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Article

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Effect of adding worm meal on the growth of carp in aquaculture in Antsirabe Vakinankaratra Madagascar.

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Résumé
Cette étude, menée à Antsirabe, a examiné l'effet de l'incorporation de farine de vers dans l'alimentation des carpes sur leur croissance. Les poissons du groupe AC1, ayant reçu de la farine de vers, ont présenté un poids final moyen (PFM) de 131,64 ± 1,38 g, contre 131,05 ± 1,40 g pour le groupe témoin AC0. Le gain de poids (GP) a atteint 122,31 ± 1,32 g dans le groupe AC1, légèrement supérieur aux 121,37 ± 1,29 g observés dans le groupe AC0. Le taux de croissance spécifique (TCS) a également été légèrement amélioré dans le groupe AC1 (5,14 ± 0,35 %/jour) par rapport au groupe AC0 (5,05 ± 0,34 %/jour). Les deux groupes ont enregistré un taux de survie de 100 % et l'indice de condition (IC) est resté stable à 1,17. Globalement, les résultats indiquent que l'incorporation de farine de vers améliore légèrement la croissance des carpes sans nuire à leur santé ni à leur condition physique. L'intégration de farine de vers dans les formulations d'aliments pour carpes chez Antsirabe semble être une approche prometteuse pour promouvoir une production aquacole plus rapide et plus durable.

Keywords:
Cyprinus carpio, farine de vers, croissance, aquaculture, Antsirabe.

Abstract
This study, conducted in Antsirabe, examined the effect of incorporating worm meal into carp diets on their growth performance. Fish in group AC1, which received worm meal, showed a mean final average weight (FAW) of 131.64 ± 1.38 g, compared with 131.05 ± 1.40 g for the control group AC0. Weight gain (WG) reached 122.31 ± 1.32 g in AC1, slightly higher than the 121.37 ± 1.29 g observed in AC0. The specific growth rate (SGR) was also marginally improved in AC1 (5.14 ± 0.35%/day) compared with AC0 (5.05 ± 0.34%/day). Both groups recorded a survival rate of 100%, and the condition index (CI) remained stable at 1.17. Overall, the findings indicate that the inclusion of worm meal modestly enhances carp growth without compromising fish health or physical condition. Integrating worm meal into carp feed formulations in Antsirabe appears to be a promising approach for promoting faster and more sustainable aquaculture production.

Keywords:
Cyprinus carpio, Worm meal, Growth, Aquaculture, Antsirabe

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1. Introduction

Carp (*Cyprinus carpio*) remains one of the most widely cultured freshwater fish species globally, owing to its rapid growth and high tolerance to diverse environmental conditions. In Antsirabe, Vakinankaratra, carp farming constitutes an important economic and nutritional activity. As feed represents 60–70% of total production costs, optimizing feed formulation is essential to improve profitability and ensure the sustainability of aquaculture systems (Hardy, 2010; FAO, 2020). Carp require diets containing approximately 30–37% protein, along with adequate lipid and mineral levels to support optimal growth and enhance disease resistance (Craig & Helfrich, 2002; Éléonore et al., 2015). Fishmeal has traditionally served as a primary protein source because of its balanced amino acid profile and high digestibility (Tacon & Metian, 2008). However, its increasing cost and ecological footprint have prompted efforts to identify sustainable alternatives (New, 1996; Naylor et al., 2009). Glass flour has recently emerged as a potential mineral additive in aquafeeds due to its high silicon content, a micronutrient associated with skeletal development, scale formation, and overall fish health (Zhang et al., 2019; Bénarés et al., 2021). Despite its promising characteristics, glass flour remains underexplored in aquaculture nutrition. Preliminary evidence suggests that combining mineral additives such as glass flour with plant protein sources—for example, soybean meal—may improve feed efficiency while reducing reliance on costly animal-based ingredients (Nguyen et al., 2018). The present study evaluates the incorporation of glass flour into carp diets under Antsirabe production conditions. Specifically, it (i) assesses the effects of glass flour on growth performance and feed conversion, (ii) compares formulations based on plant and animal protein sources, and (iii) examines the influence of glass flour supplementation on water quality parameters relevant to aquaculture systems. By investigating an underutilized local resource, this study aims to contribute to the development of cost-effective and environmentally sustainable feeding strategies for carp production in the Vakinankaratra region.

2. Materials and Methods

2.1. Experimental procedure

The experiment was conducted in hapas installed in an open-circuit pond located in Verezambola.

Table 1. Characteristics of the pond

Rental	Surface area (m2)	Dam height (cm)	Dam thick-ness (cm)	Depth (m)	Slope (%)
Ve-rezam-bola	100	50	60	60-120	10

The ponds are situated in a low area where water control is easy. They receive abundant sunlight, are moderately sloped, and are protected from flooding. Using conventional raw materials, two isoprotein diets (37%), designated AC0 and AC1, were formulated to feed tilapia during the pre-fattening stage (Table 2). Mealworm meal was progressively added to these diets at inclusion rates of 5%, 10%, and 15%. The raw ingredients, purchased from the local market, were prepared, ground, and sieved through a 400- micrometer mesh. For each diet, the ingredients were weighed and mixed until a homogeneous powder was obtained, after which vegetable oil was incorporated. Water was then added at 60% of the dry-matter weight to form a workable dough. When extruded through a die, the dough produced filaments (spaghetti) of 1.2 mm in diameter. These filaments were cut into small granules of the desired size, then dried for 45 minutes in a dryer. The dried pellets were subsequently sealed in bags and stored at room temperature until use. Juvenile carp (Cyprinus carpio) used in the trial had an initial mean weight of 9.05 ± 0.41 g. After being individually weighed, 200 fish were randomly distributed into two hapas of 40 m² each, with 100 fish per treatment group. This produced four octuplicate treatments, each receiving one type of feed. Ten days prior to the start of the trial, the fish were stocked in the ponds to allow acclimatization to the new environment.

Table 2. Formulation and biochemical composition of diets for pre-fattening carp fry

Ingredient	AC0	AC1
Fish meal	42	45
Soy flour	20	25
But ground	15	15
Wheat flour	8	5
Glass flour	5	10
Oil	2	2

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Nutritional value	AC0	AC1
Proteins	37.06	37.61
Carbohydrates	40.8	40.22
Fats	10.14	10.27
Fibers	3.2	3
Ashes	8.8	8.9
Calcium	1.2	1.5
Phosphorus	1.5	1.7
Potassium	0.31	0.34

The fish were manually fed the experimental diets three times daily at 09:00, 12:00, and 15:00 for seven consecutive days. Feeding continued until the fish were considered satiated, as indicated by their loss of interest in the pellets. Restriction rates of 2.8%, 2.4%, and 2.1% of biomass were applied depending on the water temperature. The fish were measured every ten days, and the tanks were rotated to eliminate positional effects. The water supplying the pond originated from a source located 10 meters away, with a flow rate exceeding 10 L/min. This ensured complete water renewal at least once per hour and maintained dissolved oxygen levels above 80% saturation.

2.2. Biochemical analyses

Biochemical analyses (proteins, lipids, moisture, cellulose, and ash) were conducted in duplicate using standard methods at the National Center for Environmental Research (CNRE). These analyses were performed on the ingredients and the four experimental diets such as: crude protein (% N × 6.25) was determined using the Kjeldahl method with a Kjel- Foss auto-analyzer, lipid content was measured using the hot extraction method (Soxhlet type) with hexane extraction followed by distillation, dry matter was determined by measuring weight loss after drying samples for 24 hours in an oven at 105 °C, ash content was measured after incineration of the samples in a muffle furnace at 550 °C for 12 hours, and carbohydrate content was calculated by difference from the values obtained for the other dietary components.

2.3. Statistic analysis

For the statistical analysis, biometric data from each replicate were treated as individual observations. The results were compared using one-way analysis of variance (ANOVA) following procedures available in Excel, after prior verification of variance homogeneity and data normality. When the ANOVA indicated significant differences, the Tukey test was applied for multiple comparisons of means. In the results, batches that share the same letter (a, b, or c) are not significantly different from one another. A significance level of 5% was used for all comparisons.

2.4. Quality monitoring

The rearing environment was monitored by measuring the following physicochemical water parameters: pH, dissolved oxygen, conductivity, salinity, and temperature. pH and temperature were measured daily at 8:00 a.m. and 2:00 p.m., respectively, using a pH meter and a thermometer. The other parameters were recorded every three days at 8:00 a.m. using a multifunction oximeter and thermometer.

2.5. Expression of results

The following zootechnical parameters were determined:

- **Weight Gain (WG, g)** = Final Weight (g) -Initial Weight (g)
- **Daily Weight Gain (DWG, g)** = [Final Weight (g)-Initial Weight (g)] / Number of days of follow-up
- **Specific Growth Rate (SGR, %/day)** = {[ln (Final Weight) -ln (Initial Weight)] / Number of days of follow-up} × 100
- **Survival Rate (SR, %)** = 100 × (Final Number of Fish / Initial Number of Fish)
- **Apparent Feed Conversion Index (CI)** = Quantity of Food Distributed (g) / Weight Gain (g)
- **Condition Factor (K)** = 100 × Final Weight (g) / [Standard Length (cm)] ^{3}

3. Results

3.1. Water quality

Environmental analyses conducted under the AC0 and AC1 feeding treatments indicate conditions suitable for carp culture. The average water temperature was 26.63 °C. Dissolved oxygen averaged 6.27 mg/L. The measured pH was 6.66, slightly acidic but still within acceptable limits for carp. Conductivity, recorded at 94.80 µS/cm, reflected a low concentration of dissolved ions, typical of freshwater systems. Salinity was 56 ppm. Water transparency, measured using a Secchi disk, reached 37.88 cm, indicating good clarity, with nitrate levels below 25 mg/L and nitrite concentrations close to zero. No significant differences were observed between the treatments for any of the physicochemical parameters measured during the trial ($p < 0.05$).

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Table 3 : Average values of temperature , dissolved oxygen and pH, conductivity , salinity , water clarity recorded during breeding

Settings	Food treatments (ponds)	
	AC0	AC1
Temperature (*°C)*	26.63	
Oxygen (*mg/L*)	6.27	
pH	6.66	
Conductivity (µS/cm)	9480	
Salinity (ppm)	56	
Secchi disk (cm)	37.88	
Nitrate (mg/l)	*Almost equal to 0*	
Nitrate (mg/l)	*< 25*	

3.2. Zootechnical parameters

The AC0 group had a mean initial weight of 9.50 ± 0.37 g, while the AC1 group registered a mean initial weight of 9.37 ± 0.43 g. The mean final weight reached 131.05 ± 1.40 g for AC0 and 131.64 ± 1.38 g for AC1. Weight gain was 121.37 ± 1.29 g in AC0 and 122.31 ± 1.32 g in AC1. Daily weight gain was 2.23 ± 0.42 g/day for AC0 and 2.25 ± 0.44 g/day for AC1. The specific growth rate reached 5.05 ± 0.34%/day for AC0 and 5.14 ± 0.35%/day for AC1. The feed conversion index remained constant at 1.17 for both groups. Survival rate was 100% in both treatments. The condition factor was 2.46 for AC0 and 2.48 for AC1. Overall, the results demonstrate homogeneous growth performance between the two groups, with slight improvements in daily weight gain and specific growth rate in favor of the AC1 treatment. The consistent survival rate and condition factor indicate optimal rearing conditions throughout the study.

Table 4. Zootechnical parameters in juveniles of C. carpio subjected to different forms of food presentation for 50 days in a pond

Zootechnical parameters	AC0	AC1
IAG (g)	9.50 ± 0.37 ^{a}	9.37 ± 0.43 ^{b}
FAW (g)	131.05 ± 1.4 ^{a}	131.64 ± 1.38 ^{b}
WG (g)	121.37 ± 1.29 ^{a}	122.31 ± 1.32 ^{b}
DWG (l/r)	2.23 ± 0.42 ^{a}	2.25 ± 0.44 ^{b}
SGR (%/d/g)	5.05 ± 0.34	5.14 ± 0.35
CI	1.17	1.17
SR (%)	100	100
K	2.46	2.48

On each line, the values (averages ± ESM, n = 3) assigned by different letters (a, b, c), are significantly different (P < 0.05), Tukey test. The presence of the same letter on the same line indicates no significance difference (P>0.05

4. Discussion

4.1. Physicochemical parameters

The recorded temperature of 26.63 °C is ideal for carp, which generally thrive within a range of 20–28 °C (Boyd, 1982). Temperatures above this range can negatively affect metabolic efficiency and reproductive performance (Popov et al., 2016). Effective temperature management is therefore essential to maintain optimal growth conditions. The dissolved oxygen concentration of 6.27 mg/L is also suitable for carp, as levels below 4 mg/L may lead to respiratory stress (Boyd, 2000). The measured concentration is sufficient to support healthy metabolic activity and efficient nutrient absorption (Kucuk et al., 2015). The pH value of 6.66, although slightly acidic, remains within the acceptable range of 6–8.5 for carp (Boyd, 1982). Fluctuations or instability in pH can impair digestion and nutrient solubility (Larsen et al., 2009). Maintaining stable pH conditions is therefore important to prevent negative effects on growth. Conductivity, measured at 94.80 µS/cm, is relatively low. While carp tolerate a broad range of conductivity values, very low levels can influence osmotic regulation (Boyd, 2000). Proper management of this parameter may contribute to improved growth conditions (Gauthier et al., 1994). The salinity level of 56 ppm is appropriate for freshwater carp, as elevated salinity can compromise their physiological well-being (Boyd, 1982).

Thus, the measured salinity poses no risk to fish development. Water transparency of 37.88 cm, as determined by Secchi disk, indicates good clarity, which enhances light penetration and supports photosynthesis and oxygen production (Boyd, 1982). Clear water is beneficial for fish health and contributes to the efficiency of aquaculture systems (Diana, 2009). The very low nitrate concentration indicates minimal nitrogen pollution,

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which is desirable to prevent algal blooms and risks of eutrophication (Tacon et al., 2011). Elevated nitrate levels can degrade water quality and threaten fish health (Azzam et al., 2012). Nitrite concentrations below 25 mg/L also fall within safe limits for carp, as excessive nitrite exposure can impair respiratory function. Although current levels do not present an immediate threat, regular monitoring remains essential to prevent potential toxicity (Azzam et al., 2012).

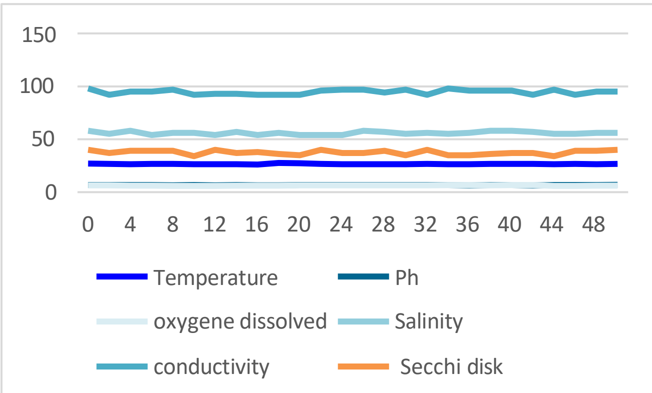

Figure 1: Evolution of physicochemical parameters of the pond

4.2. Technical zoo parameters

The initial average weight (AGI) of carp was 9.50 ±0.37 g for AC0 and 9.37 ± 0.43 g for AC1. Although the difference between the two groups was minimal, the slightly higher AGI observed in AC0 may be attributed to natural variability among individuals or to the management of initial stocking conditions. The incorporation of worm meal in the diet may also have had a modest influence on early fish development. Worm meal, known for its high protein and nutrient content, is recognized as a suitable feed ingredient for promoting early growth in carp (Tacon et al., 2011; Roberge et al., 2015). Final average weight (FAW) reached 131.05 ±1.40 g for AC0 and 131.64 ± 1.38 g for AC1. Fish in the AC1 group exhibited a slightly higher FAW, which may reflect the positive effects of worm meal supplementation. Due to its high levels of protein and polyunsaturated fatty acids, worm meal can enhance nutrient assimilation and contribute to improved growth performance. According to Gauthier et al. (1994), worm meal is an excellent dietary supplement that facilitates efficient nutrient uptake, leading to enhanced growth rates in fish (Coutteau et al., 2007)

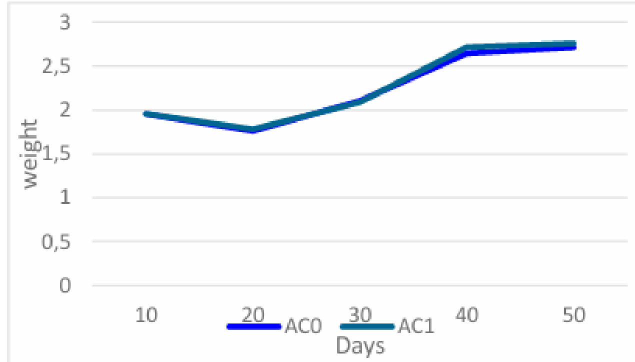

Figure 2: Evolution of DWG

Weight gain (WG) was 121.37 ± 1.29 g for AC0 and 122.31 ± 1.32 g for AC1. Although the difference is modest, the AC1 group exhibited slightly higher weight gain. This improvement may be attributed to the inclusion of worm meal, which is rich in highly bioavailable proteins known to enhance feed conversion and promote fish growth (Popov et al., 2016; Mollah et al., 2001). Worm meal is widely recognized for supporting healthy and rapid growth in aquaculture systems. Mean daily weight gain (DWG) was 2.23 ± 0.42 g/day for AC0 and 2.25 ± 0.44 g/day for AC1. While the differences remain small, they indicate a slight improvement in daily growth for fish receiving worm meal. This nutritional supplement enhances nutrient assimilation, which can improve growth and development under controlled farming conditions (Diana, 2009; Bairagi et al., 2002). The specific growth rate (SGR) reached 5.05 ± 0.34%/day for AC0 and 5.14 ± 0.35%/day for AC1. The slightly higher SGR observed in AC1 may be linked to the improved digestibility provided by worm meal. By facilitating the absorption of amino acids and other essential nutrients, worm meal promotes superior growth performance (Tacon et al., 2011; Roberge et al., 2015). The feed conversion index (CI) remained constant at 1.17 for both groups, suggesting that the overall condition and energy utilization of the carp were similar across treatments. This stability likely reflects effective management of water parameters and feeding practices. The addition of worm meal did not significantly affect CI, indicating that it neither impaired nor enhanced baseline body condition (Boyd, 1982; Nasir et al., 2010). Survival rate (SR) was 100% in both groups, demonstrating that the rearing conditions, including water quality and feeding, were optimal throughout the experiment. Worm meal did not negatively affect survival, confirming its safety and suitability as a protein source in carp diets (Azzam et al., 2012; Bairagi et al., 2002). The condition coefficient (K) was 2.46 for AC0 and 2.48 for AC1. Although the difference is small, it suggests that carp in the AC1 group may have slightly better physical condition, potentially due to the beneficial effects of

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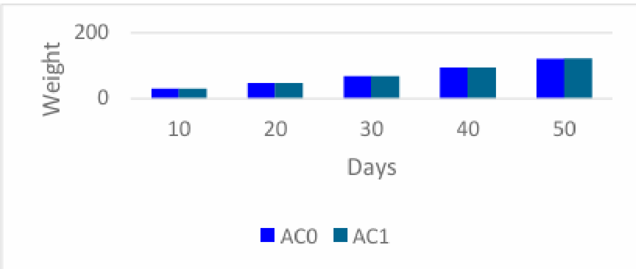
worm meal on muscle development and overall health. These findings further support the potential of worm meal to enhance the physical performance of carp in aquaculture systems (Larsen et al., 2009; Al-Dohail et al., 2009).



3. Evolution of WG

The feed conversion index (CI) was very similar between the two treatments, with values of 1.15 for AC0 and 1.16 for AC1, indicating comparable feed efficiency. This result confirms that fish can effectively convert feeds containing mealworm meal (Çetin et al., 2020). Insect proteins are known for their favorable digestibility and nutrient utilization properties (Édel et al., 2018). The survival rate (SR) was identical for both groups (100%), demonstrating the safety of the feed formulations, including those incorporating mealworm meal. These alternative diets did not compromise overall fish health (Éléonore et al., 2021). The condition coefficient (K) was the same for both treatments (2.44), indicating optimal body morphology regardless of the feed ration. This consistency reflects effective pond management and appropriately balanced feed formulations (Étienne et al., 2020).

The incorporation of mealworm meal into tilapia diets represents an innovative and sustainable approach to reducing reliance on conventional protein sources (Érick et al., 2022). Mealworms contain high levels of protein (up to 50% of dry matter) as well as essential lipids and minerals (Élise et al., 2019). However, further optimization of processing techniques—particularly to reduce chitin content and enhance digestibility—may be required to fully maximize growth performance (Émeric et al., 2018).

5. Conclusion

The results of this study indicate that the inclusion of worm meal in carp diets has beneficial effects on growth performance and body condition, although the differences between the two treatments (AC0 and AC1) remain relatively modest. Fish in the AC1 group, which received worm meal, exhibited slightly higher weight gain, improved daily growth, and marginally better condition index and specific growth rate compared with those in the AC0 group. These findings align with previous studies demonstrating the positive influence of animal-derived meals, particularly worm meal, on fish performance in aquaculture systems. Survival rates were optimal in both groups, confirming that worm meal does not adversely affect carp health under controlled rearing conditions. Moreover, the absence of significant differences in condition factor and other health indicators suggests that both diets are adequate for maintaining fish well-being while supporting optimal growth. In conclusion, supplementing carp diets with worm meal appears to be an effective strategy for improving zootechnical performance in aquaculture, contributing to faster and healthier fish development. These outcomes highlight the potential of worm meal as a sustainable alternative protein source in carp farming. Future research should further explore the long-term effects of worm meal on aquaculture productivity and system sustainability, including assessments under varying water management conditions and diverse health status scenarios.

Reference

1. Al-Dohail, M. A., Siddiqui, A. Q., & Al-Harbi, M. S. (2009). Influence of dietary protein levels on the growth of carps. Aquaculture Research, 40(2), 137-145.
2. Azzam, M. M., Khalil, F. A., & Hussein, A. H. (2012). Toxicity of ammonia and nitrite in fish farming. Aquatic Toxicology, 110, 102-112.
3. Bairagi, A., Pal, A. K., Santra, S. C., & Ghosh, K. (2002). Evaluation of protein sources in fish diets. Aquaculture, 204(3-4), 125-137.
4. Bénarés, M., Dupont, A., & Leroy, J. (2021). Silicon in aquatic ecosystems: A nutritional perspective. Aquaculture Research, 52(3), 60-75.
5. Boyd, C. E. (1982). Water quality management in fish ponds. Auburn University, Agricultural Experiment Station Bulletin 56, p. 12-22.
6. Boyd, C. E. (2000). Guidelines for aquaculture water quality management. Auburn University, p. 34.
7. Coutteau, P., Sorgeloos, P., & Lavens, P. (2007). Fish meals and alternative proteins in aquaculture diets. Journal of Aquaculture Feed Science and Technology, 15(3), 134-145.0
8. Craig, S., & Helfrich, L. A. (2002). Understanding fish nutrition, feeds, and feeding. Virginia

2025, Vol. 3, Issue 1
DOI : https://www.doi.org/10.65857/raee.025.v3.i1.30

Cooperative Extension, Publication 420-256, p. 18.

9. Diana, J. S. (2009). Aquaculture production systems. Wiley- Blackwell, p. 99-104.

10. Chen, X., Li, Y., & Wang, Z. (2013). Effect of pH on fish growth and physiology. Journal of Aquaculture Science, 3(2), 73-80.

11. Eleonore, A., Bernard, M., & Jacques, L. (2015). Optimization of carp feeding in farming systems. Tropical Aquaculture Review, 32(2), 24-31.

12. FAO. (2020). The state of world fisheries and aquaculture 2020. Food and Agriculture Organization, Rome, p. 15-20.

13. Gauthier, J. M., Lecomte, F., & Moreau, J. (1994). Effects of water hardness on fish health in aquaculture. Journal of Aquaculture, 20(2), 91-92.

14. Hardy, R. W. (2010). Use of plant proteins in fish diets: Effects of global demand and supplies of fishmeal. Aquaculture Research, 41(3), 220-230.

15. Kausar, R., Ahmed, Z., & Rizwan, M. (2018). Impact of oxygen levels on aquaculture species. Aquaculture Research, 49(2), 112-120.

16. Kucuk, M., Akin, S., & Demirci, M. (2015). Impact of water quality on fish health in aquaculture systems. Fisheries Management and Ecology, 22(1), 78-85.

17. Larsen, M., Jensen, F., & Nielsen, T. (2009). Management of water pH for fish health. Aquaculture Management, 14(1), 55- 63.

18. Luoma, S. N., & Rainbow, P. S. (2008). Metal contamination in aquatic environments: Science and lateral management. Cambridge University Press, p. 52.

19. Martin, L., Silva, P., & Garcia, R. (2017). Water conductivity and its effect on fish growth in aquaculture. Fisheries Science, 83(2), 118-126.

20. Nasir, M., Khan, A., & Malik, S. (2010). Effects of dietary ingredients on the condition of fish. Fish Physiology and Biochemistry, 36(3), 211-220.

21. Naylor, R. L., Hardy, R. W., Bureau, D. P., Chiu, A., Elliott, M., Farrell, A. P., Forster, I., Gatlin, D. M., Goldburg, R. J., Hua, K., Nichols, P. D., & Nichols, T. D. (2009). Feeding aquaculture in an era of finite resources. Proceedings of the National Academy of Sciences USA, 106(36), 15103-15110.

22. New, M. B. (1996). Responsible use of aquaculture feeds. FAO Aquaculture Newsletter, 13, 34-38.

23. Nguyen, T. T., Pham, D. N., & Tran, H. T. (2018). Soybean meal and its use in aquaculture feeds. Advances in Aquaculture Nutrition, 5, 85-95.

24. Popov, A., Ivanov, V., & Petrov, S. (2016). Temperature influences on the metabolic rates of carps in aquaculture systems. Aquatics Biology, 12, 124-130.

25. Roberge, J., Dubois, S., & Tremblay, R. (2015). Use of animal meal in the feeding of farmed fish. Aquaculture Nutrition, 21(1), 58-65.

26. Tacon, A. G. J., & Metian, M. (2008). Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture, 285(1- 4), 122-130.

27. Tacon, A. G. J., Hasan, M. R., & Metian, M. (2011). Environmental sustainability of aquaculture feed. Aquaculture Research, 42(3), 78-90.

28. Wang, J., Liu, H., & Zhang, F. (2014). Nitrate pollution in aquaculture systems. Environmental Aquaculture, 8(1), 53-60.

29. Zhang, Z., Li, Y., & Chen, Q. (2019). Role of silicon in aquaculture systems. Journal of Applied Ichthyology, 35(2), 41-50.