Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(6): 3197 – 3210 (2025)
www.ejabf.journals.ekb.eg

Comparative Evaluation of Three Vegetable Oil Supplements on the Growth and Feed Conversion Ratio of the Juvenile Nile Tilapia *Oreochromis niloticus* (Linnaeus, 1758) Under Laboratory Conditions

Qusay H. Al-Hamadany, Kadhim H. Younis, Khalid W. Farnar, Ali T. Yaseen*, Abdul Hussein J. Abdullah, Amir A. Jabir

Marine Vertebrates, Marine Science Center, University of Basrah, Basrah, Iraq

***Corresponding Author: ali.taha@uobasrah.edu.iq**

ARTICLE INFO

Article History:
Received: Sep. 20, 2025
Accepted: Dec. 15, 2025
Online: Dec. 25, 2025

Keywords:
Nile tilapia,
Oreochromis niloticus,
Growth performance,
Feed conversion ratio,
Vegetable oils,
Peppermint oil,
Chamomile oil,
Ginger oil,
Sustainable aquaculture

ABSTRACT

The increasing need for sustainable aquaculture practices highlights the importance of identifying natural feed additives that can enhance fish growth and reduce reliance on synthetic promoters. The present study evaluates the effects of three vegetable oils, peppermint (*Mentha piperita*), chamomile (*Matricaria chamomilla*), and ginger (*Zingiber officinale*), as dietary additives on the growth performance and feed conversion ratio (FCR) of the juvenile Nile tilapia (*Oreochromis niloticus*) under controlled laboratory conditions. A total of 120 fish were distributed into four treatments (control and three oil-supplemented diets at 0.5%). The results showed significant differences ($P<0.05$) among treatments, with ginger oil achieving the best performance. Fish fed ginger oil reached a final weight of 29.10g, representing a 12.9% increase compared to the control (25.78g), and recorded a weight gain of 16.68g, which is 24.2% higher than the control (13.43g). Ginger oil also produced the lowest FCR (3.12), representing a 23.9% improvement over the control treatment (4.10). In addition, peppermint and chamomile oils enhanced growth indicators and FCR, but to a lesser extent than ginger. The superior performance of ginger is attributed to its bioactive compounds, such as gingerol and shogaol, which enhance digestion and nutrient absorption. The study recommends incorporating vegetable oils, particularly ginger oil, as natural growth promoters to support sustainable aquaculture practices.

INTRODUCTION

Aquaculture is one of the fastest-growing sectors of animal food production, currently providing approximately 17% of global animal protein, a figure expected to rise with increasing seafood demand (**FAO, 2022**). However, the rapid expansion of aquaculture typically depends on high stocking densities, which can deteriorate water quality and increase the frequency of disease outbreaks, ultimately reducing survival rates and elevating economic losses (**Austin, 2023; Diao *et al.*, 2024; Mohammed *et al.*, 2025**). Consequently, veterinary medicines, including antibiotics, are commonly used to prevent and treat fish diseases (**Lulijwa *et al.*, 2020; Antimicrobial resistance in aquaculture, 2024**). Excessive antibiotic use has become a significant concern due to the accumulation of drug residues in fish tissues and the potential spread of antimicrobial resistance through the food chain (**Schar *et al*., 2020; Abed *et al*., 2025; Qu *et al*., 2025**). These challenges have driven interest in natural alternatives such as medicinal plants, which exhibit anti-stress, antimicrobial, and immunomodulatory properties, helping fish resist a wide range of pathogens (**Reverter *et al*., 2014; Jumaa *et al*., 2016; Phytobiotics in finfish & shellfish, 2025**). Medicinal plants also serve as growth-promoting feed additives due to their rich bioactive content, which enhances digestion, appetite, and immune responses (**Chang, 2000; Chakraborty & Hancz, 2011; Mohammed *et al*., 2025; Phytobiotics in finfish & shellfish, 2025**).

Previous studies have demonstrated that plant extracts, powders, and oils can enhance feed intake and increase growth rates in fish by providing bioactive compounds, including phenols, flavonoids, and volatile oils (**Dawood *et al*., 2018; Karim *et al*., 2022**). However, although vegetable oils represent a sustainable option in fish diets, replacing marine oils may reduce EPA and DHA levels in fish flesh and increase omega-6 fatty acids, potentially affecting nutritional value **(Nichols *et al*., 2023; Liang *et al*., 2024)**. Despite the widespread use of plant-derived additives, limited research has compared the effects of specific vegetable oils such as peppermint, chamomile, and ginger under the same experimental conditions in the Nile tilapia. These oils contain distinct bioactive compounds (e.g., menthol, bisabolol, gingerols) that may enhance digestion, immunity, and nutrient utilization. Based on their known properties, we hypothesize that ginger oil will produce superior growth performance and better feed conversion efficiency compared to peppermint and chamomile oils. Accordingly, this study aims to evaluate the effectiveness of these three oils as dietary additives in the Nile tilapia by analyzing growth performance and feed conversion ratio, with the goal of supporting sustainable aquaculture practices.

MATERIALS AND METHODS

The Nile tilapia juveniles (*O. niloticus*) were obtained from the fish farming station of the Marine Science Center at the University of Basrah. A total of 120 fish were used in the experiment, with an average initial weight of 12.39 ± 0.15g.

Nutritional Experiment

Fish were randomly distributed into 12 plastic tanks, each with a capacity of 45 liters, at a density of 10 fish/tank. The tanks were equipped with a continuous aeration system to ensure the availability of dissolved oxygen. Before stocking, the tanks were sterilized using a 200-ppm sodium hypochlorite solution for one hour to provide a contaminant-free and pathogen-free environment. The experiment consisted of four treatments (a control treatment and three treatments containing different vegetable oils), with three replicates per treatment. Fish feeds were prepared locally using raw materials sourced from local markets, taking into account the nutritional needs of the fish. Vegetable oils (peppermint oil, chamomile oil, and ginger oil) were added to the experimental feeds at a rate of 0.5g per 100g of the total feed weight to test their effect on growth performance and feed conversion. Table (1) shows the proportions of the raw materials used in preparing the feeds, while Table (2) shows the chemical analysis of the prepared feeds to determine the percentages of crude protein, fat, moisture, and ash.

Table 1. Ratios and components of experimental diets

Component	A	B	C	D
Fishmeal	15	15	15	15
Soybean meal	35	35	35	35
Yellow corn	17	17	17	17
Wheat flour	10	10	10	10
Wheat bran	10	10	10	10
Barley	10	10	10	10
Sunflower oil	1	0.5	0.5	0.5
Vitamins and minerals	2	2	2	2
Peppermint oil	0	0.5	0	0
Chamomile oil	0	0	0.5	0
Ginger oil	0	0	0	0.5
Total	%100	%100	%100	%100

Table 2. Actual chemical composition of experimental diets

Component	(%)
Moisture	7.12
Protein	27.51
Fat	7.36
Ash	8.57
Carbohydrate	49.44
Energy (kcal/100g)	440.68

Four experimental treatments were conducted in this study:
- Treatment 1 (A): The control group, to which no vegetable oils were added.
- Treatment 2 (B): Peppermint oil was added at a rate of 0.5%.
- Treatment 3 (C): Chamomile oil was added at a rate of 0.5%.
- Treatment 4 (D): Ginger oil was added at a rate of 0.5%.

The fish were fed the experimental diets daily at a rate of 3% of their total body weight, divided into two meals, one in the morning and one in the evening. The feed quantities were adjusted based on the fish's live weight, which was measured every 15 days, to ensure accurate calculation of the daily feed quota. The experiment lasted for 60 days, excluding a five-day acclimatization period before the start of the actual experiment.

Growth Indicators

Fish growth indicators and feed efficiency were evaluated using internationally recognized standard equations. These equations align with current industry recommendations, as used by **Rahman and Arifuzzaman (2021)**, and include:

$$Average\ weight\ gain\ (g) = Final\ weight\ (g) - Initial\ weight\ (g)$$

$$Growth\ rate\ (g/day) = Weight\ gain\ (g)\ /\ Period\ (days)$$

$$Specific\ growth\ rate\ (\%g/day) = \{Normal\ logarithm\ of\ final\ weight\ (g) - Natural\ logarithm\ of\ initial\ weight\ (g)\}/Period\ (days) \times 100$$

$$Feed\ conversion\ ratio = Weight\ of\ feed\ consumed\ (g)\ /\ Weight\ gain\ of\ fish\ (g).$$

Non-nitrogenous carbohydrates (NFE) were calculated using the difference method, as described by **Al-Aswad (2000)**, to evaluate the components of animal diets, including fish. This equation serves as an indirect way to estimate digestible carbohydrates:

$$Carbohydrates\ (\%) = 100 - (\%\,Moisture + \%\,Protein + \%\,Fat + \%\,Ash).Dietary\ energy\ (kcal/100g)$$

Energy was calculated based on **Changsu *et al.* (2021)** using the following formula:

$$Energy\ (kcal/100g) = (\%\,Protein \times 5.56) + (\%\,Carbohydrate \times 4.45) + (\%\,Fat \times 9.2).$$

These values, which represent the general rates of energy produced from the oxidation of each nutrient in fish, are widely used in estimating the nutritional value of diets.

Statistical Analysis

A completely randomized design (CRD) was employed to statistically analyze the significant differences between the relationships used in the experiment, utilizing SPSS software (version 2000). Differences between treatments were tested and their statistical significance was determined at a probability level of 0.05, based on the statistical method described by **Al-Rawi and Khalafallah (2000)**.

RESULTS AND DISCUSSION

Environmental measurements of the pond water, taken weekly during the experiment, showed a water temperature of 26.01°C, a dissolved oxygen concentration of 7.06mg/ L, a salinity of 1.28g/ L, and a pH of approximately 8.01. These values are within the optimal range for rearing the Nile tilapia juveniles, as indicated by **El-Sayed (2019)**, who demonstrated that such environmental conditions provide a suitable environment for the growth and physiological health of this fish species. The Nile tilapia juveniles readily accepted the formulated feed after a period of acclimatization. Nutritional balance in feed components is a crucial factor in improving feed utilization efficiency and achieving optimal growth rates in farmed fish. The compatibility of the feed composition with the specific nutritional requirements of each fish species directly contributes to enhancing vital and physiological activities, leading to maximum utilization and benefit from nutrients.

Conversely, any deficiency in essential nutrients such as necessary amino acids, unsaturated fatty acids, vitamins, and minerals may lead to a disruption in metabolic processes, negatively impacting feed conversion efficiency and limiting growth. The National Research Committee (**NRC, 2011**) confirmed that imbalances in these components are among the most significant factors affecting fish growth performance, emphasizing the need to formulate feeds tailored to the specific requirements of each species to ensure optimal results in aquaculture systems. Recent studies have increasingly focused on the use of medicinal herbs as fish feed additives, given their numerous advantages, including improved production efficiency, reduced reliance on antibiotics and chemical compounds, and their positive role in promoting environmental sustainability. Among the most notable of these benefits, research results indicated the direct effect of some medicinal plants in fostering growth and improving weight gain rates in fish, making them a promising option in aquaculture nutrition improvement programs (**Mohammadi *et al*., 2020**).

Fig. (1) illustrates the absence of significant differences ($P > 0.05$) in the average initial weights among the different treatments. This indicates that the fish in all treatments were similar in terms of biomass at the start of the experiment, which strengthens the credibility of the subsequent results and confirms the homogeneity and equivalence of the experimental groups under the initial experimental conditions. Regarding the average final weights of the Nile tilapia, statistical analysis revealed significant differences ($P < 0.05$) between the different treatments, reflecting the effect of the plant oil additives used in the experimental treatments on growth performance. Treatment D recorded the highest average final weight of 29.10g, followed by Treatment B with an average of 28.45g, then Treatment C with an average of 27.92g. In comparison, Treatment A achieved the lowest average final weight of 25.78g. Although there were statistical differences between some treatments, the statistical analysis showed no significant differences ($P > 0.05$) between treatments D and B, as well as between B and C, indicating similar performance in these treatments in terms of final weight gain, which may reflect similarity in the efficiency of ration utilization or similarity in the physiological effects of the added components in these treatments.

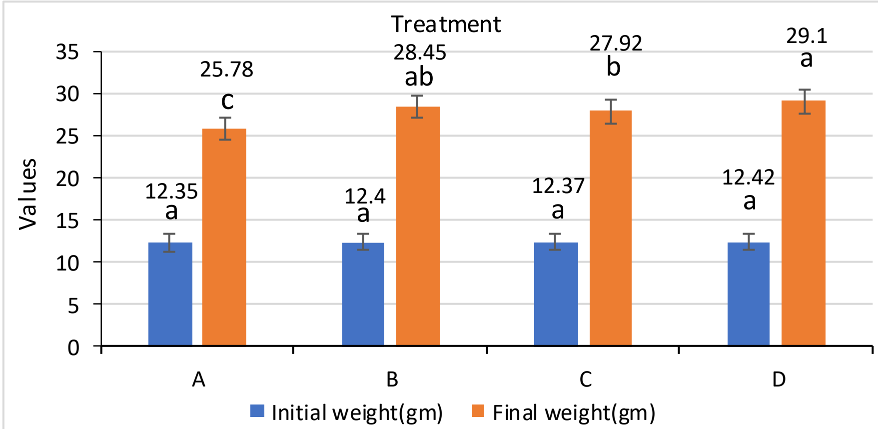

Fig. 1. Initial and final weight rates of experimental fish

As shown in Fig. (2), treatment D recorded the highest weight gain of 16.68g, a significant difference ($P< 0.05$) compared to treatments B (16.05g) and C (15.55g), while treatment A recorded the lowest gain (13.43g). No significant differences were found between D and B or between B and C, indicating a similar effect of the three vegetable oils on productive performance. The likely superiority of treatment D is related to the dominance of gingerol and its derivatives, which enhance the secretion of digestive enzymes and improve nutrient metabolism, thus increasing growth efficiency (**Abbasi *et al.*, 2017; Al-Khafaji *et al.*, 2021**). Treatment B promotes fish growth by improving the presence of active compounds, such as menthol and menthone, which increase the activity of digestive enzymes, improve feed conversion, and reduce oxidative stress. A recent study documented a significant improvement in weight and feed efficiency when peppermint oil was included in the diet of the Nile tilapia (**Aguiar *et al.*, 2023**). In the case of treatment C, its rich content of apigenin and α-bisabolol compounds contributes to enhancing immunity and reducing oxidative stress, thus supporting growth even under challenging conditions such as exposure to alumina nanoparticles (**Farag *et al.*, 2023**).

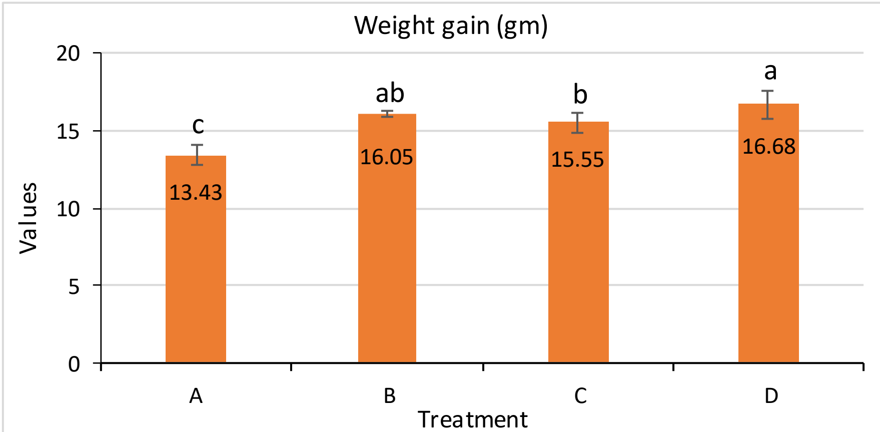

Fig. 2. Weight gain of fish during the experimental period

The results in Figs. (3, 4) show that treatment D significantly outperformed treatment A in both the daily growth rate and specific growth rate indices. Fish fed the ginger-containing diet recorded average values of 0.278g/ day and 1.41%/ day, respectively, compared to the relatively low values in the control group of 0.224g/ day and 1.22%/ day. The results also showed that treatment B achieved 0.267g/ day and 1.39% per day, while treatment C recorded 0.259g/ day and 1.35% per day, respectively. Statistical analysis revealed significant differences between treatments D and A at a significance level of ($P<0.05$), confirming the positive role of ginger supplementation in improving fish growth indicators. This improvement is attributed to ginger's active compounds, most notably gingerol and its derivatives, which possess digestive-stimulating and nutrient-enhancing properties, as well as antioxidant and antimicrobial properties that reduce oxidative stress and promote gut health (**Wei *et al.*, 2025**).

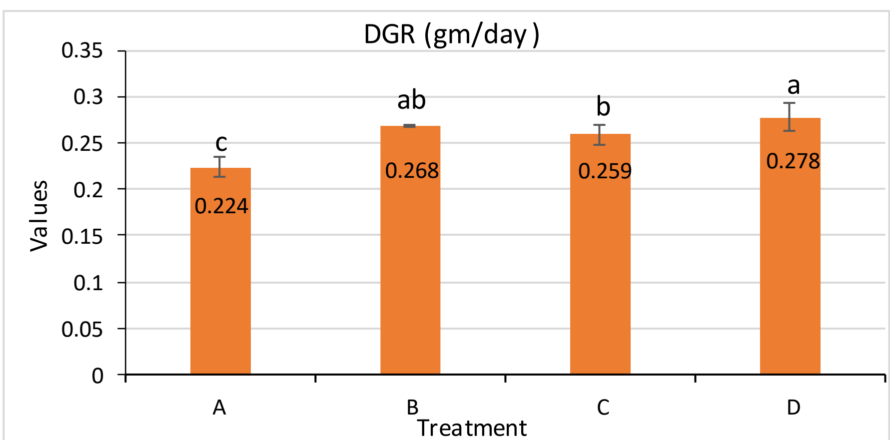

Fig. 3. Daily growth rate of fish during the experimental period

Furthermore, improving the gut microbiome contributes to increased feed conversion efficiency, which positively impacts growth rates. These results are consistent with those reported by **Nya and Austin (2009)**, who tested different levels of ginger extract (0.05, 0.1, 0.5, and 1g/ 100g feed) in diets for *Oreochromis*. *mykiss* trout. All treatments showed a significant improvement in growth indicators compared to the control. These results are from the study by **Abdelhamid *et al.* (2007)** on the Nile tilapia juveniles (*O. niloticus*), where the use of ginger extract at a rate of 0.5% led to a significant improvement in both daily and qualitative growth rates, consistent with the findings in the current study. Therefore, ginger represents one of the promising natural additives in fish nutrition, as it enhances feed utilization efficiency and stimulates growth, thereby reducing the reliance on chemical stimulants and traditional antibiotics in fish farming systems.

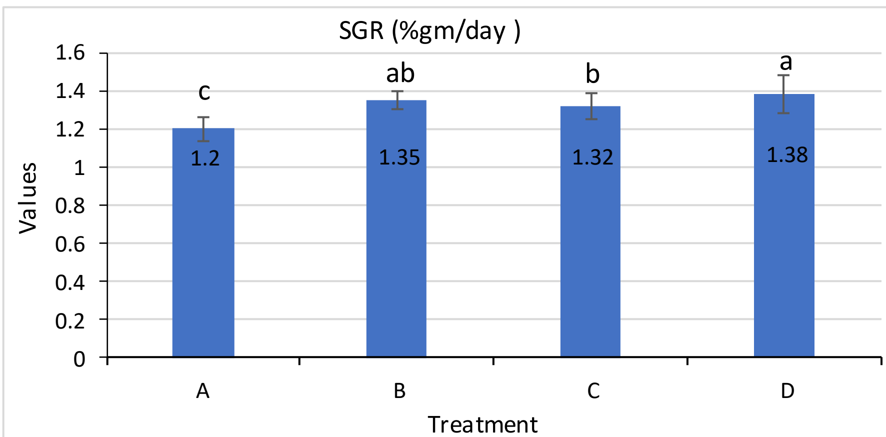

Fig. 4. Specific growth rate of fish during the experimental period

The feed conversion ratio (FCR) is one of the most important indicators used to evaluate feed utilization efficiency in fish farming systems. It represents the amount of feed consumed to produce one unit of fish. The lower the FCR value, the higher the efficiency in feed utilization and conversion into biomass. The results of the current study showed that treatment D outperformed all other treatments at a significant level ($P < 0.05$), recording the best FCR of 3.12, which surpassed that of all other therapies, especially treatment A (Fig. 5). This may be attributed to the presence of phenolic compounds in ginger, which enhance nutrient absorption and have appetite-stimulating properties, as well as containing natural organic substances that promote growth (**Maqsood *et al*., 2011; Yaseen *et al*., 2018**). The results of treatment D's superiority over treatment A are consistent with those of the study by **Mohammadi *et al.* (2020)**, which used 1% ginger oil in the diets of *Huso huso* fish. For treatment B, its feed conversion ratio reached 3.21. The results of the superiority of treatment B over treatment A are consistent with what **Leyciane *et al*. (2019)** found when using peppermint oil at a rate of 0.125% in the Nile tilapia fish diets. While, they do not match the results of **Adem *et al.***

(2015) used peppermint oil at three concentrations (500, 1000, and 1500mg/ kg) in the diets of *O. mykiss* trout. The superiority may be attributed to the presence of menthone in peppermint oil, which plays a crucial role in stimulating the intestines, in addition to its antioxidant and antimicrobial properties, thereby enhancing the digestive system's ability to utilize nutrients (**Mohadde & Nastaran, 2014; Al-Baghdadi *et al*., 2024**). The results of the current study showed that treatment C achieved a feed conversion ratio of 3.27, representing a significant improvement compared to treatment A, which recorded a feed conversion ratio of 4.10. This reflects higher efficiency in utilizing nutrients in fish fed a diet enriched with chamomile. This improvement is attributed to the physiological and chemical properties of the polyphenolic compounds found in chamomile, which contribute to enhancing the fish's ability to resist oxidative stress by neutralizing harmful free radicals and reducing the occurrence of internal inflammation. These positive effects help create a metabolic environment. More stable, chamomile supports energy and protein metabolism, increasing the efficiency of feed utilization. It also stimulates the activity of certain digestive enzymes, improving intestinal health and absorption capacity, which leads to more efficient nutrient conversion into body tissues rather than being lost undigested. Furthermore, chamomile helps reduce inflammatory responses within the digestive tract, limiting energy expenditure typically directed towards fighting inflammation and redirecting it instead towards growth and increased biomass. When comparing treatments B and C, no significant differences were observed at the significance level ($P > 0.05$), indicating that they have similar effectiveness in improving feed conversion efficiency. Treatment A, however, recorded the highest feed conversion ratio, clearly indicating that the absence of plant additives in the diet resulted in poor feed conversion efficiency, with fish consuming larger quantities of feed for less weight gain. This confirms that the introduction of vegetable oils, particularly ginger, is an effective way to improve production performance and reduce feed loss in fish farming systems.

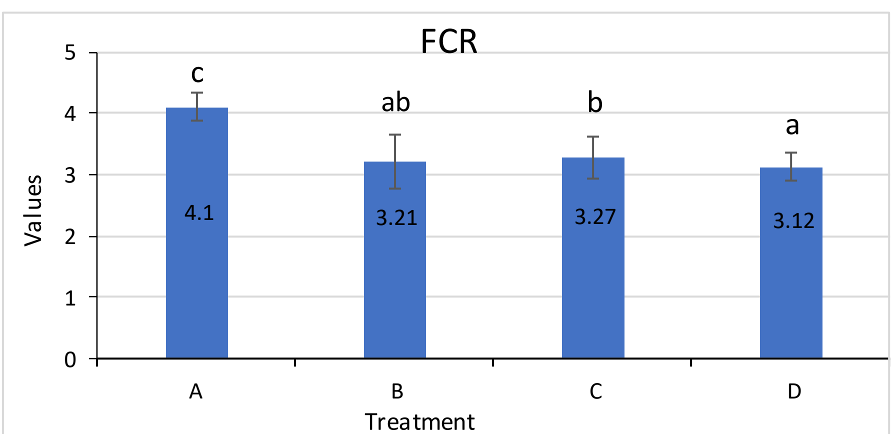

Fig. 5. Feed conversion ratio of fish during the experimental period

CONCLUSION

Environmental water measurements showed that temperature, oxygen, salinity, and pH values were within the optimal range for the Nile tilapia fingerling growth, providing a suitable environment for optimal growth performance. The fish readily accepted the formulated feed after the acclimatization period. The results confirmed the importance of nutritional balance in feed components for higher feed utilization efficiency and better growth rates.

The results showed an apparent positive effect of adding vegetable oils (ginger, peppermint, and chamomile) on improving the productive performance of the Nile tilapia compared to the control treatment. Treatments D, B, and C outperformed Treatment A in terms of final weight and weight gain.

The ginger treatment recorded the best results in final weight, weight gain, daily growth rate, specific growth rate, and feed conversion efficiency, reflecting the practical physiological effect of gingerol compounds in improving digestion and absorption and reducing oxidative stress. The results did not show significant differences between treatments B and C in most growth and feed conversion indicators, indicating similar efficacy between peppermint oil and chamomile oil in promoting growth and improving feed utilization. The control treatment showed the lowest performance in all growth and feed conversion indicators, demonstrating the vital role of plant additives in improving overall fish performance and reducing feed loss.

RECOMMENDATIONS

The study recommends adding vegetable oils, especially ginger oil, to the Nile tilapia feed due to its clear role in improving growth and enhancing feed efficiency. It is recommended to adopt natural alternatives such as vegetable oils to reduce the use of antibiotics and chemicals in fish farming systems, thus contributing to environmental sustainability.

Future studies are needed to determine the optimal concentration of vegetable oils used to avoid overuse and achieve the best feed efficiency and economic performance. It is preferable to expand research on the immunological and physiological effects of vegetable oils on fish, and their role in disease resistance and improving meat quality. It is recommended to conduct an economic analysis to estimate the financial return from using vegetable oils compared to traditional feed, which will help farmers make informed decisions.

REFERENCES

Abbasi, G.H.; **Kamali, A.**; **Soltani, M. and Sharifian, M.** (2017). Effects of *Zingiber officinale* powder on growth parameters, survival rate and biochemical composition of body in juvenile common carp (*Cyprinus carpio*), *Iranian Journal of Fisheries Sciences*, 16: 67–85.

Abdelhamid, A.M.; **Salem, M.F.I.**; **Mehrim, A.I. and El-Sharawy, M.A.M.** (2007). Nutritious attempts to detoxify aflatoxic diets of tilapia fish performance, feed and nutrients utilization, organs indices, residues and blood parameters, *Egyptian Journal of Nutrition and Feeds*, 10(1): 205–223.

Abed, J.M.; **Ali, A.H.**; **Yaseen, A.T.**; **Al-Faisal, A.**; **Mutlak, F.**; **Jassim, F.K. and Jawad, L.A.** (2025). Barramundi (*Lates calcarifer*) from Iraq: a new record for the Arabian Gulf, with a highlight on it genetic origins and description of two skeletal deformities, *New Zealand Journal of Zoology*, 52(1): 40–54.

Adem, Y.S.; **Soner, B.**; **Gonca, A.**; **Olcay, H. and Talat, Y.G.** (2015). Growth performance and antioxidant enzyme activities in rainbow trout *Oncorhynchus mykiss* juveniles fed diets supplemented with sage, mint and thyme oils, *Fish Physiology and Biochemistry*, 41: 165–175.

Aguiar, G.A.; **Carneiro, C.**; **Campelo, D.A.**; **Rusth, R.C.**; **Maciel, J.F. and Baldisserotto, B.** (2023). Effects of dietary peppermint (*Mentha piperita*) essential oil on growth performance, plasma biochemistry, digestive enzyme activity, and oxidative stress responses in juvenile Nile tilapia (*Oreochromis niloticus*), *Fishes*, 8(7): 374.

Ahmad, I.; **Irm, M.**; **Ahmed, I.**; **Haoran, Y.**; **Taj, S.**; **Bhat, T.A.**; **Khan, S.K.**; **Puswal, S.M.**; **Khalil, H.S. and Sopjani, M.** (2024). Role of ginger in fish nutrition with special emphasis on growth, health, gut and liver morphology, *Journal of the World Aquaculture Society*, 55(6): e13101.

Al-Aswad, M.B. (2000). Meat science and technology, *Ministry of Higher Education and Scientific Research, Dar Al-Kutub Foundation for Printing and Publishing, University of Mosul*: 139.

Al-Baghdadi, N.M.; **Abbas, M.F.**; **Al-Najare, Gh.A.**; **Younis, K.H. and Karim, R.M.** (2024). Monitoring environmental changes in the Shatt al-Arab River using the organic pollution index (OPI) and two species of benthic invertebrates *Melanoides tuberculata* and *Neritina violacea*, *Egyptian Journal of Aquatic Biology and Fisheries*, 28(3): 889–909.

Al-Khafaji, K.H.; **Karim, R.M. and Al-Baghdadi, N.M.** (2021). Study of aquatic gastropods (Mollusca) in Shatt al-Arab River, Iraq, *Egyptian Journal of Aquatic Biology and Fisheries*, 25(3): 137–146.

Al-Rawi, K.M. and Khalaf, A.A.M. (2000). Design and analysis of agricultural experiments, *Dar Al-Kutub for Printing and Publishing, University of Mosul*: 488.

Antimicrobial resistance in aquaculture: Occurrence and strategies in Southeast Asia. (2024). *Science of the Total Environment*, 914: 170904.

Austin, B. (2023). The impact of disease on the sustainability of aquaculture, *Sustainable Aquatic Research*, 2(1): 74–91.

Chakraborty, S.B. and Hancz, C. (2011). Application of phytochemicals as immunostimulant, antipathogenic and anti-stress agents in finfish culture, *Reviews in Aquaculture*, 3: 103–119.

Chang, J. (2000). Medicinal herbs: Drugs or dietary supplements, *Biochemical Pharmacology*, 59: 211–219.

Changsu, K.; **Kyoung, H.K.**; **Sang, Y.J. and Beob, G.K.** (2021). Energy concentration and phosphorus digestibility in meat meal, fish meal, and soybean meal fed to pigs, *Animal Bioscience*, 34(11): 1822–1828.

Dawood, M.A.O.; **Koshio, S. and Esteban, M.Á.** (2018). Beneficial roles of feed additives as immunostimulants in aquaculture: A review, *Reviews in Aquaculture*, 11(4): 1096–1112.

Diao, W.; **Jia, R.**; **Hou, Y.**; **Gong, J.**; **Zhang, L.**; **Li, B. and Zhu, J.** (2024). Effects of different stocking densities on the growth, antioxidant status, and intestinal bacterial communities of carp in the rice–fish co-culture system, *Fishes*, 9(7): 244.

El-Sayed, A.F.M. (2019). Tilapia culture (2nd ed.), *Academic Press*: 358.

FAO. (2022). The state of world fisheries and aquaculture 2022: Towards blue transformation, *Food and Agriculture Organization of the United Nations, Rome*.

Farag, M.R.; **El Behery, E.I.**; **Nouh, D.S.**; **Attia, Y.A.**; **Alhotan, R.A.**; **Alagawany, M.**; **Di Cerbo, A. and Al-Hassan, M.** (2023). Chamomile essential oil improves the growth, immunity, and antioxidant status of Nile tilapia exposed to nanosized alumina, *Aquaculture International*, 32: 1613–1628.

Jumaa, M.N.; **Yaseen, N.Y.**; **Karim, R.M.**; **Shehab, A.F. and Sagban, L.H.** (2016). Study of genetic variations of FTO gene and its relationship to obese in Iraqi population, *Der Pharma Chemica*, 8(18): 242–254.

Karim, R.M.; **Al-Khafaji, K.h.**; **Yaseen, A.T. and Mutlak, F.M.** (2022). First occurrence of two crab species, *Actaea calculosa* (Milne Edwards, 1834) and *Atergatis integerrimus* (Lamarck, 1801), family Xanthidae in Iraqi coast waters, *Egyptian Journal of Aquatic Biology and Fisheries*, 26(2): 331–338.

Leyciane, T.d.; **Souza, S.**; **Ulisses, P.**; **Hugo, M.**; **Elenice, M.**; **Scheila, A.P.**; **Edsandra, A.**; **Gabriel, F.**; **Alves, J.**; **Lucas, C.**; **José, L.P. and Maurício, L.M.** (2019). Hemato-immunological and zootechnical parameters of Nile tilapia fed essential oil of *Mentha piperita* after challenge with *Streptococcus agalactiae*, *Aquaculture*, 506: 205–211.

Liang, C.; **Gao, Q. and Zhang, Y.** (2024). Exogenous fatty acids remodel the muscle fatty acids composition of the GIFT tilapia (*Oreochromis niloticus*), *Aquaculture Nutrition*, 30(1): 115–128.

Lulijwa, R.; **Rupia, E.J. and Alfaro, A.C.** (2020). Antibiotic use in aquaculture, policies and regulation, health and environmental risks: a review of the top 15 major producers, *Reviews in Aquaculture*, 12(2): 640–663.

Maqsood, S.; **Singh, P.**; **Samoon, M. and Munir, K.** (2011). Emerging role of immunostimulants in combating the disease outbreak in aquaculture, *International Aquatic Research*, 3: 147–163.

Mohaddese, M. and Nastaran, K. (2014). Chemical composition and antimicrobial activity of peppermint *Mentha Piperita* L. essential oil, *Songklanakarin Journal of Science and Technology*, 36(1): 83–87.

Mohammadi, G.; **Rashidian, G.**; **Hoseinifar, S.**; **Naserabad, S. and Van Doan, H.** (2020). Ginger (*Zingiber officinale*) extract affects growth performance, body composition, haematology, serum, and mucosal immune parameters in common carp (*Cyprinus carpio*), *Fish and Shellfish Immunology*, 99: 267–273.

Mohammed, E.A.H.; **Ahmed, H.M. and Mahmoud, A.F.** (2025). Antibiotic resistance in aquaculture: Challenges, trends analysis, and alternative approaches, *Antibiotics*, 14(6): 598.

Nichols, P.D.; **Sprague, M. and Lutfi, E.** (2023). Evaluation of long chain omega 3 canola oil on Atlantic salmon growth, performance, and essential fatty acid tissue accretion across the life cycle: a review, *Aquaculture International*, 31: 2559–2579.

NRC (National Research Council). (2011). Nutrient requirements of fish and shrimp, *The National Academies Press, Washington, DC*: 392.

Nya, E.J. and Austin, B. (2009). Use of dietary ginger, *Zingiber officinale* Roscoe, as an immunostimulant to control *Aeromonas hydrophila* infections in rainbow trout, *Oncorhynchus mykiss* (Walbaum), *Journal of Fish Diseases*, 32: 971–977.

Phytobiotics in finfish and shellfish: A systematic review. (2025). *Discover Animals*, 5(1): 98.

Rahman, M.H. and Arifuzzaman, M. (2021). An experiment on growth performance, specific growth rate (SGR) and feed conversion ratio (FCR) of rohu (*Labeo rohita*) and tilapia (*Oreochromis niloticus*) in tank based intensive aquaculture system, *International Journal of Aquaculture and Fishery Sciences*, 7(4): 035–041.

Reverter, M.; **Bontemps, N.**; **Lecchini, D.**; **Banaigs, B. and Sasal, P.** (2014). Use of plant extracts in fish aquaculture as an alternative to chemotherapy: Current status and future perspectives, *Aquaculture*, 433: 50–61.

Schar, D.; **Klein, E.Y.**; **Laxminarayan, R.**; **Gilbert, M. and Van Boeckel, T.P.** (2020). Global trends in antimicrobial use in aquaculture, *Scientific Reports*, 10: 21878.

Spss. (2000). SPSS for windows base system users guide, release 10.0, *SPSS Inc., Chicago, USA.*

Wei, L.S.; **Tahiluddin, A.B. and Wee, W.** (2025). A glimpse on influences of ginger and its derivatives as a feed additive in finfish farming: A mini-review, *Heliyon*, 11(2): e41914.

Yaseen, A.T.; **Mutlak, F.M. and Yesser, A.K.T.** (2018). Environmental assessment of Shatt al Arab fish using the index of biotic integrity (F-IBI)/Basra-Iraq, *Journal of King Abdulaziz University*, 28(1): 55–73.

Zargaran, A.; **Borhani-Haghighi, A.**; **Faridi, P.**; **Daneshamouz, S.**; **Kordafshari, G. and Mohagheghzadeh, A.** (2014). Potential effect and mechanism of action of topical chamomile *Matricaria chammomila* L. oil on migraine headache: A medical hypothesis, *Medical Hypotheses*, 83(5): 566–569.