Indian J. Anim. Nutr. 2024. 41 (2): 189-197
doi: 10.5958/2231-6744.2024.00024.0

Indian Journal of Animal Nutrition

Feed Additives in Aquaculture - A Review

P.Singh[1], B.N. Paul[1*] and S.S. Giri[2]
ICAR-Central institute of Freshwater Aquaculture
[1]Regional Research Centre, Rahara, Kolkata-700118
[2]ICAR-Central Institute of Freshwater Aquaculture
Kausalyaganga, Bhubaneswar-751002
*Correspondence:bnpaulcifa@gmail.com

ABSTRACT

Aquaculture stands as one of the fastest-growing sectors globally, playing a significant role in bolstering overall production. To ensure sustainable growth in aquaculture, it's crucial to use additives in appropriate quantities. Feed additives, edible substances added in small amounts to fish feeds, aim to enhance growth performance and reduce fish mortality rates. These additives are valued for their specific medicinal properties and environmentally friendly metabolism within the digestive system. Probiotics, immune stimulants, enzymes, hormones, organic acids, essential oils, and food colourants, among others, are recognized as effective functional feed additives for optimizing fish performance and increasing aquaculture profitability. There's an urgent call for research into novel feed additives that can lower feed costs, improve digestibility, and mitigate the residual effects of antibiotics on fish muscle. This review explores the roles and significance of various feed additives in ensuring high-quality aquaculture production.

KEYWORDS: Attractants, Aquaculture, Eco-friendly, Feed additives, Medicinal properties

Article received: 03 August 2023; Article accepted: 01 May 2024

INTRODUCTION

Fish, being a crucial source of global dietary protein with over half the world relying on them, necessitate the use of feed additives. These additives, such as those enhancing intake and palatability, play a vital role in meeting nutrient needs (Harpaz, 1997). They not only boost feed quality, fish health, and production efficiency but also include binders, preservatives, stimulants, and colourants. While attractants and processed ingredients enhance feed appeal (Deng et al., 2006), the literature on their use in fish feeds is limited. Hence, this article aims to review the application of selected feed additives in fish feeds, a topic of significant importance in the field of aquaculture and fish nutrition.

Attractants

Feed attractants are incorporated in trace amounts to enhance fish diet palatability and meet nutrient needs (Harpaz, 1997). Positive growth outcomes were seen in *Cirrhinus mrigala* with 1% dietary inclusion of *Cuscuta reflexa* (Paul et al., 2014), *Ompok pabda* with ekangi (Paul et al., 2012), *Catla catla* with tambul (Paul et al., 2013), and *Labeo rohita* with kharboj (Singh et al., 2020) and ghee residue (Singh et al.,2015).Betaine, a water-soluble compound, is commonly used as a fish feed attractant. Diets with 1.5% betaine showed enhanced growth in rainbow trout (Tiril et al., 2008).

Livol, a growth promoter, improves metabolic efficiency and protein deposition. Livol at 1% led to highest weight gain in *P.indicus* (Sambhu and Jayprakash, 2001) and *C. carpio* (Abraham et al., 2001).

Spirulina, a nutritional supplement rich in protein, minerals, vitamins, and antioxidants, enhances fish feed intake, growth, and reproduction (Farag et al., 2016). A 1% dietary addition of Spirulina increased weight gain and growth rate in Nile tilapia (Belal et al., 2012).

Nutraceuticals

Incorporating nutraceuticals or feed additives into fish diets is a key strategy for promoting growth and health. These additives encompass various components such as minerals, vitamins, prebiotics, probiotics, attractants, phytobiotics, synbiotics, and organic acids. Organic acids and salts commonly used in aquaculture include fumaric, malic, tartaric, valeric, and sorbic acids. Acidifiers, such as those mentioned, can enhance gut morphology and stimulate digestive enzymes in fish (Luckstadt, 2008). They also exhibit bacteriocidal, bacteriostatic, and antifungal effects depending on their inclusion levels (Luckstadt, 2008). For instance, Anutha et al. (2011) found that acidic calcium sulfate (vitoxal) at 1.2% and 2.0% levels improved growth performance in *Litopenaeus vannamei*. In *Clarias gariepinus*, dietary inclusion of 1% fumaric acid enhanced both growth and disease resistance (Omosowone et al., 2015). Additionally, Kumar et al. (2017) observed improved growth performance and immune response in *Cirrhinus mrigala* with a 1.5% dietary supplementation of a formic acid and calcium propionate mixture.

Medicinal plant polysaccharide

Herbs play a crucial role in enhancing the growth and health of aquatic species. For instance, Safari et al. (2016) found that *Cyprinus carpio* showed improved growth with 10 and 20g/kg of dietary *Ferula asafetida* (asafetida) powder. Similarly, Zahran et al. (2014) observed weight gain and specific growth rate (SGR) enhancement in *Oreochromis niloticus* with a 1.5% Astragalus (Milkvetch) polysaccharides diet.

Christybapita et al. (2007) demonstrated that Eclipta alba (Bhangra) leaf extract boosted the immune response and disease resistance in *Oreochromic mossambicus* against *A. hydrophila* infection. Ahmad et al. (2011) and Ahmad and Abdel (2011) highlighted the immune-enhancing effects of 1% cinnamon and 1.25% caraway seed meal, respectively, in Tilapia niloticus.

Garlic (*Allium sativum*) and ginger (*Zingiber officinalis*) are also notable additives. Yilmaz and Ergun (2012) showed that 1% garlic inclusion improved growth and antioxidant status in *O.mykiss*, while Soltanian et al. (2019) reported increased survivability against *Yersinia ruckeri* with 0.6-1% ginger supplementation. Thyme (*Thymus vulgaris* L.) and Oregano (*Origanum vulgare* L.) are recognized for their antimicrobial properties. Zaki et al. (2012) observed positive effects on growth and physiological parameters in *Oreochromis niloticus* with 1% dietary supplementation of these herbs. Krishan and Narang (2014) highlighted oregano's antimicrobial activity against various pathogens.

Curcumin, a component of turmeric, is valued for its antioxidant properties. Mahmoud et al. (2017) noted growth improvements in tilapia with dietary curcumin supplementation, while Jiang et al. (2016) found enhanced growth indices in crucian carp with 5mg/kg curcumin supplementation.

Table. Level and type of Feed Additive used in Aquaculture

Name of the Feed Additives	incorporation level	Species	References
Ekangi	1%	*O. pabda*	Paul et al. (2012)
Awbel	1%	*C.mrigala*	Paul et al. (2014)
Tambul	1%	*C.catla*	Paul and Giri (2013)
Kharboj	1%	*L.rohita*	Singh et al. (2020)
Betain	1.5%	*O.mykiss*	Tiril et al.(2008)
	1%	*C.carpio*	Abraham et al. (2001)
	1%	*P.indicus*	Sambhu and Jayprakash (2001)
Calcium sulfate	1.2 & 2%	*L.vannamei*	Anutha et al. (2011)
Fumaric acid	1%	*C.gariepinus*	Omosowone et al. (2015)
Formic acid+ Calcium propionate (1:1)	1.5%	*C.mrigala*	Kumar et al. (2007)
Asafoetida	10 and 20g/kg	*C.carpio*	Safari et al. (2016)
Milkvetch	1.5%	*O.niloticus*	Zahran et al. (2014)
Cinnamon	1%	*T. niloticus*	Ahmad et al. (2011)
Caraway seed meal	1.25%	*T.niloticus*	Ahmad and Abdel (2011)
Garlic	1%	*O.mykiss*	Nya andAustin (2009)
	2.5%	*O. niloticus*	Diab et al. (2002)
Ginger	0.5-1%	Asian sea bass	Talpur et al. (2013)
	0.6-1%	*O.mykiss*	Soltanian et al. (2019)
Thyme+medicinal palnts	1%	*O.niloticus*	Zaki et al. (2012)
Allium Mongolicum Regel Flavonoids	4%	*Channa argus*	Li et al. (2019)
Origanum extract	6-10g/kg	*O.mykiss*	Rafieepour et al. (2019)
Origano oil	15g/kg	*C.carpio*	Abdel-Latif et al. (2020)
O.onites oil	1%	*D.rerio*	Rashidian et al. (2020)
	50 or100mg/kg	*O.niloticus*	Mahmoud et al. (2017)
Curcumin	5mg/kg	*C.carassius*	Jiang et al. (2016)
Chitin	5%	*P.monodon*	Shiau and Yu (1998)
	2%	*E. Dagasti*	Panalikul et al. (2017)
Chitosan	2.13-2.67g/kg	Shrimp	Niu et al. (2011)
	0.5%	*C.gibelio*	Chen and Zhou (2005)
Amylase	50mg/kg	*L.rohita*	Kumar et al. (2006)
Cellulose	3g/kg	*T.idella*	Zhou et al. (2013)
Phytase	300FTU/kg	*P.hypothalamus*	Rachmawati and Samidjan (2018)
Norethisterone	0.75ppm	*C.carpio*	Gangadhar et al. (2000)
L.carnitine	375-555mg/kg	*C.gariepinus*	Torreele et al. (1993)
	500mg/kg	*L.rohita*	Keshavanath and Renuka (1998)
	150mg/kg	Hybrid tilapia	Becker et al. (1999)
	369.7mg/kg	Striped bass	Twibell and Brown (2000)
	50 or 100mg/kg	Tilapia	Mahmoud et al.(2017)
Curcumin	5mg/kg	Crucian carp	Jiang et al. (2016)

Plant flavonoids

Flavonoids, potent medicinal plant compounds with estrogen-like activity, exhibit strong antioxidant properties. Zhou et al. (2015) showed that dietary supplementation with soybean isoflavones enhanced growth, innate immunity, and disease resistance against *Vibrio harveyi* in *Trachinotus ovatus*.

Complement activity is a crucial indicator of fish immunocompetence, often bolstered by oral immunostimulant administration. Plant extracts like soybean isoflavones have been noted to elevate C_3, IgM, and lysozyme levels in fish serum (Zhou et al., 2015). Li et al. (2019) demonstrated that *Allium mongolicum* Regel flavonoids (AMRF) at 40 mg/kg increased survival rates in *Channa argus* and

boosted immune-related gene expression, enhancing disease resistance against *Aeromonas hydrophila*.

Probiotic

Probiotics live microbial supplements, enhance host health by improving intestinal microbial balance (FAO/WHO, 2002). Predominantly bacterial probiotics like Aeromonas, Bacillus, and Vibrio species are crucial in aquaculture, boosting growth and disease resistance (Ringo, 2020). They enhance feed digestibility, alter gut microbial composition, and stimulate enzyme activity, improving nutrient utilization (Opiyo et al., 2019). Probiotics also elevate immune response, metabolic activity, and growth performance while maintaining water quality (Opiyo et al., 2019).

Chitin and Chitosan

Chitin and chitosan have been used in the aquaculture industry as a feed additive in the diets of fish and shellfish. Chitin is vital and renewable natural resource. The primary commercial sources of chitin are crustacean shells, such as crab, shrimp and lobster. *Daphnias* are good sources of chitin containing 2.9-7% chitin of total body weight and 18-21% chitin in their resting egg (Kaya et al., 2013). Exoskeleton-extracted chitin and its derivatives, prized for their biocompatibility, biodegradability, and antimicrobial properties, find diverse applications. Chitosan from *D. similis* boosts shrimp growth by enhancing digestive enzymes and gene expression (Panalikul et al., 2017). Similarly, Niu et al. (2011) observed improved growth in white shrimp postlarvae with chitosan supplementation. Chen and Zhou (2005) noted enhanced enzyme activities in silver crucian carp with 0.5% chitosan supplementation. and enzyme activity in tiger puffer with 0.5-2% chitosan oligosaccharide supplementation.

Enzymes

Enzyme supplementation in fish feed enhances digestibility and absorption of nutrients, thereby improving aquaculture production. The effectiveness of enzyme pretreatment on plant-derived raw materials for enhancing fish feed digestibility and growth rate. Protease improves protein digestibility by hydrolyzing proteins into peptides. Dalsgaard et al. (2012) demonstrated increased digestibility coefficients in *Oncorhynchus mykiss* with exogenous protease supplementation in soybean meal. Amylase, crucial for starch degradation, boosts glucose metabolism and starch utilization. Kumar et al. (2006) observed increased liver glycogen and blood sugar levels in *Labeo rohita* with á-amylase supplementation. Lipase supplementation enhances lipid digestion, leading to increased fat content and final weight, as observed in *Huso huso* (Ghomi et al., 2012). Cellulases, like those from duckweed, release glucose units from cellulose, providing energy. Zhou et al. (2013) noted improved growth in grass carp with cellulase supplementation. Hemicellulases, particularly xylanases and glucanases, aid in breaking down complex carbohydrates in aquafeed, improving nutrient utilization. Phytase breaks down phytic acid, enhancing plant phosphorus utilization. Rachmaati and Samidjan (2018) recommended 300 FTU/kg phytase for optimal utilization in catfish. Lysozyme exhibits bactericidal effects, enhancing survival against bacterial infections in fish, as seen in *Cyprinus carpio* (Nakamura et al., 1996).

Hormones

Hormonal additives regulate anabolic processes in fish, influencing growth rates, sexual development, and osmoregulation. Notably, androgenic steroids like 17á-methyl testosterone (MT) and diethyl stilbesterol are pivotal for inducing male development in tilapia fry (*Tilapia mossambica, O. nilotica, or O. aureus*) at 30-60 mg/kg (Gangadhar et al., 2000). Gangadhar et al. (2000) also observed enhanced growth in common carp with norethisterone at 0.75 ppm. Moreover, fish meal derived from mature fish contains testosterone compounds that stimulate muscle growth. In the future, incorporating growth hormone into feed may expedite growth and reduce raising time for long-lived fish.

Carotenoids

Carotenoids, essential for fish colouration, nutrient metabolism, and immune function, are sourced from feed ingredients like yellow corn, corn gluten meal,

and marigold meal (Anbazahan et al., 2014). Astaxanthin, crucial for red pigmentation, is commonly supplemented in aquaculture diets using synthetic forms like carophyll pink (Booth et al., 2004). Crustacean exoskeletons, rich in carotenoproteins, serve as valuable sources of antioxidants and growth promoters in fish feed. Ketocarotenoids like astaxanthin and canthaxanthin, vital for antioxidant properties, are widely used in aquaculture to enhance colouration (Ambati et al., 2014). As fish cannot synthesize astaxanthin, it must be provided in their diet, commonly through supplementation in aquaculture settings.

L-carnitine

L-carnitine, vital for fatty acid transportation into mitochondria, acts as a growth promoter in fish by enhancing fat utilization, thus sparing protein (Zammit et al., 2009) synthesized from lysine and methionine, it aids in fat metabolism, yielding efficient energy from dietary fat. Carnitine's structure also serves as a potent attractant for fish and crustaceans (Harpaz, 1997). Studies have demonstrated the growth-promoting effects of L-carnitine supplementation in various fish species. Torreele et al. (1993) found improved growth in *Clarias gariepinus* with L-carnitine supplementation, while Keshavanath and Renuka (1998) observed positive effects on *Labeo rohita* growth and body composition. Becker et al. (1999) reported growth enhancement in hybrid tilapia, and Twibell and Brown (2000) noted increased weight gain in hybrid striped bass. Chen et al. (2020) found enhanced weight gain in largemouth bass with L-carnitine supplementation, while Sanchez et al. (2021) observed improved growth performance and reduced lipid content in Nile tilapia with L-carnitine inclusion.

CONCLUSION

Feed plays a vital role in aquaculture production systems. However, with feed ingredients becoming scarce and facing increased costs and competition from the poultry and cattle industries, there's a growing need to explore new resources for feed formulation. In such conditions, feed additives are crucial in enhancing fish dry matter intake and boosting aquaculture production, particularly when fish are initially reluctant to consume new feeds.

REFERENCES

Abdel-Latif, H.M.R., Abdel Tawwab, M., Khafaga,A.F. and Dawood, M.A.O. 2020.Dietary oregano essential oil improved thegrowth performance via enhancing the intestinal morphometryand hepato-renal functions of common carp (*Cyprinus carpio* L.) fingerlings. Aquaculture.526:735432.

Abraham, S., Ramesha, T.J., Gangadhara, B. and Varghese, T.J. 2001.Growth response of common carp, *Cyprinus carpio* (Linn.) to varied levels of Livol, a non-hormonal growth promoter.Indian Journal of Fisheries.48(4):397-401.

Ahmad, M.H., El Mesallamy, A.M.D., Samir, F. and Zahran, F. 2011.Effect of Cinnamon (*Cinnamomum zeylanicum*) on growth performance, feed utilization, whole-body composition, and resistance to Aeromonas hydrophilain Nile Tilapia.Journal of Applied Aquaculture. 23: 289–298.

Ahmad, M.H. and Abdel-Tawwab, M. 2011.The use of caraway seed meal as a feed additive in fish diets: Growth performance, feed utilization, and whole-body composition of Nile tilapia, *Oreochromis niloticus* (L.) fingerlings. Aquaculture. 314: 110–114.

Ambati, R.R., Moi, P.S., Ravi, S. and Aswathanarayana, R.G. 2014. Astaxanthin: sources, extraction, stability, biological activities and its commercial applications - a review. Marine Drugs. 12: 128–152.

Anbazahan, S.M., Mari, L.S.S., Yogeshwari, G., Jagruthi, C., Thirumurugan, R., Arockiaraj, J., Velanganni, A.A.J., Krishnamoorthy, P., Balasundaram, C. and Harikrishnan, R. 2014. Immune response and disease resistance of carotenoids supplementation diet in *Cyprinus carpio* against *Aeromonas hydrophila*. Fish and Shell Immunology. 40(1): 9–13.

Anuta, J.D., Buentello, A., Patnaik, S., Lawrence, A.L., Mustafa, A., Hume, M.E., Gatlin, D.M.and Kemp, M.C. 2011. Effect of dietary supplementation of acidic calcium sulfate (Vitoxal) ongrowth, survival, immune response and gut microbiota of the Pacific white shrimp, *Litopenaeusvannamei*.Journal of World Aquaculture Society.42: 834-844.

Becker, K., Schreiber, S., Angoni, C. and Blum, R. 1999. Growth performance and feed utilization response of *Oreochromis niloticus_Oreochromis aureus* hybrids to l-carnitine measured over a full fattening cycle under commercial conditions. Aquaculture.174: 313–322.

Belal, E.B., Khalafalla, M.M.E. and El-Hais, A.M.A. 2012.Use of Spirulina(*Arthrospira fusiformis*) for promoting growth of Nile Tilapia fingerlings. African Journal of Microbiology Research. 6: 6423–6431.

Booth, M.A., Warner-Smith, R.J., Allan, G.L. and Glencross, B.D. 2004. Effects of dietary astaxanthin source and light manipulation on the skin colour of Australian snapper *Pagrus auratus* (Bloch and Schneider, 1801). Aquaculture Research. 35(5): 458–464

Chen, Y., Sun, Z., Lian, Z., Xie, Y., Tan, X., Su, J., Luo, Q., Zhu, J., Liu, Q. and Wang, A. 2020. Addition of L-carnitine to formulated feed improved growth performance,antioxidant status and lipid metabolism of juvenile largemouth bass,*Micropterus salmoides*. Aquaculture.518:734432.

Chen, Y. and Zhou, H.Q. 2005. Effect of three kinds of polysaccharide on protease activity, amylase activity in intestine and hepatopancreas of allogynogenetic silver crucian carp. Journal of Shanghai Fish University. 14: 468–471.

Christybapita, D., Divyagnaneswari, M. and Michael, R.D. 2007. Oral administration of *Eclipta alba* leaf aqueous extract enhances the non-specific immune responses and disease resistance of o*reochromis mossambicus*. Fish & Shellfish Immunology.23(4): 840-852.

Dalsgaard, J., Verlhac, V., Hjermitslev, N.H., Ekmann, K.S., Fischer, M., Klausen, M. and Pedersen, P.B. 2012. Effects of exogenous enzymes on apparent nutrient digestibility in rainbow trout (*Oncorhynchus mykiss*) fed diets with high inclusion of plant-based protein.Animal Feed Science Technology. 171:181–191

Deng, J., Mai, K., Ai, Q., Zhang, W., Wang, X., Xu, W. and Liufu, Z. 2006. Effects of replacing fish meal with soy protein concentrate on feed intake and growth of juvenile Japaneseflounder, Paralichthys olivaceus. Aquaculture.258**:**503-513.

Diab, A.S., El-Nagar, G.O.and Abd-El-Hady, Y.M. 2002.Evaluation of *Nigella sativa* L (black seeds;baraka), *Allium sativum* (garlic) and BIOGEN as feed additives on growth performance and immunostimulants of *O. niloticus* fingerlings.Suez Canal Veterinary Medical Journal.745–775.

FAO/WHO. 2002. Guidelines for the Evaluation of Probiotics in Food Report of a Joint FAO/ WHO Working Group on Drafting Guidelines for the Evaluation of Probiotics in Food, London Ontario, Canada, 1–11.

Farag, M.R., Alagawany, M., Abd El-Hack, M.E. and Dhama, K. 2016.Nutritional and healthical aspects of *Spirulina* (*Arthrospira*) for poultry, animals and human.International Journal of Pharmacology. 12: 36–51.

Gangadhara,B., Nandeesha, M., Varghese, T.J. and Keshavanath,P.2000. Effect of 19-norethisterone on growth, biochemical composition and gut digestive enzyme activity of common carp, *Cyprinus carpio* L. Journal of Aquaculture in the Tropics. 15: 1-10.

Ghomi, M.R., Shahriari, R., Langroudi, H.F., Nikoo, M. and Von Elert, E. 2012. Effects of exogenous dietary enzyme on growth, body composition, and fatty acid profiles of cultured great sturgeon *Huso huso* fingerlings. Aquaculture International. 20:249–254

Harpaz, S. 1997. Enhancement of growth in juvenile freshwater prawn, *Macrobrachium rosenbergii*, through the use of chemoattractant.Aquaculture.156:221-227.

Jiang, J., Wu, X., Zhou, X., Feng, L., Liu, Y., Jiang, W., Wu, P. and Zhao, Y. 2016. Effects of dietary curcumin supplementation on growth performance, intestinal digestive enzyme activities and antioxidant capacity of crucian carp *Carassius auratus*. Aquaculture. 463: 174–180.

Keshavanath, P. and Renuka, P. 1998. Effect of dietary L-carnitine supplements on growth and bodycomposition of fingerling rohu, *Labeo rohita* (Hamilton).Aquaculture Nutrition.4; 83–87.

Krishan, G. and Narang, A. 2014. Use of essential oils in poultry nutrition: A new approach. Journal of Advanced Veterinary and Animal Research. 1(4): 156-162.

Kumar, S., Sahu, N.P., Pal, A.K., Choudhury, D. and Mukherjee, S.C. 2006.Non-gelatinized corn supplemented with á-amylase at sub-optimumprotein level enhances the growth of *Labeo rohita* (Hamilton) fingerlings. Aquaculture Research. 37:284–292

Kaya, M., Sargin, I., Tozak, K.O., Baran, T., Erdogan, S. and Sezen, G. 2013.Chitin extractionand characterization from *Daphnia magna* resting eggs. International Journal ofBiological Macromolecules. 61:459–464.

Kumar, P., Jain, K.K., Sardar, P., Sahu, N.P. and Gupta, S. 2017. Dietary supplementation of acidifier:effect on growth performance and haemato-biochemical parameters in the diet of *Cirrhinus mrigala*juvenile. Aquaculture International. 25: 2101-2116.

Li,M., Zhu, X., Tian, J., Liu, M. and Wang, G. 2019.Dietary flavonoids from Allium mongolicum Regel promotes growth, improves immune, antioxidant status, immune-related signaling molecules and disease resistance in juvenile northern snakehead fish (*Channa argus*).Aquaculture. 501: 473-481.

Luckstadt, C. 2008. The use of acidifiers in fish nutrition. In: *CAB Reviews:* Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources.

Mahmoud, H.K., Al-Sagheer, A.A., Reda, F.M., Mahgoub, S.A. and Ayyat, M.S. 2017. Dietary curcumin supplement influence on growth, immunity, antioxidant status, and resistance to *Aeromonas hydrophila* in *Oreochromis niloticus*. Aquaculture. 475:569 16–23.

Nakamura, S., Gohya, Y., Losso, J.N., Nakai, S. and Kato, A. 1996. Protective effect of lysozyme-galactomannan or lysozyme-palmitic acid conjugates against *Edwardsiella tarda* infection in carp, *Cyprinus carpio* L. FEBS Lett 383:251–254.

Niu, J., Liu, Y.J., Lin, H.Z., Mai, K.S., Yang, H.J., Liang, G.Y. and Tian, L.X. 2011.Effects of dietary chitosan on growth, survival and stress tolerance of post larval shrimp,*Litopenaeus vannamei*.Aquaculture Nutrition. 17:e406–e412.

Nya, E.J. and Austin, B. 2009.Use of garlic, *Allium sativum*, to control *Aeromonas hydrophila* infection in rainbow trout, *Oncorhynchus mykiss* (Walbaum).The Journal of Fish Disease. 32: 963–970.

Omosowone, O., Dada, A. and Adeparusi, E. 2015. Effects of dietary supplementation of fumaric acidon growth performance of African catfish *Clarias gariepinus* and *Aeromonassobria* challenge. Croatian Journal of Fisheries. 73: 13-19.

Opiyo, M. A.,Jumbe, J.,Ngugi, C. C. and Charo-Karisa, H. 2019. Different levels of probiotics affect growth, survival and body composition of Nile tilapia (*Oreochromis niloticus*) cultured in low input ponds. Scientific African. 4: e00103.

Panalikul, P., Wongmaneeprateep, S. and Doolgindachbaporn, S. 2017. Effects of chitosan levels on growth performance, feed utilization and survival rate of rice-field crab

(*Esanthelphusa dugasti*). Journal of Pure and Applied Microbiology. 11: 1357–1364.

Paul,B.N., Das,S., Datta,A.K., Giri,S.S. and Mohanty,S.N. 2012. Effect of Dietary Protein Levels on Growth of *Ompok pabda* (Siluridae) Fry. Animal Nutrition and Feed Technology.12: 241-246.

Paul,B.N. and Giri,S.S. 2013. Utilization of plant based attractants in *Catla catla* fingerlings. Indian Journal of Animal Nutrition. 30 (4): 400-403.

Paul, B.N., Pandey, B.K. and Giri, S.S. 2014. Effect of plantbased attractants on growth of *Cirrhinus mrigala* fingerlings. Animal Nutrition and Feed Technnoogyly. 14: 393-398.

Rafieepour, A., Hajirezaee, S., and Rahimi, R. 2019. Moderating effects of dietary oregano extract (*Origanum vulgare*) on the toxicity induced by organophosphate pesticide, diazinon in rainbow trout, *Oncorhynchus mykiss*: metabolic hormones, histology and growth parameters. Turkish Journal of Fisheries and Aquatic Sciences.20(3):207–219.

Rachmawati, D. and Samidjan, I. 2018.Effect of phytase enzyme on growth,nutrient digestibility and survival rate of catfish (*Pangasiushypothalamus*) fingerlings.Pertanika Journal of Tropical Agricultural Science. 41:865–878.

Rashidian, G., Boldaji, J.T., Rainis, S., Prokic, M.D. and Faggio, C. 2021. Oregano (*Origanum vulgare*) Extract Enhances Zebrafish (*Danio rerio*) Growth Performance, Serum and Mucus Innate Immune Responses and Resistance against *Aeromonas hydrophila* Challenge. *Animals.11*: 299.

Ringo, E. 2020.Probiotics in shellfish aquaculture.Aquaculture and Fisheries. 5(1): 1–27.

Safari, R., Hoseinifar, S.H., Nejadmoghadam, S. and Jafar, A. 2016. Transciptomic study ofmucosal immune, antioxidant and growth related genes and non-specific immune response of common carp (*Cyprinus carpio*) fed dietary Ferula (*Ferula asafoetida*). Fish and Shellfish Immunology. 55: 242–248.

Sambhu, C. and Jayprakash, V. 2001.Livol (IHF-1000), a new herbal growth promoter in white prawn, *Penaeus indicus*.Indian Journal of Marine Science.30:(1): 38-43.

Sanchez, M., Lins-Rodrogues, M.,Pessini, J.E., Bittercourt, F., Boscoda, W.R. and Signor, A. 2021. Dietary supplementation with L-carnitine for Nile tilapia juveniles.Aquaculture, 539, 736616.

Shiau,S.Y. and Yu,Y.P. 1988. Chitin but not chitosan supplementation enhances growth of grass shrimp, *Penaeus monodon*. Journal of Nutrition. 128:(8): 908-912.

Singh P., Paul, B.N., Rana G.C., Mandal R.N., Chakrabarti P.P. and Giri, S.S. 2015. Evaluation of Ghee Residue as Feed ingredient for *Labeo rohita*. Indian Journal of Animal Nutrition,32 (1):101-107.

Singh, P., Mahintamani,J. and Maity, J. 2020. Utilization of plant based attractants in *Labeo rohita* advanced fingerlings. Indian Journal of Animal Nutrition.37 (1): 82-86.

Soltanian, M., Langodi, H.F. and Nejad, M.M. 2019.The use of *Zingiber officinale* extract against *Yersinia ruckeri* and its effects on the antioxidant status and immune response in *Oncorhynchus mykiss*. International Journal of Aquatic Biology. 7(5): 301-314.

Talpur A.D., Ikhwanuddin M. and Bolong A.A. 2013.Nutritional effects of ginger (*Zingiber officinale* Roscoe) on immune response of Asian sea bass, *Lates calcarifer* (Bloch) and disease resistance against Vibrio harveyi.Aquaculture. 400-401: 46-52.

Tiril S.U., Alagil F., Yagci F.B. and Aral,O. 2008. Effects of betaine supplementation inplant protein based diets on feed intake andgrowth performance in rainbow trout(*Oncorhynchus mykiss*). Israeli Journal of Aquaculture.– Bamidgeh.60(1):57-64.

Torreele, E.L.S., Sluiszen, A.V.D. and Verreth, J. 1993.The effect ofdietary L-carnitine on the growth performance in fingerlings of the African catfish, *Clarias gariepinus* in relation to dietary lipid.British Journal of Nutrition.69: 289–299.

Twibell, R.G. and Brown, P.B. 2000. Effects of dietary carnitine ongrowth rates and body composition of hybrid striped bass (*Morone saxatilis* male & *M. chrysops* female). Aquaculture.187: 153– 161.

Yilmaz, S. and Ergun, S. 2012.Effects of Garlic and Ginger oils on Hematological and Biochemical Parameters of Sea bass, *Dicentrachus labrax*.Journal of Animal Health. 24:219-224.

Zahran, E., Risha, E., AbdelHamid, F., Mahgoub, H.A. and Ibrahim, T. 2014.Effects of dietary Astragalus polysaccharides (APS) on growth performance, immunological parameters, digestive enzymes, and intestinal morphology of Nile tilapia (*Oreochromis niloticus*).Fish Shellfish Immunology. 38 (1): 149–157.

Zaki, M.A., Labib,E.M., Nour,A.M.,Tonsy, H.D.and Mahmoud, S.H. 2012. Effect of some medicinal plants diets on mono sex Nile Tilapia (*Oreochromic niloticus*), growth performance ,feed utilization and physiological parameters. APCBEE Percedia, 4: 220-227.

Zammit, V.A., Ramsay, R.R., Bonomini, M. and Arduini, A. 2009.Carnitine, mitochondrial function and therapy.Advanced Drug Delivery Reviews. 61: 1353–1362.

Zhou, C., Lin, H., Ge, X., Niu, J., Wang, J., Wang, Y., Chen, L., Huang, Z., Yu, W. and Tan, X. 2015. The Effects of dietary soybean isoflavones on growth, innate immune responses, hepatic antioxidant abilities and disease resistance of juvenile golden pompano Trachinotus ovatus. Fish & Shellfish Immunology. 43: 158–166.

Zhou. Y., Yuan, X., Liang, X.F., Fang, L., Li, J., Guo, X., Bai, X. and He, S. 2013.Enhancement of growth and intestinal flora in grass carp: The effect of exogenous cellulase. Aquaculture. 416–417:1–7.