.22	0.22
Vegetable Oil	4.33	3.42	2.51	1.61	0.70
Vitamin Premix	2.50	2.50	2.50	2.50	2.50
Mineral Premix	2.50	2.50	2.50	2.50	2.50
Cellulose	16.85	12.76	8.64	4.54	0.44
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

D1, D2, D3, D4, D5: Experimental diets containing 0%, 10%, 20%, 30%, and 40% RCMSM, respectively. RCMSM: Raw *Momordica charantia* Seed Meal. Diets were formulated to be isonitrogenous and isoenergetic.

2.5 Experimental Design and set-up

Hapa of 0.5m x 0.5m x 1m size was suspended in outdoor concrete ponds (8mx5mx1.5m) with the aid of kuralon twine tied to plastic poles. The concrete ponds were filled to 5/6 of its volume (40m^3) with filtered and dechlorinated tap water for the rearing of

Coptodon guineensis. A total of 225 healthy fingerling of C. *guineensis* was purchased from NIOMR Tilapia hatchery and transported

immediately to the experimental site using close transportation system. This was followed by acclimatisation for two weeks before stocking all fish were fed the control for this period, after which 15 fingerlings were weighed and randomly stocked per hapa for each of the five treatments and control in replicated three times and arranged in a Randomized Complete Block Design (RCBD).

2.6 Feeding Trial and fish samples collection
The feeding trial lasted for a period of 84 days. The fish were fed at a feeding rate of 5% body weight according to raw *Momordica charantia* seed meal (RMCSM) dietary treatment (D1-0%, D2-10%, D3-20%, D4-30%, and D5-40%). Feeding was carried out twice every day at the hours of 9:00 and 17:00. Sampling was done on a bi-monthly bases in all the treatment. Fish in each tank was randomly selected for morphometric measurement of individuals of the different treatment. The weight of fish sample was determined to the nearest 0.1 g using a measuring board and sensitive weighing balance. At the conclusion of the trial, a 24-hr fasting was observed for fishes in each before weighing. After which four fishes were taken for proximate analysis and haematological analysis.

2.7 Survival and Growth Parameter Evaluation
In line with established methodologies [18, 19], key zootechnical parameters were computed to evaluate fish performance. The following indices and formulae were used:

Mean Weight Gain (MWG)

$$MWG = MWf - MWi \quad (1)$$

where MWf = mean final weight (g), MWi = mean initial weight (g).

Specific Growth Rate (SGR)

$$\frac{\ln MWf - \ln MWi}{T \times 100} \quad (2)$$

where T = experimental duration (days), ln MWf = logarithm of the mean final weight, ln MWi = logarithm of the mean initial.

Feed Conversion Ratio (FCR)

$$\frac{\text{weight of feed fed (dry weight)}}{\text{weight gain of fish (wet weight)}} \quad (3)$$

Average Daily Gain (ADG)

$$\frac{\text{weight of feed fed (dry weight)}}{\text{weight gain of fish (wet weight)}} \quad (4)$$

Survival Rate (SR)

$$\frac{Nf}{Ni} \times 100 \quad (5)$$

where Nf = number of fish alive at the end of the trial, Ni = number stocked at the beginning.

Protein Retention (PR)

$$\frac{\text{protein gain}}{\text{protein fed}} \times 100 \quad (6)$$

Protein Efficiency Ratio (PER)

$$\frac{\text{weight gain}}{\text{protein fed}} \times 100 \quad (7)$$

Apparent Net Protein Utilization (ANPU)

$$\frac{\text{carcass protein gain (g)}}{\text{protein fed}} \text{ x } 100 \quad (8)$$

where: ANPU apparent net protein utilization.

2.8 Water quality management
A continue water exchange system was used during the rearing period. However daily reduction of effluent and topping tanks with water was carried out. The water samples were collected and taken to the laboratory of Water Resources, Aquaculture and Fisheries Technology (WAFT) Department, Federal University of Technology (FUT) Minna, Niger State and the water quality parameters monitored were Temperature, Alkalinity, Hydrogen ion concentration, biological oxygen demand, Dissolved oxygen, Water hardness, Electrical conductivity using the method described in Association of Official Analytical Chemists [17].

2.9 Blood Collection and Haematological Analysis
The fish blood samples were collected at the beginning (initial) and end (final) of the experiment from each treatment and replicates following the procedures of [20]. These samples were then transported to the Laboratory of the Department of Biochemistry, Federal University of Technology, Minna, for haematological analysis. Clear plasma samples were pipetted into clean, sterilised bottles for haematological parameters analysis [22]. Erythrocyte values (packed cell volume (PCV), haemoglobin (Hb), and red blood cell (RBC) count) and absolute erythrocyte indices (mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV) and mean corpuscular haemoglobin concentration (MCHC) were measured and calculated. White blood cell counts were analysed as described by [23]

mean corpuscular volume (MCV):

$$\frac{\text{PCV}}{\text{Erythrocyte count}} \times 10 \quad (9)$$

corpuscular haemoglobin (MCH)

$$\frac{\text{Haemoglobin}}{\text{Erythrocyte count}} \times 10 \quad (10)$$

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mean corpuscular haemoglobin concentration (MCHC)

$$\frac{\text{Haemoglobin}}{\text{PCV}} \times 100 \quad (11)$$

2.10 Statistical Analysis

Data collected were expressed as mean ± standard errors. Statistical analysis was conducted by subjecting the data to one-way analysis of variance (ANOVA) using SSPS V 23 statistical software. Comparison between treatment means was done by using Turkey's multiple range test and the level of significant was tested at $P \leq 0.05$.

3.0 RESULTS AND DISCUSSION

Growth Performance and Feed Utilisation

This experiment provided valuable insight into the performance of *Coptodon guineensis* fed inclusion level of raw *Momordica charantia* seed meal (RMCSM). Table 4 revealed growth for inclusion of RMCSM up to D3-40% consistently delivered the performances no significant difference in terms of final mean weight (FMW), mean weight gain (MWG) and average daily again (ADG). This may be attributed to the diet or other condition in that treatment were most effective in supporting tilapia growth. Also, final weight is the primary indicator of production success in fish culture as reported by [24] and [25]

Feed efficiency is another major factor, however D3-20% and D4-30% also exhibited desirable value for feed conversion ratio (FCR) meaning they required less feed to produce more fish biomass. FCR in D4-30% is particularly impressive while the lowest FCR was observed in D2-10%. This aligns with [26] who reported FCR of 1.4-2.4 in a study on *Coptodon zillii* fed *Abrus precatorius* root bark meal diet and [27] also recommended 1.5 to 2.0 in their study on Additives Improve the Growth and Health Nile tilapia.

Protein utilization results revealed D4-30% also exhibited excellent protein retention (PR) however statistically similar to D1-0% and D5 which also demonstrated better protein retention, thus the different are small in absolute terms, but statistically significant. Efficient protein retention is crucial for sustainable aquaculture as protein is often the most expensive component of fish feed [28]. And apparent net protein utilization (ANPU) compared to the other treatment indicating efficient use of dietary. No significant different observed in PER AND ANPU across all the treatment respectively. This may suggest that digestion, absorption and utilization of protein for growth was relatively consistent across all the Diet. As reported by [29] this might be due to variation in the raw materials primary affected the palatability, digestion or overall nutrient balance rather than the essential biological efficiency of protein utilization one absorbed [30].

Table 4: Growth performance of *Coptodon guineensis* fingerlings fed varying inclusion levels of raw *Momordica charantia* seed meal for 84 days

Parameters	D1-0%	D2-10%	D3-20%	D4-30%	D5-40%
IMW (g)	1.94 ± 0.29^{a}	1.94 ± 0.29^{a}	1.94 ± 0.29^{a}	1.94 ± 0.29^{a}	1.94 ± 0.29^{a}
FMW (g)	12.54 ± 0.72^{ab}	9.82 ± 0.87^{b}	13.29 ± 0.57^{a}	14.56 ± 1.55^{a}	12.03 ± 0.31^{ab}
MWG (g)	10.59 ± 0.76^{ab}	7.88 ± 1.12^{b}	11.34 ± 0.31^{a}	12.62 ± 1.26^{a}	10.09 ± 0.32^{ab}
WG (%)	580.60 ± 125.01^{a}	447.56 ± 143.76^{a}	611.13 ± 90.78^{a}	662.43 ± 46.60^{a}	550.44 ± 103.46^{a}
SGR (%)	2.24 ± 0.21^{a}	1.95 ± 0.29^{a}	2.32 ± 0.15^{a}	2.41 ± 0.07^{a}	2.20 ± 0.18^{a}
FCR	2.11 ± 0.16^{b}	2.90 ± 0.38^{a}	1.94 ± 0.06^{b}	1.79 ± 0.18^{b}	2.20 ± 0.08^{b}
ADG (g)	0.15 ± 0.01^{a}	0.11 ± 0.02^{b}	0.16 ± 0.01^{a}	0.18 ± 0.02^{a}	0.15 ± 0.00^{ab}
SR (%)	97.78 ± 2.22^{a}	86.67 ± 0.00^{b}	80.00 ± 0.00^{c}	100.00 ± 0.00^{a}	95.55 ± 2.22^{a}
PER	5.53 ± 0.30^{a}	5.62 ± 0.31^{a}	6.00 ± 0.29^{a}	5.89 ± 0.16^{a}	6.11 ± 0.27^{a}
PR (%)	22.15 ± 0.02^{a}	22.00 ± 0.00^{b}	22.04 ± 0.04^{b}	22.18 ± 0.02^{a}	22.18 ± 0.02^{a}
ANPU	25.40 ± 5.83^{a}	26.83 ± 7.97^{a}	35.60 ± 7.47^{a}	33.53 ± 2.52^{a}	38.80 ± 6.44^{a}

Note: Values in the same row with different superscripts are significantly different ($p<0.05$).
IMW = Initial mean weight; FMW = Final mean weight; MWG = Mean weight gain; WG = Percentage weight gain; SGR = Specific growth rate; FCR = Feed conversion ratio; ADG = Average daily gain; SR = Survival rate; PER = Protein efficiency ratio; PR = Protein retention; ANPU = Apparent net protein utilization.

This study suggests a potential positive effect of *Momordica charantia* seed meal on certain haematological parameters in *Coptodon guineensis* fingerlings. The treatment groups show significantly higher packed cell volume, haemoglobin, red blood cell counts, and white blood cell counts compared to the initial values. However, the optimal inclusion level was obtained from the fish fed diet D2-10% as higher levels do not show further significant improvements. This could indicate a potential threshold effect, where beyond 10 % inclusion level of RMCSM diminishes or negates beneficial effects. [31,32] reported that haematological alterations signal systemic physiological disruptions or homeostatic imbalances, reflecting the health status of individual fish or entire populations. The platelet count shows a significant increase across all treatment groups compared to the initial values, with the fish fed diet D5-40% exhibiting the highest platelet count [33]. This suggests a potential

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stimulatory effect of the seed meal on platelet production. [34] reported that reduced platelet concentration impairs coagulation, increasing bleeding risk upon injury. Similarly, significant differences exist between treatment groups in mean corpuscular haemoglobin volume and mean corpuscular haemoglobin concentration. These do not corroborate with the findings of [35]. The variations could be attributed to different experimental diets and rearing conditions. The mean corpuscular haemoglobin concentration is a good indicator of red blood cell swelling [36].

Table 5: Haematological indices of *Coptodon guineensis* fingerlings fed varying inclusion levels of raw *Momordica charantia* seed meal for 84 days

Parameters	Initial	D1-0%	D2-10%	D3-20%	D4-30%	D5-40%
PCV (%)	18.70 ± 0.09	21.76 ± 0.34^{c}	29.58 ± 1.18^{a}	26.86 ± 0.34^{b}	25.50 ± 1.56^{b}	26.86 ± 0.34^{b}
WBC ($\times10^9$/L)	1.12 ± 0.02	1.63 ± 0.06^{c}	2.93 ± 0.20^{a}	2.48 ± 0.06^{b}	2.25 ± 0.26^{b}	2.48 ± 0.06^{b}
RBC ($\times10^9$/L)	3.16 ± 0.02	3.67 ± 0.06^{c}	4.97 ± 0.20^{a}	4.52 ± 0.06^{b}	4.29 ± 0.26^{b}	4.52 ± 0.06^{b}
Hb (g/dL)	6.30 ± 0.03	7.32 ± 0.11^{c}	9.93 ± 0.39^{a}	9.02 ± 0.11^{b}	8.57 ± 0.52^{b}	9.02 ± 0.11^{b}
PLC ($\times10^9$/L)	85.82 ± 3.05	112.72±7.54^{bc}	158.61±36.02^{bc}	195.19±35.97^{ab}	189.95±20.73^{ab}	246.03±28.60^{a}
MCHC (%)	33.68 ± 0.00	33.63 ± 0.01^{a}	33.55 ± 0.01^{c}	33.58 ± 0.00^{bc}	33.59 ± 0.02^{b}	33.58 ± 0.00^{bc}
MCH (pg)	19.96 ± 0.00	19.96 ± 0.00^{b}	19.97 ± 0.00^{a}	19.97 ± 0.00^{a}	19.97 ± 0.00^{a}	19.97 ± 0.00^{a}

Note: Values in the same row with different superscripts are significantly different ($p < 0.05$).
PCV = Packed cell volume; Hb = Haemoglobin; RBC = Red blood cells; WBC = White blood cells; PLC = Platelet count; MCV = Mean corpuscular volume; MCH = Mean corpuscular haemoglobin; MCHC = Mean corpuscular haemoglobin concentration.

The Water quality parameter results in Table 6 revealed that there were significant differences (p<0.05) among the treatment means in water temperature. The fish fed D4-30% recorded the highest temperature, while the fish fed D2-10% had the least which all fall within the recommended range for tolerate(22-29^{0}C) and optimum temperature range (27-30 ^{0}C) for culture of tilapia culture as reported by [25,38]. All the values recorded for Dissolve Oxygen (D3-20% low and D5 high, which revealed there were significant differences among the treatment, however, they were all within the ideal range of 5mg/l and above reported by [38,39] to avoid stress higher level of 5mg/l lead to optimal growth and feed conversion. The Biological Oxygen Demand values from the pollution which is desirable for fish culture as reported by [39]. pH revealed in D3-20% and the highest D5. This conforms with recommended range of 6.5 to 9.0 for growth of tilapia in a culture environment reported by [25,37]. The values for Electrical Conductivity, alkalinity and water hardness are all within the desirable range for fish culture according to [38, 39].

Table 6: Water quality parameters of *Coptodon guineensis* fingerlings fed varying inclusion levels of raw *Momordica charantia* seed meal for 84 days

Parameters	Initial	D1-0%	D2-10%	D3-20%	D4-30%	D5-40%
T (°C)	27.87 ± 0.02	28.67 ± 0.00^{b}	28.03 ± 0.00^{d}	28.56 ± 0.00^{c}	28.78 ± 0.00^{a}	28.67 ± 0.00^{b}
DO (mg/L)	5.14 ± 0.20	6.47 ± 0.07^{b}	7.83 ± 0.17^{a}	6.00 ± 0.00^{c}	6.37 ± 0.09^{bc}	8.17 ± 0.17^{a}
BOD (mg/L)	2.95 ± 0.16	5.07 ± 0.13^{c}	5.83 ± 0.17^{a}	4.47 ± 0.07^{d}	5.27 ± 0.15^{bc}	5.67 ± 0.17^{ab}
pH	7.00 ± 0.34	7.91 ± 0.02^{ab}	7.59 ± 0.02^{b}	6.93 ± 0.02^{c}	8.03 ± 0.08^{ab}	8.21 ± 0.02^{a}
EC (µS/cm)	194.67 ± 5.24	218.67 ± 1.76^{d}	174.77 ± 4.91^{e}	359.33 ± 2.73^{b}	387.33 ± 1.20^{a}	348.33 ± 1.76^{c}
AKT (mg/L)	84.00 ± 3.79	90.33 ± 8.41^{cd}	103.67 ± 1.45^{c}	125.33 ± 4.81^{b}	135.00 ± 1.53^{b}	156.67 ± 2.40^{a}
WH (mg/L)	101.67 ± 3.84	108.67 ± 1.33^{e}	126.33 ± 0.88^{d}	153.00 ± 1.53^{c}	162.67 ± 1.76^{b}	175.33 ± 1.33^{a}

Note: Values in the same row with different superscripts are significantly different ($p < 0.05$).
T = Temperature; DO = Dissolved oxygen; BOD = Biological oxygen demand; pH = Hydrogen ion concentration; EC = Electrical conductivity; AKT = Alkalinity; WH = Water hardness.

4.0 CONCLUSION

In conclusion, the study revealed that the optimal growth response varied depending on the inclusion level of the *Momordica charantia* seed meal. Raw MCSM showed optimal growth at 20 – 30 % inclusion. *Momordica charantia* seed meal can be incorporated into *Coptodon guineensis* diets, but the optimal inclusion level is crucial for maximizing growth performance and minimizing negative effects on fish health. The haematological parameters such as packed cell volume (PCV), haemoglobin (Hb), red blood cell (RBC), white blood cell (WBC), platelet count (PLC), mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC) showed significant differences across treatments. There was a trend towards increased values at optimal MCSM inclusion levels, suggesting a positive effect on haematopoiesis. Water quality parameters (temperature, dissolved oxygen, biological oxygen demand, pH, electrical conductivity, alkalinity, and hardness) varied across

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treatments. However, these variations were not consistently linked to the MCSM inclusion levels and remained largely within acceptable ranges for fish culture. This study provided quantitative data on the effect of RMCSM inclusion levels of 30% for C. guineensis growth, feed efficiency and the potential impact on fish health and immune function was established.

Conflict of Interest

The authors declare no conflicts of interest related to this work.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors' Contributions

All the Authors, contributed to the work from the start, literature search, data organization, and manuscript drafting. All authors revised the manuscript for intellect, supervised the study, and monitored the writing process. All authors agreed with the final version.

Authors' Declaration

The authors certify that this research is original, has not been published previously, and is not under consideration by any other journal. We assume full responsibility for the integrity of the data and the accuracy of the reported findings and will accept all liability for any claims about the content.

Ethical Declarations – Human/Animal Studies

Not applicable.

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