(KEJAANS)

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES

January, 2025 Vol. 1, issue 1

KEJAANS

CONTACT:
The Editor,
Kebbi Journal of Agriculture and Natural Sciences,
Faculty of Agriculture,
Kebbi State University of Science and Technology Aliero,
PMB 1144, Birnin kebbi, Nigeria.
Email: kejaanseditor@ksusta.edu.ng, kejaans.foa@gmail.com.
Phone: +234 8039370546

ISSN: 1595-5776

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)

JANUARY, 2025: Volume 1, Issue 1

OFFICIAL JOURNAL OF THE

FACULTY OF AGRICULTURE

KEBBI STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY, ALIERO

Editors

I.S. Jega
M.I. Ribah
I. Sani
M. Atiku
M.N. Kwaifa

ISSN: 1595-5776

(c) 2025

About the Journal

This official scientific publication of the Faculty of Agriculture, Abdullahi Fodiyo University of Science and Technology Aliero, is a non-profit, open access, double-blind peer-reviewed Journal publishing four issues (January, April, July and October) per annum. The Journal is a platform open to collaborations with researchers, authors, institutions, research agencies and private companies related to Agriculture. The Mission of the Journal is to disseminate scientific knowledge through the publication of original research articles, research notes, book reviews, letters to the editor and reviews of Literature, representing a contribution to scientific and technological knowledge in respective areas covered by the Journal. The Kebbi Journal of Agriculture and Natural Sciences seeks to validate and disseminate new knowledge, making it public in order to strengthen the human capacity, constitute a link in the scientific community to the society and encouraging the expansion of University and academic researches.

Scope of Kebbi Journal of Agriculture and Natural Sciences (KEJAANS)

The Kebbi Journal of Agriculture and Natural Sciences has the sole aim of providing an intellectual platform and ideas for scholars, by promoting interdisciplinary studies related to agriculture and natural science through publishing the latest scientific research findings that are of direct policy implications and beneficial to the research community. Consequently, the journal covers all aspects of Crop Science, Animal Science, Agricultural Economics, Agricultural Extension and Rural Development, Food Science, Fisheries and Aquaculture, Biotechnology, Soil Science and Agricultural Engineering, Forestry and Environment, Wildlife, Agricultural Education, Agro-allied Industries as well as all Natural Science researches related to Agriculture.

KEJAANS

INSTRUCTIONS FOR AUTHORS

Submission of Manuscript

Submission of manuscript to JAANS shall be on an online platform. Papers could also be submitted as e-mail attachment to the Editor-in-Chief using the kejaanseditor@ksusta.edu.ng or kejaans.foa@gmail.com. The paper should be submitted as a single file in Microsoft Word Format (no other formats will be accepted) and the file shall not be more than 5 Megabytes so that it can be e-mailed to reviewers. The first author, month and year of submission shall be the file name (e.g Ibrahim *et al.* Aug 2010 doc). Once the Editorial Board receives the submission, acknowledgement shall be sent to the corresponding author. If acknowledgement of submission is not received within a week, the author shall remind the Editor-in-Chief through the official email.

Preparation of Manuscript

General presentation: The manuscript should be presented clearly and concisely in English Language. Manuscripts must be prepared (preferably with MS word package) using l2-point New Times Roman (TNR) font, double line-spaced on A4 size paper (210 — 297mm) with at least 3cm margins on all sides. All typing should be justified. Pages including figures and Tables, should be numbered consecutively in the bottom middle with the title page as page l. Manuscript should contain the following sections (except for review and commentary articles): **Title page; Abstract; Introduction; Materials and Methods; Results, Discussion (Results and Discussion could be combined); Conclusion and References**.

Title page

The first page of the manuscript should contain the title of the article, which should be concise and explicit, typed with upper-case, bold, 14 font size, TNR and not more than 21 words. The surname and forenames (in full) of authors, affiliation of each author should be provided. Phone number and email address of the corresponding author (identified by an asterisk) should be provided. Superscripts should be used to relate authors to their affiliations.

Abstract

The next page should contain abstract in English. Abstract should not be more than 250 words and should provide sufficient information to give the reader a full understanding of the content of the article. Paragraphs, footnotes, references and undefined abbreviations should be avoided.

Keywords

Up to five keywords in normal fonts, separated by semi-column, should be provided to assist the reader and facilitate information retrieval.

Body of Text

The title of the article should be typed in upper-case letters and bold. All other headings should be typed in upper-case letters and bolded while sub-headings should be in lower-case and bolded. The main headings should not be indented. The SI unit system must be used. Standard abbreviations may be used without definition, and specialized abbreviations should be used only after they are defined when they first appear. Use capital 'T' for Table and 'F' for figure. Mathematical formulae should be carefully typed with symbols, correct alignment and must be adequately spaced. Statistical evaluation of results should be described briefly and if necessary, supported by references.

Introduction

A conscience introduction of the background to the subject is required and should include a brief statement of the problem, significance and purpose of the research and relationship to earlier works with well acknowledged references.

Materials and Methods

This section must be presented with adequate clarity and provide sufficient details to permit the repetition of the experimental work. The techniques and the methodologies adopted should be supported with standard references. Subheadings under this section should be in lower case except the first letter.

Results and Discussion

Results should be presented concisely. Only in exceptional cases will it be permissible to present the same set of results in both Table and figure. In discussion, point out the significance of the results and place the results in the context of other work and theoretical background. Results and Discussion part could be written separately if author so wish.

References

Only published articles (Journals and Proceedings) or Books may be cited. In addition, articles with evidence of Journal acceptance are considered as "in press" and are also citable. The reference list should be arranged alphabetically. Authors should be referred to in text by name and year (Harvard system). Examples:

For Journals, list as:

Jega, I.S. and Kwaifa, M..N. (2017). Statistics of Cassava Yield Trials with the Additive Main Effects and Multiplicative Interaction (AMMI) model. *African Journal of Root and Tuber Crops*, 3 (1), 46-50.

Within the text, references should be given as: Meaza *et al*. (2007), or similar results have been obtained (Meaza *et al*., 2007).

For proceedings, list as:

Aina, O.O., Dixon, A.G.O.and Akinrinde, E.A. (2021). Influence of shoot and root characteristics of cassava genotypes on yields in Nigeria. *African Crop Science Conference Proceedings, Vol. 5*. pp. 1119-1125.

For Books, list as:

DeVries, J. and Toenniessen, G. (2001). *Securing the Han/est Biotechnology, Breeding and Seed Systems for African Crops*. The Cromwell Press, Trowbridge, Wiltshire, UK. 208pp.

For electronic resource materials (online publications) list as:

Zachary, G.P. *Africa plays the rice card*. Foreign Policy. May/June 2008 (web-exclusive story).http://WWW.foreignpolicycom/stogg/cms. php? story id = 4306. Accessed 26 August 2008.

Tables and Figures

Tables and Figures should be labelled serially using Arabic numerals (e.g Table 1, Table 2, etc; Figure 1, Figure 2, etc.)

Abbreviations

Avoid the use of abbreviations at the beginning of the title, heading or sentence. The following abbreviations with numerals can be used without spelling out at first use. H, min, s, yr, mo, mm, kg, g, DNA, RNA, cpDNA, dNTP.

Numbers

Avoid the use of figures /numbers at the beginning of a sentence. Write out one through nine unless a measurement, a designator, or a range (e.g five seeds, 8cm, 3yr, 5-11 flowers)

Ethical matters

The author using experimental animals must seek permission and include a statement that the investigation was approved by the Ethics Clearance Committee of the researchers' institution.

Copyright

Submission of a copyright to **KEJAANS** implies that the study presented has not been published before or under consideration for publication elsewhere. Once an article has been accepted for publication, author concedes the copyright to **KEJAANS**. However, authors are responsible for the content that appeared in their manuscripts.

Plagiarism Check on Submitted Papers

Since academic Journals must strictly audit the quality of the papers, prevent plagiarism, fraud and other phenomena, ensure that the papers are scientific, original and standardized; cultivate the author's research integrity and consciousness in the process, create a healthy and fair academic environment. It is advisable that each author first conduct a plagiarism check on their paper before submission. Every submitted paper undergoes a plagiarism check by the editors. The editors of **KEJAANS** shall liaise with the Academic Librarians of the organization/institution to do this. Any paper that is more than 20% (or less as determined by the editors) in its plagiarism check shall be sent back to the author for reworking and resubmission.

Blind Peer-review of Submitted Papers

Submitted papers that passed a plagiarism check by **KEJAANS** shall be sent to at least two reviewers that are expert in the field, after every piece of information that can reveal the identity or the affiliation of authors has been concealed for fair, blind peer review. The reviewers shall give a comprehensive report of their review. The editors shall design a Form to be completed by the reviewers after the review. The reports and completed forms shall guide the editors in their further decisions on the reviewed article. The reviewers shall recommend the paper for publication or otherwise.

Publication of Papers

This shall be done after the acceptance of articles for publication in line with the next publication time of the Journal. Prior to publication, a galley proof copy shall be sent to the corresponding author who shall immediately effect correction (if any), and return to the editors. The number of articles to be published in a given issue of the Journal shall be at least 15. It is not compulsory for **KEJAANS** to produce an issue of the Journal if there are no accepted articles ready for publication at a given time of publication.

KEJAANS

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
JANUARY, 2025: Volume 1, Issue 1:22-27
p-ISSN: 1595-5776

PERFORMANCE OF HYBRID AFRICAN CATFISH (*Heteroclarias*) FINGERINGS FED DIETS CONTAINING *Aphodius rufipes* LARVAE MEAL AND *Hermetia illucens* LARVAE MEALS

*GANA, Aminu Baba; BAKE, Gabriel Gana; SADIKU, Suleiman Omeiza Eku; and ORIRE, Abdullahi Mohammed

Department of Water Resources, Aquaculture and Fisheries Technology, Federal University of Technology, P.M.B. 65 Minna, Niger State Nigeria

Corresponding Author: aminu.pg209490@st.futminna.edu.ng, +234 8037531711

ABSTRACT

This study investigated the growth performance and health of hybrid African catfish (Heteroclarias) fingerlings fed diets containing varying inclusion levels (0 %, 15 %, 30 %, and 45 %) of Aphodius rufipes larvae meal (ARLM) and Hermetia illucens larvae meal (HILM). Seven (7) iso-nitrogenous diets (40 % crude protein) were formulated and ten (10) fingerlings were stocked per aquarium (45 × 30 × 24 cm³) for a 70-day feeding trial. Growth parameters (weight gain, specific growth rate, feed conversion ratio), haematological indices (packed cell volume, haemoglobin, platelet count), proximate and mineral compositions of fish carcasses were assessed. One-way analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) were used for statistical analysis ($p<0.05$). Results showed no significant differences ($p>0.05$) in weight gain, average daily gain, protein efficiency ratio or feed conversion ratio among treatments. However, the 30 % ARLM diet yielded the highest weight gain (25.26 g). Significant differences ($p<0.05$) were observed in protein retention, apparent net protein utilization, protein retention efficiency, survival rate, haematological indices and carcass compositions (proximate and minerals). The study revealed that ARLM and HILM could be incorporated into Heteroclarias fingerlings diets up to 45 % without negatively impacting growth or health.

Keywords: Performance, Heteroclarias, Diets, Fingerlings

Introduction

Aquaculture is the growing of aquatic organisms in confined areas (Huntington *et al*., 2017) which play an important role in economies worldwide, in both developed and developing countries (Subasinghe *et al*., 2009). Aquatic food consumption globally is projected to reach 21.4 kg per capita in 2031, up from the baseline of 20.5 kg per capita (Mair *et al*., 2023). Per capita, consumption will increase in all continents except Africa, the region with the fastest-growing population (FAO, 2022). By 2030, projections indicate a significant and substantial increase in aquaculture production compared to capture fisheries, with an estimated 6 million tonnes (Mair *et al*., 2023). However, if growth in aquaculture can be sustained, it is likely to meet the increasing demand for aquatic food supplies by supplying more than 50 percent of the total aquatic food consumption (Subasinghe *et al*., 2009; Tran *et al*., 2022).

Fish farming is a branch of aquaculture that grows fish in an enclosed system (Walia and Kaur, 2023). Fish is highly nutritious, rich in micronutrients, minerals, essential fatty acids and protein (Selamoglu and Naeem, 2023). Fish contributes to or exceeds 50 percent of total animal protein intake in some small Islands and other developing States like Nigeria (Norman *et al*., 2019). The observed expansion of fish farming directly correlates with the progressive intensification of its production systems (Azim and Little, 2007). Intensive production systems in this sector rely heavily on manufactured feeds designed to meet the specific nutritional requirements of the cultured fish species (Gabriel *et al*., 2007). Fish feed constitutes up to 70 % of the variable operating costs in commercial fish farming. The cost of fishmeal, a crucial protein source in fish feed, is a major determinant of the overall feed production expenses (Jannathulla *et al*., 2019). Conventional fish feeds predominantly utilize both plant and animal-derived (fishmeal, soybean meal and maize meal) protein sources (Jimoh *et al*., 2014). However, economic viability necessitates the development and utilization of cost-effective feed formulations (non-conventional materials) for sustainable fish farming practices (Shipton *et al*., 2013).

Aphodius rufipes larvae, an insect from Scarabaeidae, are found within cattle dung in natural savannah and grassland grazing ecosystems (Bake *et al*., 2021). Analysis reveals that edible *Aphodius rufipes* larvae feeding on cattle dung possess high protein levels and other essential nutrients (Alamu *et al*., 2013; Tang *et al*., 2019). The larvae of *Hermetia illucens* are saprophagous, consuming a wide variety of decaying organic matter, including animal manure and human excreta, with minimal substrate disruption (Suriya *et al.*, 2024). It produces a biomass with approximately 42 % protein and up to 35 % fat content (Stamer *et al.*, 2014). The high protein content and favorable amino acid profile of *Hermetia illucens* larvae suggest their potential as a novel animal feed ingredient (Cammack and Tomberlin, 2017). *Hermetia illucens* larvae demonstrate significant potential as a sustainable protein source due to its efficient bioconversion of low-value organic substrates into nutritionally rich biomass (Danieli *et al*., 2019). The readily available larvae, possessing a high-protein content and favourable amino acid profile, represent a promising candidate species for animal feed applications (Cammack and Tomberlin, 2017). Therefore, this study was conducted to evaluate the growth responses of hybrid African catfish (*Heteroclarias*) fingerings fed diets containing *Aphodius rufipes* larvae meal (ARLM) and *Hermetia illucens* larvae meal (HILM).

Materials and Methods

Study Area

This study was conducted at the Department of Water Resources, Aquaculture and Fisheries Technology (WAFT), Old Teaching and Research Farm, Bosso Campus, Federal University of Technology (FUT) Minna, Niger State, Nigeria. Minna exhibits a sub-humid climate characterized by a mean annual rainfall of 1284 mm and a distinct dry season lasting from November to March (Ojanuga, 2006). Mean maximum temperatures remain consistently high, averaging approximately 32°C, with peak values observed in March and June. Geographically, Minna is situated (9°31′N, 6°30′E) within Nigeria's Southern Guinea savanna vegetation belt of Nigeria (Lawal *et al*., 2012).

Experimental Ingredients

Fishmeal (FM), soybean meal (SBM), maize meal (MM), starch, vegetable oil and a vitamin/mineral premix were obtained from Kure Ultra-modern Market, Bosso Local Government Area, Niger State. The soybean was slightly toasted. The larvae of *Aphodius*

rufipes (dung beetles) were collected from compacted cattle dung in Wuyagi village (9°8'31"N, 5°51'36"E), Lavun Local Government Area, Niger State, Nigeria. Following dissection to remove unwanted materials, the larvae were euthanized and cleaned by immersion in 60°C water for 30 minutes. Subsequently, samples were oven-dried at 100°C for 8 hours. *Hermetia illucens* (black soldier fly) eggs were sourced from a reputable farm in Minna, Nigeria and incubated in an open container with moistened maize chaff (*Dusa*). After 48 hours, hatched larvae were fed a diet of fruit waste (watermelon, pineapple and cucumber) for three weeks. Larvae were harvested using a water-based flotation technique, sieved (0.5 mm mesh size) and oven-dried at 100°C for four hours. All ingredients were individually processed, milled, sieved and packed in an airtight polyethene bag until needed. The ingredients were analysed for proximate and mineral compositions (Table 1).

Table 1
Proximate and Mineral Compositions of the Major Feed Ingredients

Ingredients/ Parameters	**FM**	**ARLM**	**HILM**	**SBM**	**MM**
	Proximate Compositions (%)				
Crude protein	56.88	39.50	28.00	43.01	9.62
Ether extract	12.98	14.83	15.76	21.39	6.71
Crude fibre	0.00	14.65	7.70	6.22	2.55
Ash content	13.37	11.55	23.62	5.36	1.54
Moisture content	10.43	9.29	4.41	3.73	9.05
Nitrogen free extract	6.34	10.18	20.51	20.29	70.53
	Mineral Compositions (g/kg)				
Sodium	1.52	1.68	1.78	0.06	0.09
Potassium	8.56	7.10	7.26	1.76	0.83
Phosphorus	0.21	0.13	0.19	0.09	0.06
Calcium	1.88	1.14	1.66	0.21	1.26
Magnesium	0.77	0.39	0.76	0.51	0.43

FM = Fishmeal, ARLM = Aphodius rufipes larvae meal, HILM = Hermetia illucens larvae meal, SBM = Soybean meal, MM = Maize meal

Formulation of the Experimental Diets

Seven (7) iso-nitrogenous diets of 40 % crude protein (CP) were formulated (Table 2) for *Heteroclarias* fingerlings using linear programming (Microsoft Excel) with varying inclusion levels of insects meal and designated as T1 (0 %: Control), T2 (15 % ARLM), T3 (30 % ARLM), T4 (45 % ARLM), T5 (15 % HILM), T6 (30 % HILM) and T7 (45 % HILM). Feed ingredients were independently weighed using a weighing (Golden Mettler 2000L: Model) balance. A moist dough was created by homogenizing the ingredients in a plastic bowl with added steam for gelatinization. This dough was then pelletized (2 mm diameter) using a manual pelletizer and oven-dried at 80°C for 40 minutes. The formulated diets were then analysed for proximate and mineral compositions (Table 3).

Table 2. Compositions of the Experimental Diets

Treatments/Ingredients	T1	T2	T3	T4	T5	T6	T7
Aphodius rufipes larvae meal	0.00	15.00	30.00	45.00	0.00	0.00	0.00
Hermetia illucens larvae meal	0.00	0.00	0.00	0.00	15.00	30.00	45.00
Fishmeal	64.76	54.35	43.93	33.51	52.55	40.34	28.13
Maize meal	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Soybean meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Vegetable oil	2.92	2.02	1.12	0.21	2.37	1.81	1.26
Vitamin/Mineral premix	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Cellulose	12.32	8.63	4.95	1.28	10.08	7.85	5.61
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Energy kcal/100 g	271.76	271.81	271.84	271.77	271.80	268.73	271.81

Table 3. Proximate and Mineral Compositions of the Experimental Diets

Treatments/ Parameters	T1	T2	T3	T4	T5	T6	T7
	Proximate Compositions (%)						
Crude protein	39.21	39.56	39.44	38.96	39.61	39.06	39.15
Ether extract	10.97	13.84	10.21	9.13	13.96	10.51	11.12
Crude fibre	2.52	2.66	3.52	3.96	3.02	4.02	3.78
Ash content	11.06	13.56	14.12	13.33	14.12	15.75	15.42
Moisture content	6.88	5.18	5.56	3.61	4.43	5.73	4.08
Nitrogen free extract	29.36	25.20	27.15	31.01	24.86	24.93	26.45
	Mineral Compositions (g/kg)						
Sodium	0.48	0.45	0.53	0.79	0.43	0.86	0.69
Potassium	1.02	0.96	0.86	1.12	1.43	1.10	1.33
Phosphorus	0.11	0.14	0.12	0.11	0.15	0.20	0.19
Calcium	0.29	0.21	0.22	0.25	0.29	0.26	0.25
Magnesium	0.52	0.57	0.49	0.62	0.76	0.54	0.43

Experimental Fish

The hybrid African catfish (*Heteroclarias*) fingerlings were obtained from a reputable fish farm in New Bussa, Niger State and transported in an open plastic container to the experimental site. They were acclimatized upon arrival in an outdoor nursery tank (150 × 150 × 75 cm^3) for two weeks before the experiment commenced. They were fed a conditioning diet (vital fish feed) twice daily.

Determination of Growth Parameters

The growth parameters were calculated using the formulae:

Weight gain (WG) = Final weight (Wf) – Initial weight (Wi) of the fish.

Specific growth rate (SGR) = $\frac{\ln Wf - \ln Wi}{T} \times 100$

Where: ln Wf = logarithm of the final weight, ln Wi = logarithm of the initial weight and T = experimental duration.

Feed conversion ratio (FCR) = $\frac{\text{Weight of feed fed (dry weight)}}{\text{Weight gain of fish (wet weight).}}$

Average daily gain (ADG) = $\frac{\text{Mean final body weight – Mean initial body weight}}{\text{Number of days of the experiment.}}$

Survival rate (SR) = $\frac{Nf}{Ni} \times 100$

Where: Nf = number of alive at the end of the experiment, Ni = number stocked at the beginning of the experiment.

Protein retention (PR) = $\frac{\text{Protein gain}}{\text{Protein fed}} \times 100$

Protein efficiency ratio (PER) = $\frac{\text{Weight gain}}{\text{Protein fed}} \times 100$

Apparent net protein utilization (ANPU) = $\frac{\text{Carcass protein gain (g)}}{\text{Protein fed (g)}} \times 100$

Protein retention efficiency (PRE) = $\frac{\text{Protein retained}}{\text{Protein consumed}}$

Haematological Indices

The fish blood samples (Table 4) were collected from each treatment group by bleeding the fish from the caudal fin using a dissecting blade at the beginning and end of the feeding trial as described by Vijayan and Moon (1992); and Stoskoph (1993). The collected blood samples were immediately placed into plastic tubes containing ethylene diamine tetra-acetic acid (EDTA) as an anticoagulant and transported to the Veterinary Hospital laboratory (Niger State Ministry of Livestock and Fisheries Minna) for analysis. The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated using the formulae described in Doig and Zhang (2017).

MCV (fl) = PCV/RBC × 10; MCH (pg) = Hb/RBC × 10 and MCHC (g/dl) = Hb/PCV × 100.

Biochemical Analysis

The samples of feed ingredients formulated diets and fish carcasses (Table 5) were taken to the WAFT laboratory for analysis of proximate and mineral compositions. The proximate analysis (crude protein, ether extract, moisture, ash and fibre content) was conducted according to AOAC (2000) methods. Nitrogen-free extract (NFE) was calculated by difference: 100 – (crude protein + ether extract + moisture + ash + fibre). For mineral analysis, 2 g samples were weighed (Atom-110C balance) in a crucible and ash (M110 muffle furnace at 500 °C for 4 hours), followed by acid digestion (10 ml HCl).

Table 4: Haematological Indices of *Heteroclarias* Fingerlings Fed the Experimental Diets for 70 Days

Treatments/ Parameters	PCV (%)	Hb (g/dl)	RBC (×10^9/l)	WBC (×10^9/l)	PLC (%)	MCV (fl)	MCH (pg)	MCHC (%)
Initial	13.67	4.56	2.28	0.28	102.67	60.03	20.01	33.34
T1	17.67^{bc}	5.89^{bc}	2.95^{bc}	0.95^{bc}	116.33^{ab}	59.96^{a}	19.98^{a}	33.32^{a}
T2	20.00^{b}	6.67^{b}	3.33^{b}	1.33^{b}	124.00^{ab}	60.06^{a}	20.03^{a}	33.35^{a}
T3	17.00^{bcd}	5.67^{bcd}	2.83^{bcd}	0.83^{bcd}	121.00^{ab}	60.00^{a}	20.00^{a}	33.33^{a}
T4	13.33^{d}	4.44^{d}	2.22^{d}	0.22^{d}	107.00^{b}	59.97^{a}	19.98^{a}	33.33^{a}
T5	15.00^{cd}	5.00^{cd}	2.50^{cd}	0.50^{cd}	106.00^{b}	60.00^{a}	20.00^{a}	33.33^{a}
T6	27.00^{a}	9.00^{a}	4.50^{a}	2.50^{a}	160.67^{a}	60.00^{a}	20.00^{a}	33.33^{a}
T7	21.00^{b}	7.00^{b}	3.50^{b}	1.50^{b}	131.00^{ab}	60.00^{a}	20.00^{a}	33.33^{a}
±SE	1.02	0.34	0.17	0.17	5.79	0.01	0.01	0.00

Values in the same column with different superscripts are significantly different ($p<0.05$) from each other.
PCV = Packed cell volume, Hb = Haemoglobin, RBC = Red blood cell, WBC = White blood cell, PLC = Platelet count, MCV = mean corpuscular volume, MCH = Mean corpuscular haemoglobin, MCHC = Mean corpuscular haemoglobin concentration

Table 5: Proximate and Mineral Compositions of the Experimental Fish (Carcass: Dry Basis) Fed the Diets for 70 Days

Treatments/ Parameters	Proximate Compositions (%)								
	Initial	T1	T2	T3	T4	T5	T6	T7	±SE
Crude protein	48.18	58.52^{ab}	54.83^{bcd}	60.74^{a}	56.74^{bc}	53.38^{cd}	51.46^{d}	58.25^{ab}	0.77
Ether extract	9.16	10.37^{d}	11.03^{cd}	11.95^{bc}	12.29^{bc}	12.53^{b}	15.18^{a}	11.77^{bc}	0.34
Ash content	18.18	16.91^{ab}	17.73^{a}	13.81^{bc}	13.78^{bc}	11.65^{c}	17.06^{ab}	14.40^{abc}	0.58
Crude fibre	7.25	5.72^{de}	7.03^{b}	5.32^{e}	6.26^{bcd}	6.12^{cd}	6.58^{bc}	8.39^{a}	0.22
Moisture content	6.15	5.28^{b}	5.50^{ab}	4.96^{b}	5.08^{b}	5.25^{b}	6.25^{a}	5.57^{ab}	0.12
Nitrogen free extract	11.09	3.20^{b}	3.87^{b}	3.23^{b}	5.85^{b}	11.07^{a}	3.47^{b}	1.62^{b}	0.77
Mineral Compositions (g/kg)									
Sodium	0.44	0.48^{c}	0.51^{b}	0.55^{ab}	0.52^{b}	0.48^{c}	0.56^{a}	0.53^{ab}	0.01
Potassium	1.06	1.28^{bc}	1.42^{b}	1.79^{a}	1.70^{a}	1.20^{c}	1.40^{b}	1.35^{bc}	0.05
Phosphorus	0.11	0.11^{b}	0.11^{ab}	0.12^{ab}	0.12^{a}	0.09^{c}	0.12^{ab}	0.11^{b}	0.00
Calcium	0.42	0.39^{b}	0.35^{b}	0.28^{c}	0.40^{b}	0.29^{c}	0.51^{a}	0.52^{a}	0.02
Magnesium	0.2	0.40^{a}	0.34^{a}	0.21^{b}	0.34^{a}	0.23^{b}	0.36^{a}	0.21^{b}	0.02

Values in the same row with different superscripts are significantly different ($p<0.05$) from each other.

The resulting solution was filtered (50 ml volumetric flask) and analysed for sodium (Na) and potassium (K) using flame photometry (Jenway FF-200), phosphorus (P) using spectrophotometry (Jenway 741501), calcium (Ca) via EDTA titration (10 % KOH, casein indicator), and magnesium (Mg) via EDTA titration (ammonia buffer, Eriochrome black T indicator).

Experimental Conditions

The experiment was conducted using plastic aquaria (45 × 30 × 24 cm^3). Following initial weighing to determine the mean weight (2.28 – 2.29 g), ten (10) fingerlings were stocked per aquarium at the commencement of the trial. The fingerlings were fed to satiation three times daily, with uneaten feed and faecal matter siphoned from aquaria each morning using a 7.5 mm diameter rubber hose. Sampling was done every two weeks. The fish were removed from each aquarium using a hand net and weighed using a sensitive weighing balance (Model: 2000L Golden Mettler). The water samples were collected bi-weekly and transported to the WAFT Department laboratory for analysis (Table 7) of dissolved oxygen (DO), temperature (T), pH, biological oxygen demand (BOD), alkalinity (ALK), water hardness (WH) and electrical conductivity (EC).

Data Analysis

The collected data were analysed using analysis of variance (ANOVA) with the aid of a statistical package for the social sciences (SPSS) version 27. Treatment means were compared using Duncan's Multiple Range Test (DMRT). Statistical significance was set at 5 % ($p<0.05$).

Results and Discussions

The results in Table 1 showed that the *Aphodius rufipes* larvae meal (ARLM) contained a CP of 39.50 % and ether extract (EE) of 14.83 %. This was similar (34.41 % CP and 12.15 % EE) to that reported by Gana *et al*. (2022). The *Hermetia illucens* larvae meal (HILM) contains 28.00 % and 15.76 % CP and EE respectively. However, Wardhana *et al*. (2016); Loho and Lo (2023) report that the CP content of *Hermetia illucens* larvae typically falls within the range of 30 – 50 %, while the crude lipid content ranges from 29 – 32 %. These variations may be attributed to seasons, size, geographical locations and processing methods. The results in Table 6 show the growth performance of *Heteroclarias* fingerlings fed varying levels of ARLM and HILM based diets for 70 days. There was no significant difference ($p>0.05$) in the initial mean weight, final weight and weight gain of the fish fed the experimental diets. Although the fish fed T3 (30 % ARLM) had the highest weight gain (25.26 g) while the T1 (0 %: Control) had the least weight gain of 17.02 g. This does not corroborate with the findings of Maranga *et al*. (2022) and Mundida *et al*. (2023). These researchers reported a significant difference ($p<0.05$) among the treatments in *Clarias gariepinus* fingerlings when fed inclusion levels of HILM based diets. The observed differences could be because of different culture mediums, species, diet compositions and feeding periods. Weight gain in fish fingerlings is crucial for their survival and growth, ultimately impacting fish farming productivity and sustainability. No significant differences ($p>0.05$) were observed among the treatment means in FCR. Mitra (2021) and Oteri *et al*. (2021) demonstrated that high-quality feeds directly improve FCR, a key factor in enhancing the economic viability of fish farming by minimizing feed costs and maximizing profitability. However, significant variations ($p<0.05$) were observed among the treatment means in PR, ANPU and PRE. The percentage survival in all the fish fed dietary treatments ranged between 73.33 – 90.00 %

and they differ significantly. However, this was lower compared to the values (98.52 – 98.86 %) reported by Bake *et al*. (2021) while investigating the growth performance, body composition and apparent nutrient digestibility of hybrid catfish fingerlings fed with blended insect meal. The enhanced survival in the experimental group was likely due to the high palatability and nutritional quality of the experimental diets, promoting improved health status and reduced mortality. High survival rates are essential for the economic sustainability of fish farming operations (Simasiku *et al*., 2024). Figure 1 represents the growth curve of *Heteroclarias* fingerlings fed varying levels of ARLM and HILM based diets.

Table 6
Growth Indices of *Heteroclarias* Fingerlings Fed the Experimental Diets for 70 Days

Treatments/ Parameters	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**±SE**
IW (g)	2.29	2.28	2.29	2.28	2.28	2.29	2.28	0.00
FW (g)	19.31	21.17	27.55	22.36	24.34	27.15	20.95	1.06
WG (g)	17.02^{a}	18.89^{a}	25.26^{a}	20.08^{a}	22.06^{a}	24.86^{a}	18.67^{a}	1.06
SGR (%)	3.04^{a}	3.17^{a}	3.54^{a}	3.26^{a}	3.30^{a}	3.53^{a}	3.16^{a}	0.06
FCR	1.96^{a}	1.74^{a}	1.31^{a}	1.60^{a}	1.67^{a}	1.31^{a}	1.69^{a}	0.08
PI	13.27^{a}	12.94^{ab}	12.86^{ab}	12.77^{ab}	12.81^{ab}	12.96^{ab}	12.44^{b}	0.07
ADG (g)	0.24^{a}	0.27^{a}	0.36^{a}	0.29^{a}	0.32^{a}	0.35^{a}	0.27^{a}	0.02
SR (%)	83.33^{ab}	80.00^{ab}	73.33^{b}	90.00^{a}	76.67^{ab}	86.67^{ab}	76.67^{ab}	1.81
PR	33.17^{a}	32.35^{ab}	32.16^{ab}	31.93^{ab}	32.03^{ab}	32.39^{ab}	31.10^{b}	0.19
PER	0.42^{a}	0.47^{a}	0.63^{a}	0.50^{a}	0.55^{a}	0.62^{a}	0.47^{a}	0.03
ANPU	21.45^{ab}	13.85^{cd}	26.07^{a}	17.81^{bc}	10.72^{de}	6.84^{e}	20.92^{ab}	1.53
PRE	4.41^{ab}	4.24^{bc}	4.73^{a}	4.45^{ab}	4.17^{bc}	3.97^{c}	4.68^{a}	0.07

Values in the same row with different superscripts are significantly different ($p<0.05$) from each other

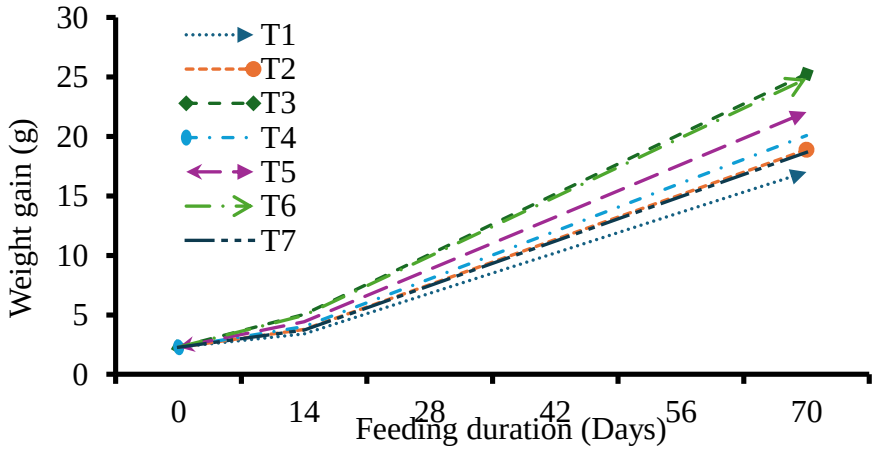

Figure 1: Growth Response Curve of *Heteroclarias* Fingerlings Fed Insects Meals for 70 Days

Haematological indices in African catfish fingerlings serve as valuable biomarkers reflecting physiological status and stress responses (Dahunsi and Oranusi, 2013; Muyiwa *et al*., 2020). The result (Table 4) revealed that the PCV, Hb and PLC differ significantly ($p<0.05$) across the treatment means. The values recorded in this study are similar to those reported by Okore *et al*. (2016) while investigating the growth and haematological studies of African catfish (*Clarias gariepinus*) juveniles fed with housefly larva (*Musca dometica*) as a feed supplement. Fagbenro (2003) stated that poor water quality (high ammonia, low oxygen), temperature fluctuations and handling stress significantly alter haematological profiles. The Hb values ranged between 4.44 – 9.00 g/dl. Isaac *et al*. (2013) reported that haemoglobin transports oxygen to tissues for oxidative metabolism and carbon dioxide away from tissues. The PLC values recorded (106.00 – 160.67 %) were higher compared to the value (102.67 %) recorded at the initial (before the commencement of the experiment). Low platelet concentration suggests that the process of clot-formation (blood clotting) will be prolonged resulting in excessive loss of blood in the case of injury (Etim *et al*., 2014).

The proximate and mineral compositions (Table 5) results revealed that the protein content (carcass) ranged between 51.46 – 60.74 %, 10.37 – 15.18 % for ether extract, 4.96 – 6.25 % for moisture content and differed significantly ($p<0.05$) across the treatment means. This finding corroborates with the report of Muin *et al*. (2016) and Mundida *et al*. (2023), as they observed significant differences across the treatment means in fish body (carcass) compositions when fed inclusion levels of insect meals. The variations in body composition could indicate differences in fish species, age, diet and environmental conditions. Arbex *et al*. (2015) reported that high protein content is essential for human health, while lipid content influences energy density and the presence of essential fatty acids. Hossain *et al*. (1992) reported that the ability to digest fat appears to be influenced by temperature and the level of fat in the diet. Therefore, the levels of these components are vital for assessing the quality and suitability of fish for human consumption or use in aquaculture feeds. The mineral compositions (carcass: dry basis) range from 0.48 – 0.56, 1.20 – 1.79, 0.09 – 0.12, 0.28 – 0.52 and 0.21 – 0.40 g/kg for sodium, potassium, phosphorus, calcium and magnesium respectively which differs significantly ($p<0.05$) across the treatment means. Boyd and Pillai (1985); and Martínez-Valverde *et al*. (2000) stated that fish mineral composition varies according to species, age, diet and ambient water mineral content. Minerals are essential structural components of the skeletal system, constituents of organic compounds, enzyme activators and regulators of acid-base and osmotic balance (Soetan *et al*., 2010). Selamoglu and Naeem (2023) reported that fish is a significant dietary source of essential minerals crucial for bone health, oxygen transport, immune function, thyroid hormone production and antioxidant defence.

Water quality is a critical determinant of fish farming success, significantly impacting fish growth, survival rates and overall health status (Simasiku *et al*., 2024). The results (Table 7) showed no significant variations in water parameters (temperature, alkalinity and electrical conductivity) among the treatments fed the experimental diets. However, significant differences were observed across the treatment means in dissolved oxygen, biological oxygen demand, pH and water hardness. The experimental temperature range (25.90 – 27.50 °C) fell within the optimal range (24 – 30 °C), as reported by Santhosh and Singh (2007). The recorded dissolved oxygen

levels (5.53 – 6.77 mg/l) in this study were within the recommended range (4.98 – 6.70 mg/l) for maintaining fish health and promoting efficient feed conversion, as reported by Mulugeta *et al*. (2024). Low levels of oxygen could lead to hypoxia, causing stress, reduced feed intake and impaired growth (Simasiku *et al*., 2024).

Table 7: Water Quality Parameters (Monitored) of the *Heteroclarias* Fingerlings Fed the Experimental Diets for 70 Days

Treatments/ Parameters	T (^{o}C)	pH	DO (mg/l)	BOD (mg/l)	ALK (mg/l)	WH (mg/l)	EC (µS/cm)
Initial	26.90	7.27	5.67	3.07	68.67	103.33	501.00
T1	26.80^{a}	6.88^{b}	6.30^{ab}	4.53^{ab}	75.33^{a}	113.67^{ab}	558.00^{a}
T2	26.20^{a}	6.81^{b}	6.77^{a}	4.97^{a}	73.33^{a}	111.67^{b}	540.00^{a}
T3	26.70^{a}	6.84^{b}	6.37^{ab}	4.57^{ab}	74.67^{a}	115.67^{ab}	552.00^{a}
T4	26.90^{a}	8.93^{a}	5.83^{ab}	4.10^{b}	71.33^{a}	115.33^{ab}	522.00^{a}
T5	25.90^{a}	6.80^{b}	5.53^{b}	3.83^{b}	78.67^{a}	121.00^{ab}	588.00^{a}
T6	27.50^{a}	6.90^{b}	5.87^{ab}	3.93^{b}	74.00^{a}	118.33^{ab}	546.00^{a}
T7	27.40^{a}	6.79^{b}	6.47^{ab}	4.07^{b}	79.33^{a}	128.67^{a}	594.00^{a}
±SE	0.12	0.21	0.14	0.11	1.11	1.94	9.97

Values in the same column with different superscripts are significantly different ($p<0.05$) from each other.

T = Temperature, pH = Hydrogen ion concentration, DO = Dissolved oxygen, BOD = Biological oxygen demand, ALK = Alkalinity, WH = Water hardness EC = Electrical conductivity

Conclusion

This study demonstrated that incorporating *Aphodius rufipes* larvae meal (ARLM) and *Hermetia illucens* larvae meal (HILM) into *Heteroclarias* fingerling diets, at varying inclusion levels, did not significantly ($p>0.05$) affect weight gain or feed conversion ratio. However, T3 (30 % ARLM) showed the highest weight gain (25.26 g) and T1 (0 %: control) the lowest (17.02 g). Therefore, these insect meals could be a suitable feed ingredient in *Heteroclarias* fingerling diet and could be included up to 45 %. Furthermore, it showed no negative impacts on the health and well-being of *Heteroclarias* fingerlings, as indicated by growth parameters and haematological indices, even at the highest inclusion level (45 %) of ARLM and HILM in the diets. The haematological values could serve as baseline information for comparison in conditions of nutrient deficiency, physiology and health status of fish fingerlings. The variations observed in body proximate composition and mineral content highlight the need for careful consideration of insect meal incorporation to ensure optimal fish nutritional value.

References

Alamu, O. T., Amao, A. O., Nwokedi, C. I., Oke, O. A. and Lawa, I. O. (2013). Diversity and nutritional status of edible insects in Nigeria: A review. *International Journal of Biodiversity and Conservation*, 5 (4), 215-222.

Association of Official Analytical Chemists (2000). *Official Methods of Chemical Analysis*. 18th Edition, Gaithersburg, M.D., U.S.A. 2000, 24-44.

Arbex, A. K., Bizarro, V. R., Santos, J. C. S., Araújo, L. M. M., De Jesus, A. L. C., Fernandes, M. S. A. and Marcadenti, A. (2015). The impact of the essential fatty acids (EFA) in human health. *Open Journal of Endocrine and Metabolic Diseases*, 5 (7), 98-104.

Azim, M. E. and Little, D. C. (2007). Intensifying aquaculture production through new approaches to manipulating natural food: CAB Reviews. *Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 1 (62), 1 – 23.

Bake, G. G., Ajibade, D. O., Gana, A. B., Yakubu, F. B., Samaila, J., Abdulkarim, I. A. and Gatlin III, D. M. (2021). Growth performance, body composition and apparent nutrient digestibility of hybrid catfish fingerlings fed with blended insect meal. *Nigerian Journal of Fisheries*, 18 (1), 2118 – 2128.

Boyd, C. E. and Pillai, V. K. (1985). Water quality management in aquaculture. *CMFRI Special Publication*, 22, 1-44.

Cammack, J. A. and Tomberlin, J. K. (2017). The impact of diet protein and carbohydrate on select life-history traits of the black soldier fly *Hermetia illucens* (L.) (Diptera: Stratiomyidae). *Insects*, 8 (2), 1 – 14.

Dahunsi, S. O. and Oranusi, U. S. (2013). Haematological response of *Clarias gariepinus* to rubber processing effluent. *Annual Research and Review in Biology*, 3 (4), 624-635.

Danieli, P. P., Lussiana, C., Gasco, L., Amici, A. and Ronchi, B. (2019). The effects of diet formulation on the yield, proximate composition and fatty acid profile of the black soldier fly (*Hermetia illucens* L.) prepupae intended for animal feed. *Animals*, 9 (4), 1 – 18.

Doig, K. and Zhang, B. (2017). A methodical approach to interpreting the red blood cell parameters of the complete blood count. *American Society for Clinical Laboratory Science*, 30 (3), 173-185.

Etim, N. N., Williams, M. E., Akpabio, U. and Offiong, E. E. (2014). Haematological parameters and factors affecting their values. *Agricultural Science*, 2 (1), 37-47.

Fagbenro, O. A. (2003). Effects of acute and chronic exposure to ammonia on some haematological parameters of *Clarias gariepinus*. *Journal of Applied Ichthyology*, 19 (5), 349-356

Food and Agriculture Organization (2022). OECD-FAO Agricultural Outlook 2022-2031. *Outlook, 2031*.

Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Onunkwo, D. N. and Anyanwu, P. E. (2007). Locally produced fish feed: potentials for aquaculture development in sub-Saharan Africa. *African Journal of Agricultural Research*, 2 (7), 287-295.

Gana, A. B., Bake, G. G., Abubakar, F. N., Ibrahim, R., Iriobe, T. and Jega, I. S. (2022). Growth responses, body compositions and haematological indices of *Clarias gariepinus* (Burchell, 1822) fingerlings fed dung beetle (*Aphodius rufipes* Linnaeus, 1758) larvae meal. *Equity Journal of Science and Technology*, 8 (2), 90-97.

Hossain, M. A., Nahar, N., Kamala, M. and Islam, M. N. (1992). Nutrient digestibility coefficients of some plants and animal protein for tilapia. *Journal of Aquaculture in the Tropics*, 7, 256-266.

Huntington, T., Avarre, J. C., Focken, U., Osward, M., Pucher, J. and Sorgeloos, P. (2017). Opportunities and challenges

for aquaculture in developing countries. *Joint Report*, 1- 25.

Isaac, L. J., Abah, G., Akpan, B. and Ekaette, I. U. (2013). Haematological properties of different breeds and sexes of rabbits. *Proceedings of the 18th Annual Conference of Animal Science Association of Nigeria*, Vol. 6. pp. 24-27.

Jannathulla, R., Rajaram, V., Kalanjiam, R., Ambasankar, K., Muralidhar, M. and Dayal, J. S. (2019). Fishmeal availability in the scenarios of climate change: Inevitability of fishmeal replacement in aquafeeds and approaches for the utilization of plant protein sources. *Aquaculture Research*, 50 (12), 3493-3506.

Jimoh, W. A., Fagbenro, O. A. and Adeparusi, E. O. (2014). Response of African catfish, *Clarias gariepinus* (Burchell 1822), fingerlings fed diets containing differently timed wet-heat-treated sesame (*Sesamum indicum*) seed meal. *Agricultural Sciences*, 5 (12), 1159 – 1171.

Lawal, B. A., Adeboye, M. K. A., Tsado, P. A., Elebiyo, M. G. and Nwajoku, C. R. (2012). Properties, classification and agricultural potentials of lateritic soils of Minna in sub-humid agroecological zone, Nigeria. *International Journal of Development and Sustainability*, 1 (3), 903-911.

Loho, L. and Lo, D. (2023). Proximate and fatty acid analysis of black soldier fly larvae (*Hermetia illucens*). *IOP Conference Series: Earth and Environmental Science*, 1169 (1), 1 – 6.

Mair, G. C., Halwart, M., Derun, Y. and Costa-Pierce, B. A. (2023). A decadal outlook for global aquaculture. *Journal of the World Aquaculture Society*, 54 (2), 1 – 62.

Maranga, B., Kagali, R., Mbogo, K., Orina, P., Munguti, J. and Ogello, E. (2022). Growth performance of African catfish (*Clarias gariepinus*) fed on diets containing black soldier fly (*Hermetia illucens*) larvae under aquaponic system. *Aquaculture Studies*, 23 (5), 1 – 10.

Martínez-Valverde, I., Periago, M. J., Santaella, M. and Ros, G. (2000). The content and nutritional significance of minerals on fish flesh in the presence and absence of bone. *Food Chemistry*, 71 (4), 503-509.

Mitra, A. (2021). Thought of alternate aquafeed: Conundrum in aquaculture sustainability. *Proceedings of the Zoological Society*, Vol. 74. pp. 1-18.

Muin, H., Taufek, N. M., Kamarudin, M. S. and Razak, S. A. (2017). Growth performance, feed utilization and body composition of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fed with different levels of black soldier fly, *Hermetia illucens* (Linnaeus, 1758) maggot meal diet. *Iranian Journal of Fisheries Sciences*, 16 (2), 567-577.

Mulugeta, H., Yalew, A., Tilahun, G. and Melaku, A. (2024). Effect of stocking density on the physico-chemical characteristics of pond water and survival rate of Nile tilapia (*Oreochromis niloticus*) fish in Bahir Dar, Ethiopia. *Journal of Agriculture and Environmental Sciences*, 9 (1), 97-109.

Mundida, G. B., Manyala, J. O., Madzimure, J. and Rono, K. (2023). Growth performance and carcass composition of African catfish (*Clarias gariepinus* Burchell, 1822) fed on black soldier fly (*Hermetia illucens* Linnaeus, 1758) larvae based diets. *African Journal of Agricultural Research*, 19 (3), 216-225.

Muyiwa, B. O., Emmanuel, N. S., Yahuza, F. M., Aliyu, M., Inegbenosun, C. U. and Musah, I. (2020). Physico-Chemical evaluation and hematological responses in *Clarias gariepinus* (Burchell 1822) juveniles exposed to *Adenium obesum* stem bark acute bioassay. *Advances in Biological Chemistry*, 10 (2), 43-54.

Norman, R., Crumlish, M. and Stetkiewicz, S. (2019). The importance of fisheries and aquaculture production for nutrition and food security. *Revue scientifique et technique* (*International Office of Epizootics*), 38 (2), 395-407.

Ojanuga, A. G. (2006). *Agroecological Zones of Nigeria Manual*. FAO/NSPFS, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria, 124 pp.

Okore, O. O., Ekedo, C. M., Ubiaru, P. C. and Uzodinma, K. (2016). Growth and haematological studies of African catfish (*Clarias gariepinus*) juveniles fed with housefly larva (*Musca dometica*) as feed supplement. *International Journal of Agriculture and Earth Science*, 2 (3), 21-30.

Oteri, M., Di Rosa, A. R., Lo Presti, V., Giarratana, F., Toscano, G. and Chiofalo, B. (2021). Black soldier fly larvae meal as alternative to fish meal for aquaculture feed. *Sustainability*, 13 (10), 1 – 17.

Selamoglu, Z. and Naeem, M. Y. (2023). Fish as a significant source of nutrients. *Journal of Public Health Nutrition*, 6 (4), 1-14.

Santhosh, B. and Singh, N. P. (2007). Guidelines for water quality management for fish culture in Tripura. *ICAR Research complex for NEH Region, Tripura Center, Publication*, 29 (10), 1 – 10.

Simasiku, E. K., Hove, K., Kanyeme, M. N., Awala, S. K., Matengu, K. K. and Iita, T. I. (2024). Comparative effect of fish feeds on the initial growth and survival rate of juvenile redbreast tilapia (*Coptodon rendalli*) under early hatchery conditions. *Aquaculture Journal*, 4 (3), 180 – 191.

Shipton, T.A. and Hecht, T. (2013). Economic, regulatory and legal review of feed management practices. *In* M.R. Hasan and M.B. New, eds. *On-farm Feeding and Feed Management in Aquaculture*. FAO Fisheries and Aquaculture Technical Paper *No. 583*. Rome, FAO. pp. 565–585

Soetan, K. O., Olaiya, C. O. and Oyewole, O. E. (2010). The importance of mineral elements for humans, domestic animals and plants: A review. *African Journal of Food Science*, 4 (5), 200-222.

Stamer, A., Wessels, S., Neidigk, R. and Hoerstgen-Schwark, G. (2014). Black soldier fly (*Hermetia illucens*) larvae meal as an example for a new feed ingredients' class in aquaculture diets. *Proceedings of the 4th ISOFAR Scientific Conference: Building Organic Bridges*, Vol 4. pp. 1 - 4.

Stoskoph, M. K. (1993). *Clinical Pathology*. In Stoskoph M.K. (Ed.) Fish Medicine. 113 - 131pp.

Subasinghe, R., Soto, D. and Jia, J. (2009). Global aquaculture and its role in sustainable development. *Reviews in Aquaculture*, 1 (1), 2-9.

Suriya, S., Khan, A. A., Veeramani, S. and Shiek, S. A. (2024). The enigmatic journey of black soldier fly: Revolutionizing solid waste management. *Research Square*, 1 - 16.

Tang, C., Yang, D., Liao, H., Sun, H., Liu, C., Wei, L. and Li, F. (2019). Edible insects as a food source: A review. *Food*

Production, Processing and Nutrition, 1 (1), 1-13.

Tran, N., Chu, L., Chan, C. Y., Peart, J., Nasr-Allah, A. M. and Charo-Karisa, H. (2022). Prospects of fish supply-demand and its implications for food and nutrition security in Egypt. *Marine Policy*, 146, 1 – 10.

Vijayan, M. and Moon, T. (1992). Acute handling stress alters hepatic glycogen metabolism in food-deprived rainbow trout (*Oncorhynchus mykiss*). *Canadian Journal of Fisheries and Aquatic Sciences*, 49 (11), 2260-2266.

Wardhana, A. H. (2016). Black soldier fly (*Hermetia illucens*) sebagai sumber protein alternatif untuk pakan ternak. *Wartazoa*, 26 (2), 69-78.

Walia, S. S. and Kaur, T. (2023). *Fish Farming*. In: Basics of Integrated Farming Systems. Springer, pp 71 – 75.