

ENGINEERED NANO PARTICLE SUPPLEMENTED WITH FORMULATED FISH DIET

Submitted in partial fulfillment of the requirements for the award of bachelors of
Technology degree in Biotechnology

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **C.M. DEVISHREE (38230009)** who carried out the project entitled "**ENGINEERED NANO PARTICLE SUPPLEMENTED WITH FORMULATED FISH DIET**" under our supervision from September 2021 to April 2022.

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DECLARATION

I, **C.M. DEVISHREE (38230009)** hereby declare that the Project Report entitled **“ENGINEERED NANO PARTICLE SUPPLEMENTED WITH FORMULATED FISH DIET”** done by us under the guidance of **Dr. S. Kumaran** is submitted in partial fulfillment of the requirements for the award of Masters of Technology degree in Biotechnology.

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ABSTRACT

Removal of fisheries all over the planet is a not kidding and perilous issue in beach front regions. For the economic advancement of fisheries, it is critical to utilize solid enhancements to increment fish creation and wellbeing. Selenium (Se) is utilized in many fish enhancements to expand efficiency and resistance. The point of this study was to assess the impact of Cs-Se NP on *Oreochromis niloticus* creation, suitability, and protein digestion. This is a report on the impacts of CS-Se NPs as an enhancement to improve the development execution and resistance of *O. niloticus*. Cs-Se NPs is distinguished by filtering and electron microscopy, FT-IR, X-beam diffraction, and grain dissemination. The fish (15.30 ± 0.23 g) were taken care of a fair eating routine of 0.0, 0.25, 0.5, 1.0, and 2.0 g Cs-Se NPs/kg for 45 days. An eating routine containing 1.0 g/kg Cs-Se NP brought about a particular development rate, weight gain, and tilapia endurance rate contrasted with the benchmark group. Cs-Se NP is a functioning antiviral medication.

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LIST OF SYMBOLS AND ABBREVIATIONS

Cs	Chitosan
Se	Selenium
Cs-Se NPs	Chitosan-selenium nanoparticles
TPP	Sodium triphosphate
EDX	Energy dispersive x-ray analysis
SEM	Scanning Electron Microscopy
ZP	Zeta potential
FTIR	Fourier Transform Infrared Spectroscopy
MBM	Meat and bone meal
CSM	Cotton seed meal

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CHAPTER-1

INTRODUCTION

1.1 OVERVIEW

The aquaculture industry has been dramatically developed as the fast-growing food production and positively to global food. Tilapia will be stressed under deteriorated water quality may become susceptible to be several infections agents which will negatively affect their production rates and lead to mortalities with significant economic losses. Food waste is the major solid waste and its volume is increasing rapidly across the world. Nile tilapia, *Oreochromis niloticus*, is one of the most cultured fish species with great marketing value worldwide that have great growth performance and tolerance for adverse environments. On the other hand, the dietary supplementation of specific nutrients can play a major role in improving growth and boosting antioxidant status and immune response in fish.

1.2 SELENIUM

Selenium is significant micronutrient (Dare et al., 2001) to regulate functions and metabolism of animals (Hamilton et al., 2004) and involved in entire task of body in aquatic species (Sarkar et al., 2015; Ibrahim et al., 2021). Selenium nanoparticles have crucial minerals, which have highly efficient to regulate as a growth promotor, immunostimulant agent, antioxidant (Chris et al., 2018; Rathore et al., 2020) and has high potential to act as antifungal, antiviral and antibacterial activity in aquaculture industries (Hosnedlova et al., 2018). In fish and sea food nutrition, the Selenium has significant attention with numerous studies to evaluate its optimum dietary level (Atencio et al., 2009; Arner ESJ et al., 2000; Izquierdo MS et al., 2017; Lin Y et al., 2018; Jaramillo JR F et al., 2009). Selenium act with protein repair at the DNA level to the part of oxidative-stress defence mechanism (Arner ESJ et al., 2000) which have rapidly improved the survival and stress resistance. Selenium diet supplementation helps in bone formation and mineralization processes to prevent the oxidative damage of cytoplasmatic structures (Izquierdo MS et al., 2017) and helps in reduction of reactive oxygen species in liver and kidney of Nile tilapia

(*Oreochromis niloticus*) (Atencio et al., 2009). Selenium has high impact on protection of host cell against varied oxidative stressors and efficacy depends on fish body size and sorts (Saffari et al., 2017). Selenoproteins are produced from selenium in glutathione peroxidase which is involved in antioxidative responses (Kumar et al., 2020). In rare case, Selenium-free diets induce body abnormalities and malnutrition in fish species (Wang et al., 2021). Selenium has significant role to prevent various diseases, such as cardiovascular disease (Ray et al., 2006; Thomson, 2004), hypercholesterolemia (Navas-Acien et al., 2008), and certain cancers (Ferguson et al., 2006). Sodium selenite (inorganic Se) is most common source of selenium supplement of fish diets (Jaramillo JR F et al., 2009) and has higher bioavailability (Wang C, Lovell RT, 1997). The application of sodium selenite is limited due to its susceptibility to environmental conditions such as ionic strength and pH which decreases its water solubility, reducing its bioavailability and promoting aggregation (Zhang J et al., 2005; Penglase S et al., 2011).

1.3 CHITOSAN

Chitosan is natural prepared biopolymer polysaccharide through N-deacetylation of chitin, found in crustacean shells, fungi (Hill LE et al., 2013). Chitosan has significant applications in aquaculture like environmental, biomedical, agriculture, pharmaceutical (T. Kean et al., 2010), antibacterial activities (A. Anas et al., 2005; S.-H. Wang et al., 2005; N.M. Abu-Elala et al., 2015; S.E. Fadl et al., 2020; R. Harikrishnan et al., 2012) against pathogenic bacteria and antimicrobial growth-stimulating (Fahmed et al., 2019). Chitosan nanoparticles have been used with biological functions like drug carrier system (J.J Wang et al 2011), different types of DNA, vaccine delivery system (Shah BR, Mraz J (2020); Rajesh kumar S et al., 2008; Tian J et al., 2008; Leon-Rodriguez L et al., 2013; Li B et al., 2013; Ferosekhan S et al., 2014) and therapeutic use (K. Nagpal et al., 2010) which is due to its biodegradability, and low toxicity. Chitosan is not only low immunogenicity; it also possesses a high density of positive charge in acid solution due to glucosamine group in its backbone. It increases its application in chitosan-based micro and nanoparticles in nutraceutical and pharmaceutical field (Grenha et al., 2005; Kockisch et al., 2003; Khelifi et al., 2005; Shah et al., 2009). In aquaculture industry,

it has prospective role such as immune modulation, growth promotion and protection against oxidative stress (H.M. Abdel-Ghany et al.,2020). Chitosan improved the immunity and disease resistance in several fish species such as Nile tilapia (M. Abdel-Tawwab et al.,2019; F.S. Abd El-Naby et al., 2019), rainbow trout (A. Alishahi et al.,2011) silver carp (*Hypophthalmichthys molitrix*) (N. Younus et al.,2020) and zebrafish (C. Nikapitiya et al.,2018).

1.4. ANIMAL PROTEIN WASTE

1.4.1 Meat and Bone Meal (MBM)

Meat and Bone Meal is a magnificent source of protein, calcium, vitamin B12 and phosphorus with essential amino acid profile and high digestibility by Kellems et al. (1998) and by- product of animal rendering industry. When compared with fish meal and blood meal, meat and bone meal have lower content in amino acid and higher in minerals (Yang et al., 2004). In diets of various fish species meat and bone meal is used effectively in feeds, such as rainbow trout (Bureau et al., 2000), Australian snapper (Quartararo et al., 1998), red drum (Kureshy et al., 2000) and Nile tilapia (Fasakin et al., 2005). Tacon et al. (1983) reported that up to 50% of fish meal can replace with meat and bone meal and addition to methionine supplement for *O. niloticus* fry in diets containing 45 % crude protein. El Sayed and Tacon (1997) reported that Meat and bone meal could effectively replace up to 75% of the Fish meal in diets fed to *O. mossambicus* fry. In the diet of gilthead seabream juveniles, Moutinho *et al.* (2017) without compromising growth and feed efficiency replaced fish meal upto 50% with meat and bone meal protein. Sato and Kikuchi (1997) reported the meat and bone meal protein may replace up to 60% fish meal protein without affecting weight gain, feed or protein efficiency. Even 80% of fish meal mixture is replaced there is no substantial differences in growth performance (Millamena 2002). The effect of meat and bone meal on gibel carp (*Carrassius auratus gibelius*) was investigated by Yang *et al.* (2004) and they concluded that without reducing growth rate, meat and the bone meal could replace up to 50% of the fish meal. Kellems et al., (1998) demonstrated meat and bone meal can partial or complete replacement of fish meal at different levels of 5% to 15%, even though ash content may limit the use of meat and bone meal in feeds (Fasakin et al., 2005).

1.4.2. Poultry by-products

Poultry By-product Meal has homogeneous composition of fish meal but lower in amino acids (Yang et al., 2004) and highly protein digestible (88%) and energy (82%). The manure from the poultry also serves as a source of protein to the fish. Poultry meal is also rich in protein and can be fed to aquatic species with superior outcomes (Galkanda-Arachchige HSC et al., 2020). Poultry by-products meal can replace partially or wholly fish meal in fish feed (Robinson et al., 2007) due to their presence of rich nutrients and have productive essential amino acid such as lysine and methionine. Poultry By-product Meal has been tested for fish diets at varying success so far in tilapia (El-Sayed, 1998), channel catfish (Sadiku and Jauncey, 1995a), sea bream (Nengas et al., 1999), salmon (Yang et al., 2004), channel catfish (Sadiku and Jauncey, 1995a) and common carp (Hasan et al., 1993). Poultry By-product Meal effectively utilize as a single dietary protein in the diet of red tilapia and Nile tilapia (El-Sayed 1998). In the diet of rainbow trout, Keramat *et al.* (2014) replace up to 33% fish meal by the poultry by-product without compromising the growth performance. In Chinook salmon (*Oncorhynchus tshawytscha*), Fowler (1991) reported the poultry by-product have a potential as feed ingredients to replace up to 50% fish meal. In the diet of red drum juveniles, Kureshy *et al.* (2000) observed at various inclusions level that poultry by-product could effectively replace 67% of fish meal. Zhou et al., 2011 studied fish feed with Poultry by-products meal were not significantly lower when compared to the mix of fish meal and soybean meal in terms of survival and growth performance. Rawles et al., 2006 almost shows similar results significantly influence weight gain when 35% substituted fish meal with Poultry by-products meal and do not influence feed conversion ratio. Muzinic *et al.* (2006) reported 100% of fish meal protein can replace with turkey meal without any adverse effects on the growth of Sunshine bass (*Morone chrysops* × *Morone saxatilis*).

1.4.3. Feather meal

Feather meal is the by-product from poultry production, richness in essential amino acids such as cystine, threonine, and arginine, along with high level (75-87%) of pepsin digestible protein and contains complex structure protein called keratin (Sarmwatanakul and Bamrongtum 2000). In the diets, utilization of feather meal is

decreased due to limitation of complex protein called keration (Steffens, 1994). Without affecting growth and feed utilization efficiency, Fowler (1990) replaces 15% of fish meal by feather meal in the diet of Chinook salmon. In the diet of *O. niloticus* fingerlings without any adverse effect on the growth performance Falaye (1982) and Bishop *et al.* (1995) could replace upto 66% of fish meal by the hydrolyzed feather meal. Bureau *et al.* (2000) studied different origins as a protein source in rainbow trout (*Oncorhynchus mykiss*) diets from the hydrolyzed feather meal and meat and bone meal and concluded that didn't affect protein and energy retention of the fish. Arunlertaree and Moolthongnoi (2008) reported that fermented Feather meal could replace up to 25%- 50% of fish meal for Nile tilapia diet.

1.4.4. Fish Meal and Fish Oil

Fish meal is enormously used as a source of protein and fatty acids in the diets to fed aquatic species with more delectable when incorporated at low levels. In recent years, fish has high demand, fishmeal is becoming lavish because of the competition its usage has with humans and has high digestibility and nutritive value for the feed ingredient for aquaculture production. Several studies have been carried out to replace fish meal with plant protein sources in the diets of aquatic species. Fish oil is used in some formulation of aqua-feeds which can easily render the feed rancid at high levels.

1.4.5. Blood Meal

Blood meal has a high-quality protein source and readily available in abattoirs in fish feed formulation. Marine proteins can replace effectively by Blood meal when supplemented with methionine (Dominy and Ako, 1988). Blood meal is treated hygienically, so it does not become source of pathogens when used in aqua-feeds. In the diets of Mozambique tilapia (*O. mossambicus*) fry Davies *et al.* (1989) reported blood meal could effectively replaced up to 75% of fish meal. Blood meal used as a sole protein in the diets of Nile tilapia by El-Sayed (1998) and concluded reduction in fish performance. Aladetohun and Sogbesan (2013) studied the inclusion of blood meal in the experimental diet to improve the growth of Nile tilapia. In the diets of juvenile African Catfish Makinde and Sonaiya (Makinde OA *et al.*, 2012) appraise the potential of two vegetable-carried blood meals and culminate serve as alternatives to imported commercial fish feed. Agbebi *et al.* (2009)

completely replaced fishmeal by blood meal without adverse effect of growth, survival and feed conversion of Nile tilapia and *Clarias gariepinus* juveniles.

1.4.6. Abattoir Waste

Innumerable livestock animals and poultry are slaughtered and their waste can be treated and used as a source of proteins and minerals in the diets of aquatic species and excellent medium for growth of pathogenic organisms like blood meal. Abattoir waste need careful treatment before use as feed ingredient for fish (Opiyo MA et al., 2019).

1.4.7. Snail Meal

Snails are copious in the forest zones and its richness in sodium and potassium (Sogbesan AO et al., 2008). Snail shells are lavish in calcium but flesh is converted into a feed for aquatic species. Sogbesan and Ugwumba (2008) researched the use of garden snail as a source of protein in aquaculture in Nigeria and concluded that nutritive values will similar to fish meal feed.

1.5. Plant based protein

1.5.1. Soybean Meal

Soybean meal (SBM) is an alternative source of protein and have beneficial amino acid profile which is used to replace fish meal in the aqua-feeds. Soybeans are highly demand due to the expansion of soybean in industries like cosmetic, production of vitamin and health-supplement, and poultry industries. Soybean meal richness in lysine, tryptophan, isoleucine, threonine and valine due to this benefits content, fish meal is replaced by soybean meal in fish feed (Carrillo et al., 2012). Soybean is deficient with methionine and cystine (Cromwell, G.L.). Soybean meal is not recommended for sole protein sources, it must be integrated with another protein source to balance the fish feed. In the diet of catfish fingerling there was no reduction in growth and Siddiqui et al., (2013) reported the efficiencies by incorporating 15% of soybean meal. Yuan et al., (2011) proposed the extra addition of lysine and methionine to promote growth and health of fish. Viola and Zohar (1984) concluded that diets with crystalline essential amino acids does not improve Nile tilapia performance. Viola et al. (1988) reported that replacement of 100% fish meal with 100% soybean meal diet supplemented with Lysine, Methionine, oil and di-calcium phosphate was similar in the growth of tilapia hybrids (*O. niloticus* x *O.*

aureus). Soybean meal contain some anti-nutritional factors like trypsin (El Sayed, 1999), thermal processing used to make quality of feeds (Tacon, 1993). Heating Soybean meal raze the anti-nutritional factors and improves nutrient bio-availability (Tacon and Jackson, 1985). Sadiku and Jauncey (1995a) endorse mixing of soybean meal with animal protein sources to improve its quality for Nile tilapia. In the diet of *O. niloticus* without reduction in growth, nutrient utilization, Ajani *et al.* (2016) opened up that soybean meal can be used for partial replacement of fish meal or complete replacement with supplementation of methionine. Elangovan and Shim (2000) reported that soybean meal could replace fish meal at different levels like 27%, 37% and 52% on the growth and body composition of tin foil bark (*Barbodes altus*) juvenile. In the diets of yellow perch, *Pecra flovescens*, Kasper *et al.* (2007) concluded that up to 47.6% of the fish meal could be replaced with soybean meal without affecting the feed consumption, weight gain, feed efficiency ratio and survival of the fish. Watanabe (2002) proposed defatted soybean meal is accepted universally by both qualitatively and quantitatively, has good amino acid profile and consistently available reported to be palatable to fish species. In the presence of anti-nutritional factors in soybean meal such as antigenic compounds (antivitamins, allergens, phytic acid, saponins and phytoestrogens,), lectins, protease inhibitors and tends to fish's growth and prompt pathological in intestinal mucosa (Hussain *et al.*, 2011).

1.5.2. Groundnut cake/meal:

Groundnut meal/cake is an oilseed by-product and has high protein content. It has substandard levels of amino acids such as cysteine, methionine, and lysine (Davies *et al.*, 2010; Fagbenro, O.,1998) and also lack in calcium and vitamin B12. It has highly mild flavor (Adeniji, A.A., 2008) and have superior binding properties when compared to soybeans (So, O., O. Si,2007). Mildew groundnut cake became toxic due to the presence of mycotoxin called aflatoxin (Abowei *et al.*,2011). Absence of anti-nutritional factor has an advantage over the plant protein for formulation of fish feed as a protein replacement (Lovell, 1989). Poor performance of fish can be seen with the amino acid profile of groundnut. Enhancement of amino acid by supplementation of lysine and methionine by Enyidi *et al.* (2014) while feeding groundnut cake in *C. gariepinus* for better growth performance. Without

compromising growth performance Srivastava and Reddy (2018) replaced 15% fish meal by de oiled Groundnut oil cake in the diet of juvenile *Tilapia mossambica*. In *Heterobrenchus longifilis* fed diets Ovie and Ovie (2007) studied growth, survival and food conversion efficiency with varying level of protein with a replacement of fish meal. Groundnut cake dietary was endorsed by Ogunji and Wirth (2001) at different inclusion of about 10% in the diets of tilapia, (*O. niloticus*). Without effect on growth, feed efficiency, whole body composition and nutrient digestibility Agbo *et al.* (2011) recommended that 20%- 50% fish meal can replace with groundnut cake and groundnut husk in fish meal protein in the diets of *O. niloticus* fingerlings. So, O., O. Si (2007) replaced fish meal upto 10% with groundnut cake in 44.17% of total crude protein in diets of *H. longifilis* fingerlings.

1.5.3. Canola Meal

Rapeseed and canola products have been examined as protein sources in diets for several fish species including rainbow trout (Thiessem *et al.*, 2004), tilapia (Yigit and Olmez, 2009) and channel catfish (Lim *et al.*, 1998). Canola meal is deficient in lysine but has high levels of methionine and cystine which have good profile in amino acid for animal feed. In the diet of ovate pompano (*Trachinotus ovatus*) Kou and coworker (2015) replaced canola meal upto 18.17% fish meal without affecting the growth. In the diets of tilapia (*O. mossambicus*) Davies *et al.* (1990) examined the use of rapeseed meal as an alternative protein source for fish meal.

1.5.4. Brewer's Spent Grains

Brewer's spent grains are richness in source of protein and energy with minimal cost in the diets of aquatic species. Brewer's grains (spent grain) collected from left over after extraction of malt required for the production of beer contains good amino acid profile and 3-5% ether extract, 9-5% crude fiber, 20-23% dry matter, 19% crude protein.

1.5.5. Leguminous Grains

Leguminous grains are source of proteins such as cowpea, chick pea, pigeon pea, bambara groundnut, groundnuts are used as a ingredient of aqua- feeds which can replace partially or completely fishmeal in diets. It have anti-nutritional factors such as tannins, which can be rendered harmless through subjection to heat. In the diets

of *Clarias isheriensis*, Fagbenro (1995) appraise the use of heat processed cocoa pod husk meal as energy at 10, 30 and 45% levels. Mondal et al. (2012) culminate inclusion of mulberry leaf meal as feed diet in *L.bata* for replacement of fish meal due to crude fiber content of the diet.

1.5.6. Cereal Grains and by-Products

Cereal grains such as maize and sorghum as well as rice milling by-products and wheat bran can be used in aqua-feeds with excellent outcomes and serve as a source of carbohydrates and glucose to the aquatic species.

1.5.7. Cotton Seed Meal (CSM)

Cottonseed, *Gossypium hirsute* Linnaeus, is the third leading plant protein used worldwide (Gatlin et al., 2007) and is available at relatively lower cost than animal proteins. Cotton Seed Meal has high protein content and good amino acid profile limited in Cystine, Lysine and Methionine and has high content of gossypol, an antinutrient compound which use to limit in feeds (El Sayed, 1999). To show better performance in Nile tilapia El-Sayed (1990) used solvent extracted cotton seed meal as a source of single dietary protein in feeds. El-Sayed (1990) founded that *O. niloticus* and *O. aureus* fed on Cotton seed meal-based diets grew at slower rates when compared to fish meal-based diets, this is due to the gossypol and cyclopropionic acids contained in cotton seed meal feed. Viola and Zohar (1984) reported that about 50% cotton seed meal replaced soybean meal in diets fed to tilapia hybrids. El-Sayed (1987) discovered that *Tilapia zillii* grew on 80% cotton seed meal diets.

1.5.8. Sunflower meal

Sunflower (*Helianthus annuus*) is a widely cultivated oil seed with good source of methionine and arginine (Ramachandran et al., 2007). Devi and Vijayaraghavan (1996) employ sunflower oil cake at different inclusion levels 20%, 40% and 60% in the diets (isonitrogenous 35% crude protein). Zheng et al. (2012) reported the effect of replacing soybean meal (SBM) with cottonseed meal (CSM) on growth and health of grass carp.

1.5.9. Aquatic plants

Aquatic plants have essential feed supplements due to their excessive nutritive value, favourable bioactive compound and digestibility (Ansal and Dhawan, 2009).

In aquatic plants, duckweed had proved that have superior nutritive value and swift growth rate. Effiong *et al.* (2009) successfully replaced 10% of fish meal with duckweed meal (*L. pauciscostata*) in African catfish (*H. longifilis*) diet. In the conventional fish diets inclusion of water hyacinth, *Echornis crassipes* at different levels 50% and 20-40% in catfish *H. fossilis* (Niamat, 1985) and *L. rohita* gave better growth when compared to control.

CHAPTER-2

LITERATURE SURVEY

Juliana Araujo et al., (2021) proposed Encapsulation of sodium selenite in chitosan matrix was presented as a simple and cost-effective method to produce nanoparticles with high entrapment efficiency, small size, *in vitro* antioxidant activity, and controlled release properties. It shows great alternative to protect and delivery selenium during fish production as components of fish diet supplements. The dietary supplementations with different Se sources lead to significant improvements in final weight and feed efficiency of Nile tilapia fingerlings. Se NPs prevents oxidative stress and improved antioxidant activity in tissues of Nile tilapia fingerlings. These chitosan selenite nanoparticles can have a wide range of applications with use in multiple commercial fish productions. Additionally, these chitosan nanoparticles have large potential to encapsulate other dietary supplements for controlled delivery and bioavailability. Overall, these chitosan selenite nanoparticles have the potential to improve fish production in commercial aquaculture.

Doaa Ibrahim et al., (2021) Development of the nano delivery system for selenium as SeChNPs improved selenium bioavailability and facilitate selenoprotein expression even with low selenium level. Considering molecular data related to immunological, stress and antioxidant genes expression in current study, the ameliorative role of SeChNPs on Nile tilapia performance can result from immune stimulatory and free radicals scavenging effects of selenium and chitosan nano composite.

Mohamed E. El-Sharawy et al., (2021) proposed based on the dose-dependent effect of Se, the study gives more details about the role of Se nanoparticles on striped catfish performances. Dietary Se nanoform improved the growth performance and feed efficiency without negatively affecting the accumulated Se levels in the liver, intestine, and gills. The results also showed enhanced antioxidative capacity with regular and protected intestinal and liver histological features.

Yangchao Luo et al., (2010) demonstrated that selenite-loaded CS/TPP nanoparticles can be successfully prepared under mild conditions via ionic gelation method. Physicochemical properties, such as particle size, surface charge, encapsulation efficiency, and controlled release can be modulated by controlling critical fabricating parameters including the CS and selenite loading concentrations. The encapsulation of selenite into CS can significantly improve the in-vitro antioxidant properties, compared with free selenite.

Subramanian Kumaran et al., (2021) suggested that feed supplemented with NAG loaded CSNPs in *O. niloticus* and were significantly increased growth performance, feed intake, survival rate, non-specific immune response, and decreased feed conversion ratio. This is the first comparative study examining the effect of CSNPs and NAG loaded CSNPs as dietary supplement for *O. niloticus*. Fish fed with 1% NAG loaded CSNPs containing diets as therapeutic and preventive regimes have remarkably enhanced the growth efficiency. *In-vitro* and *in-vivo* results strongly confirm that CSNPs and NAG loaded CSNPs from shrimp disposal waste could be used as a cost-effective, value-added dietary supplement for aquaculture industry. This opens up new research to develop an effective combination of NAG loaded CSNPs as fish feed to enhance growth performance and immune response in commercial aquaculture production.

CHAPTER-3

AIM AND OBJECTIVE

3.1 AIM

1. To develop fish feed by incorporating Chitosan-Selenium nanoparticles.

3.2 OBJECTIVE

1. Designing cost-effective aqua feeds.
2. Fish fed with Chitosan loaded Selenium nanoparticles containing diets as therapeutic and preventive regimes have remarkably enhanced the growth efficiency.
3. To develop an effective combination of Chitosan loaded Selenium nanoparticles as fish feed to enhance growth performance and immune response in commercial aquaculture production.

CHAPTER-4

MATERIALS AND METHODS

4.1.SAMPLE COLLECTION

The soybean meal, groundnut meal, wheat bran were collected from cold pressed oil shop from Porur in Chennai district, Tamil Nadu. Fish meal, vitamins, minerals, corn oil, starch were collected store. Low molecular weight chitosan (85% deacetylation, Mw 50–190 kDa), sodium selenite (Na_2SeO_3) and Sodium triphosphate (TPP).

4.2. Nile tilapia

Total of 50 Nile tilapia fingerlings were obtained from Tarun fish farm from Kolathur in Chennai district, Tamil Nadu, with an average body weight. The tilapias were adapted in aerated glass tank for two weeks before to the initiation of the experiment for acclimatization.

4.3. CHITOSAN-SELENITE NANOPARTICLE PREPARATION

Chitosan selenite nanoparticles were prepared by the ionotropic gelation method. Initially, chitosan solution (2.5 mg mL^{-1} , pH 4.6) was prepared by dissolving chitosan in 1% (w/v) acetic acid solution and stirring for 6 hours at room temperature. Next, sodium selenite aqueous solution (0.6 mg mL^{-1}) was added dropwise to the chitosan solution while stirring at 500 rpm for 2 hours. Then, the tripolyphosphate (TPP) aqueous solution (0.25 mg mL^{-1}) was added dropwise into the chitosan/sodium selenite suspension and stirred for 2 hours to form the particles. Next, the particle suspension was sonicated (Sonic Wave CD-2800 ultrasonic cleaner, 60 W, Newtown, CT, USA) for 15 min, followed by centrifugation at 13,000 rpm for 30 min. Finally, pellet was lyophilization and Cs-Se NPs powder is obtained.

4.4. EXPERIMENTAL DESIGN, FISH CULTURE AND DIET PREPARATION

Tilapia's fingerlings were randomly grouped into five groups, and each group retained five replicates in glass aquaria at a density of 10 fish per tank and cultured for 12 weeks. The control group (CT) was fed a basal diet, other groups fed basal diets supplemented with Se loaded chitosan nanoparticles at levels of 0.5, 1, 1.5 and 2g/kg diet (SeChNPs0.5, 1, 1.5 and 2). Throughout the feeding trial, the water

temperature was adjusted at an average of 26.52 ± 1.43 °C, pH of 7.32 ± 0.22 , where dissolved oxygen was 7.16 ± 0.13 mg/L, and the total ammonia was 0.18 ± 0.11 mg/L, on the other side nitrite was 0.027 ± 0.03 mg/L and nitrate, 0.7 ± 0.1 mg/L.

4.5. FEED CONSUMPTION AND GROWTH RATE MEASUREMENTS:

After completion of the feeding trial analysis on the 45th day, the fishes fed with Cs-Se NPs/kg feed from each tank were harvested, measured, and recorded. The survival rate of the fishes was also calculated by enumerating the individuals in each tank. The efficiency of fish productivity and diet consumption parameters includes weight gain (WG), specific growth rate (SGR), feed intake (FI), feed conversion ratio (FCR) and feed efficiency were determined.

$$\text{Weight gain (g)} = W2 - W1 \text{ (g)}$$

$$\text{Weight gain (\%)} = \frac{100(W2 - W1)}{W1}$$

$$\text{Specific growth rate} = 100 \frac{[\ln W2(g) - \ln W1(g)]}{T}$$

$$\text{Feed intake (g feed/ fish)} =$$

$$\frac{\text{Summation of diets provided to fish throughout the number of the experiment}}{\text{Fish number}}$$

$$\text{Feed conversion ratio} = \frac{\text{Feed consumption (g)}}{\text{Weight gain (g)}}$$

$$\text{Fish survival (\%)} = 100 \frac{(\text{Fish number at final})}{(\text{Fish number at initial})}$$

$$\text{Feed efficiency} = \frac{\text{weight gain}}{\text{Dry feed intake weight}}$$

Where W1 – initial weight; W2 – final weight and T – total experiment duration.

4.6. FOURIER-TRANSFORM INFRARED SPECTROSCOPY (FTIR):

The Cs-SeNPs were measured with frequency ranges from 4000 to 500 cm^{-1} through FT-IR spectra (Bruker, France).

4.7. SCANNING ELECTRON MICROSCOPY (SEM):

Micrographs of the samples were acquired at room temperature using a scanning electron microscope (SU8010, Hitachi, Tokyo, Japan) with an accelerating voltage of 3.0 kV. The cross-sections and surfaces were coated for observation.

4.8. ZETA POTENTIAL ANALYSIS:

The mean diameter and ZP of nanoparticles were determined using a dynamic light scattering (DLS) PS analyzer (ZetaSizer Nano ZS ZEN3600 from Malvern Instrument; Particle Sizing Systems, Inc. Santa Barbara, CA). The samples were diluted to 100-fold serial dilution) with deionized water. All measurements were carried out at 25°C, and the results were reported.

CHAPTER- 5

RESULTS AND DISCUSSION

5.1. FORMULATION OF ORGANIC FISH FEED:

The powdered source includes soybean meal, fish meal, casein, groundnut cake, wheat bran, starch was collected and mix with lukewarm water with addition of corn oil, vitamins, minerals for nutrition enrichment. The Cs-Se NPs was mixed along with powdered source and then made into pellets.



FIG: 5.1 – product formulation, (a) Powdered source, (b) process flow

5.2. SYNTHESIS OF CHITOSAN – SELENIUM NANOPARTICLES:

In the present study, Ionotropic gelation of Cs-Se NPs was synthesized with drop by drop adding of sodium selenite and TPP to Cs solution. Cs-Se NPs powdered wea added to fish feed product formulation.

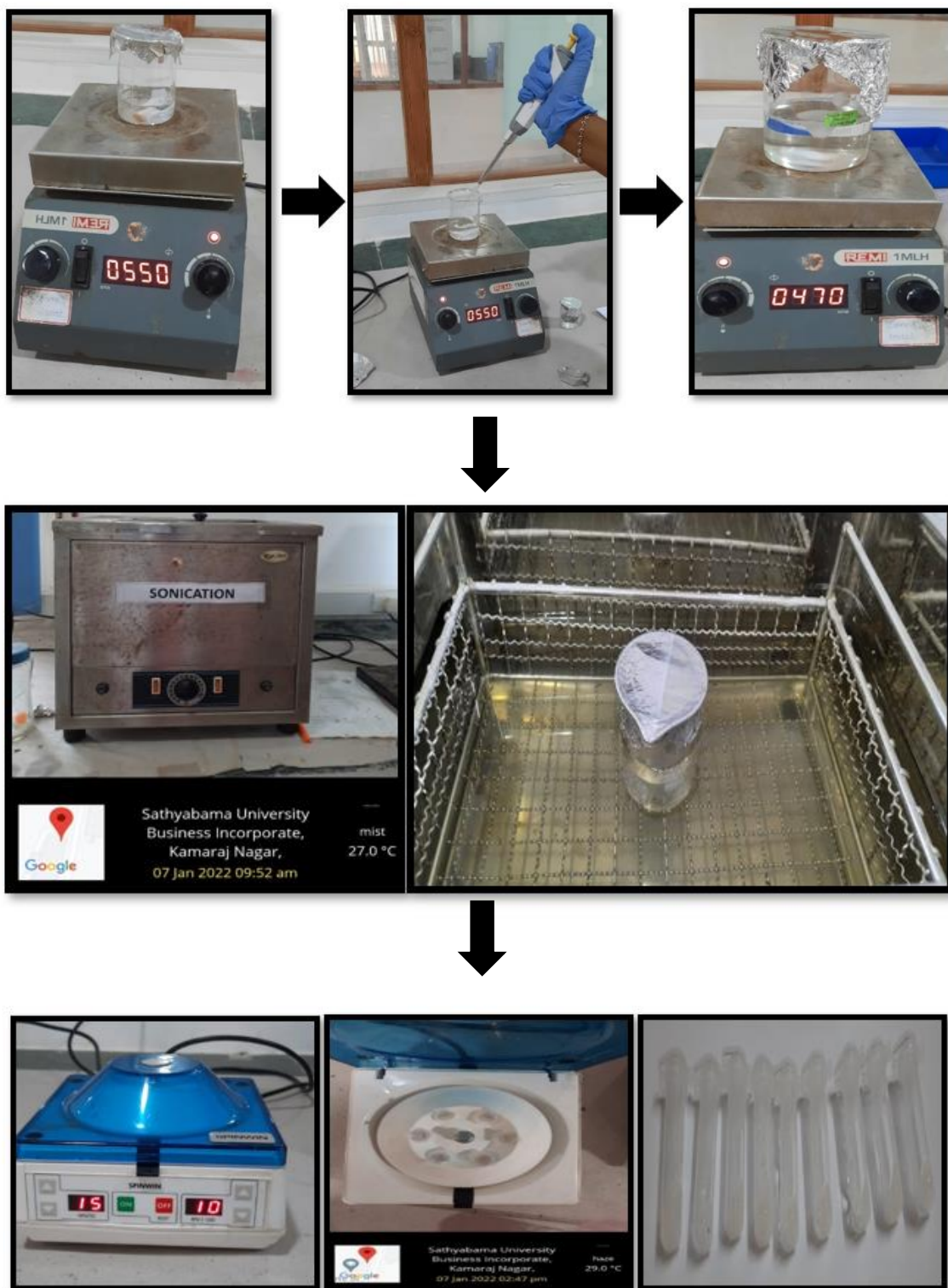


FIG: 5.2 – Synthesis of Cs-Se NPs

5.3. CHARACTERIZATION OF Cs-Se NPs

5.3.1. FOURIER-TRANSFORM INFRARED SPECTROSCOPY (FTIR):

FT-IR spectroscopy was conducted to identify the functional group's present a sample of nanoparticles. By using FT-IR analysis, the infrared emission spectrum, absorption, photoconductivity of metal nanoparticles can be determined. The FT-IR spectrum represents a character of the nanoparticles consisting of absorption peaks that determine the frequencies of vibrations between the bonds of atoms of the sample. The highest peak position is 1064.77 cm^{-1} .

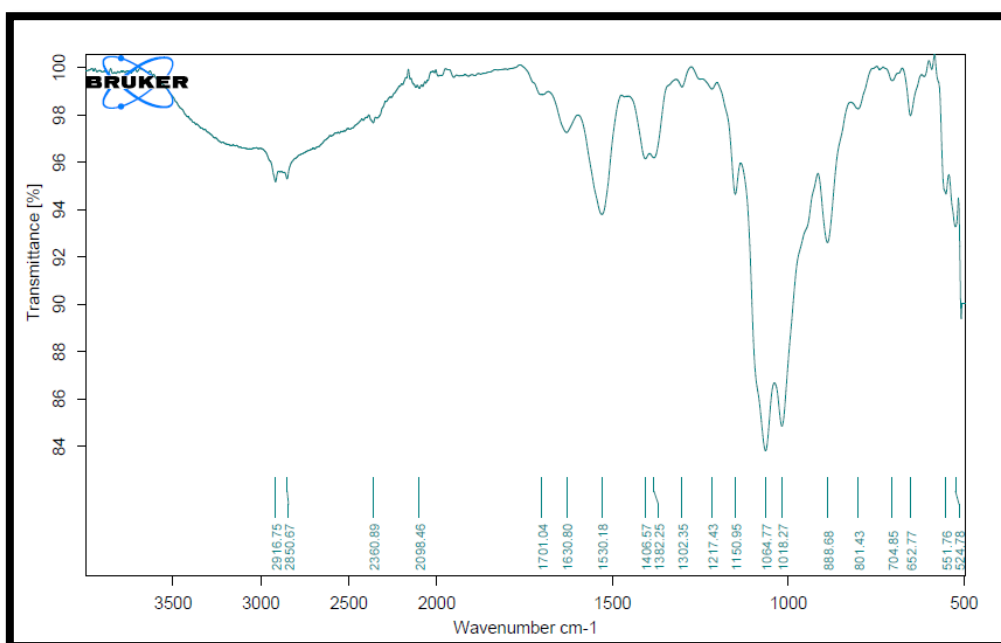


FIG: 5.3 – FTIR Spectroscopy

5.3.2. SCANNING ELECTRON MICROSCOPY (SEM)

SEM analysis was employed to characterize the microstructure of particles, such as the size, shape, and dispersion patterns of synthesized Cs-Se NPs.

The SEM micrographs of Cs-SeNPs are shown (Fig.4). In this study, the Cs-SeNPs demonstrated dense spherical particle bodies, highly dispersed and uniform nanostructure.

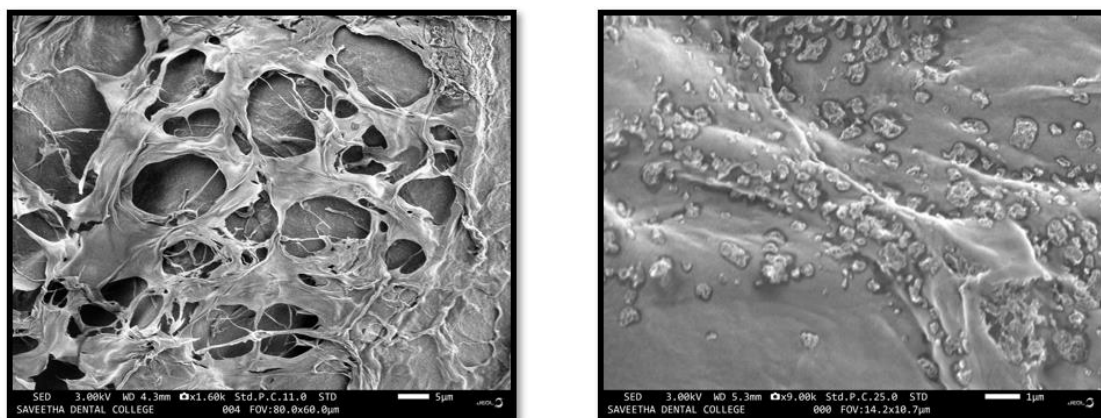


FIG: 5.4 – SEM Micrographs

5.3.3. ENERGY DISPERSIVE X-RAY ANALYSIS (EDX)

In order to confirm the formation of Cs-Se NPs composite EDX analysis was performed. During the EDX measurement area were focused and the corresponding peak is shown in (Fig:5,6). Cs-Se NPs can be seen in the synthesized composite nanostructure in the EDX spectrum. Details of the EDX spectra of the electrospun values measured in weight% and σ are listed in (Table.1)

TABLE: 5.1 – Spectrum values

spectrum 1		
	Wt %	σ
C	47	0.4
O	42.3	0.3
P	5.4	0.1
Se	2.9	0.1
Na	1.3	0
Zr	1	0.4

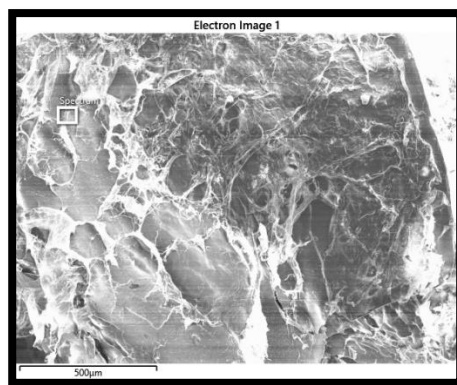


FIG: 5.5 – Electron image

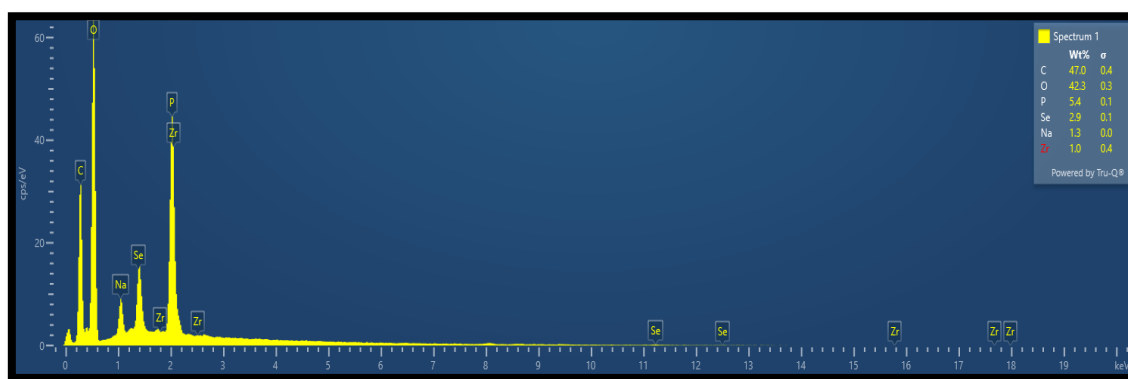


FIG: 5.6 – Spectrum graph

5.3.4. ZETA POTENTIAL ANALYSIS

The surface charges an important criterion to determine the stability and conductivity of particle systems to biological surfaces. Therefore, the investigation of zeta potential a crucial component for the characterization of nanoparticles. The Cs-Se NPs exhibited a positive zeta potential value, depending on its surface charge Fig.7.

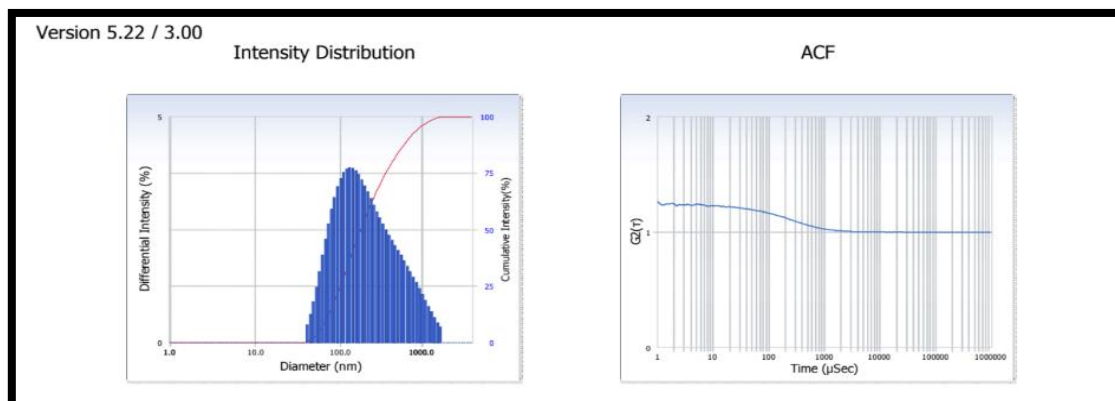


FIG: 5.7 – Zeta potential

5.4. NUTRITIONAL ANALYSIS

TABLE: 5.2 – Nutritional analysis

SL.NO	TEST PARAMETER(S)	RESULTS
1	Protein	45.92
2	Carbohydrate	31.49
3	Fat	5.89
4	Energy	362.65
5	Moisture	11.82
6	Ash	4.88
7	Sodium as Na	139.74
8	Potassium as K	1672.40
9	Calcium as Ca	616.30
10	Magnesium as Mg	289.33
11	Phosphate	2170.10

5.5. GROWTH AND FEED EFFICIENCY

Cs-Se NPs possesses diverse biological effects, very little is known about the effects of various concentrations of Cs-Se NPs on productivity and survival rate of *O. niloticus*. It was suggested that the dietary Cs-Se NPs had a positive impact on growth efficiency and feed conversion ratio when fish supplemented with control basal feed. In this study, the effects of oral Cs-Se NPs administered to *O. niloticus* on the growth efficiency was investigated. Table.3 shows that the optimal Cs-Se NP dose for *O. niloticus* was 1.0 g/ kg of feed compared to control and other treatment conditions.

TABLE: 5.3 - Growth and feed consumption efficiency of *O. niloticus* supplemented with varying quantities of Cs-Se NPs.

Parameters	Cs-Se NPs (g/kg diet)					P-value
	0.0 (control)	0.25	0.5	1	2	
Initial weight (g)	15.30 ± 0.23	15.63 ± 0.14	15.56 ± 0.08	15.83 ± 0.17	15.73 ± 0.08	<0.046
Final weight (g)	24.33 ± 0.43	30.78 ± 0.44	34.80 ± 0.20	37.3 ± 0.56	37.17 ± 0.56	<0.0001
Weight gain (g)	9.033 ± 0.66	15.37 ± 0.37	19.23 ± 0.23	21.47 ± 0.58	21.43 ± 0.24	<0.0001
Weight gain (%)	59.19 ± 5.23	98.35 ± 3.22	123.56 ± 1.91	135.63 ± 4.33	136.24 ± 2.07	<0.0001
Specific growth rate (SGR) (%)	3.17 ± 0.018	3.38 ± 0.01	3.53 ± 0.12	3.57 ± 0.15	3.28 ± 0.097	<0.0001
Total food intake (TFI) (g)	28.03 ± 0.94	32.21 ± 0.98	36.37 ± 0.68	40.61 ± 0.55	40.06 ± 0.43	<0.0001
Feed conversion ratio (FCR) (g/g)	3.14 ± 0.29	2.10 ± 0.11	1.89 ± 0.03	1.89 ± 0.02	1.86 ± 0.03	>0.145
Feed efficiency (g/g)	2.17 ± 0.09	2.32 ± 0.04	2.49 ± 0.23	2.54 ± 0.23	2.49 ± 0.09	<0.029
Survival rate (%)	100 ± 0.00	100 ± 0.00	100 ± 0.00	100 ± 0.00	100 ± 0.00	-

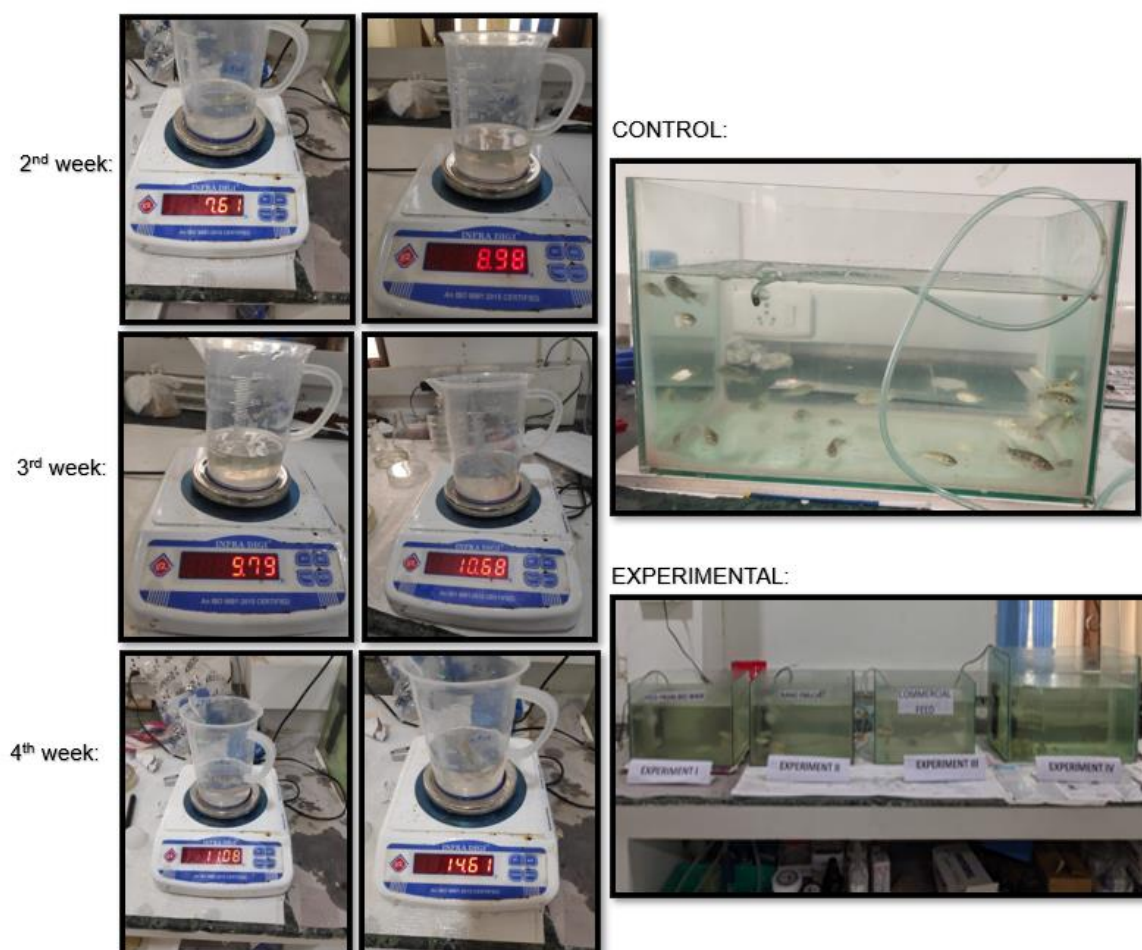


FIG: 5.8 - Feed consumption and growth rate measurements



FIG: 5.9 - Growth Length Measurement

CHAPTER- 6

SUMMARY AND CONCLUSION

The aquatic feed incorporated with chitosan selenium nanoparticles significantly showed better results than commercially available synthetic pellets. The carbohydrate and protein content of the organic feed was 31.49g and 41.52g respectively. Overall, chitosan nanoparticles containing selenite showed to be a great alternative to protect and delivery selenium during fish production as components of fish diet supplements. The dietary supplementations with different Se sources (free and encapsulated selenium) lead to significant improvements in final weight and feed efficiency of Nile tilapia fingerlings. In FTIR, Cs-Se NPs highest peak at 1064.77 cm^{-1} . Cs-Se NPs has good spherical structure and uniform nanostructures. Dietary supplement of Cs-Se NPs for fish it increased the survival rate and growth performance. The developed aquatic feed was cost-effective, toxic-free, and able to use plant and animal waste efficiently and overcome the drawback of existing commercial aquatic feed.

REFERENCES

1. Alishahi, A. Mirvaghefi, M.R. Tehrani, H. Farahmand, S. Koshio, F.A. Dorkoosh, M.Z. Elsabee, Chitosan nanoparticle to carry vitamin C through the gastrointestinal tract and induce the non-specific immunity system of rainbow trout (*Oncorhynchus mykiss*), *Carbohydr. Polym.* 86 (1) (2011) 142–146.
2. A. Anas, S. Paul, N.S. Jayaprakash, R. Philip, I.S. Bright Singh, Antimicrobial activity of chitosan against vibrios from freshwater prawn *Macrobrachium rosenbergii* larval rearing systems, *Dis. Aquat. Org.* 67 (1–2) (2005) 177–179.
3. Abowei, J.F.N., A.T. Ekubo, 2011. A review of conventional and unconventional feeds in fish nutrition, *British J. of pharmacology and toxicology*, 2(4): 179-191.
4. Adeniji, A.A., 2008. Replacement value of soyabean meal with groundnut cake with or without fishmeal supplementation in diets of pullet chicks, *J. Of Appl. Sci. Research*, 4(10): 1249-1252.
5. Agbebi, O. T., Otubusin, S. O., Ogunleye, F. O. (2009): Effect of different levels of substitution of fish meal with blood meal in pelleted feeds on catfish *Clarias gariepinus* (Burchell, 1882) cultured in net cages. *European Journal of Sciences Research*, 31(1): 6 – 10.
6. Agbo NW, Adjei-Boateng D, Jauncey K. The Potential of Groundnut (*Arachis hypogaea* L.) By-Products as Alternative Protein Sources in the Diet of Nile Tilapia (*Oreochromis niloticus*). *Journal of Applied Aquaculture*. 2011; 23:367-78.
7. Ajani EK, Orisasona O, Omitoyin BO, Osho EF. Research Article Total Replacement of Fishmeal by Soybean Meal with or Without Methionine Fortification in the Diets of Nile Tilapia, *Oreochromis niloticus*, 2016.
8. Aladetohun, N. F., Sogbesan, O. A. (2013): Utilization of blood meal as a protein ingredient from animal waste product in the diet of *Oreochromis niloticus*. *International Journal of Fisheries and Aquaculture*, 5(9): 234 – 237.
9. Ansal MD, Dhawan A. Efficacy of Duckweed-Spirodela for low-cost carp feed formulation. *Indian Journal of Animal Nutrition*. 2009; 26(4):378-83.

10. Arner ESJ, Holmgren A. Physiological functions of thioredoxin and thioredoxin reductase. *European Journal of Biochemistry*. 2000; 267(20):6102–9. <https://doi.org/10.1046/j.1432-1327.2000.01701.x> PMID: 11012661
11. Arunlertaree, C., Moolthongnoi, C. (2008): The use of fermented feather meal for replacement fish meal in the diet of *oreochromis niloticus*. *Environment and Natural Resources Journal*, 6: 1-11.
12. Atencio L, Moreno I, JosA', Prieto AI, Moyano R, Blanco A, et al. Effects of dietary selenium on the oxidativestress and pathological changes in tilapia (*Oreochromis niloticus*) exposed to a microcystin-producing cyanobacterial water bloom. *Toxicon*. 2009; 53(2):269–82. <https://doi.org/10.1016/j.toxicon.2008.11.011> PMID: 19073206
13. Bishop CD, Angus RA, Watts SA. The use of feather meal as a replacement for fish meal in the diet of *Oreochromis niloticus* fry. *Bioresource Technology*. 1995; 54(3):291-295.
14. Bureau DP, Harris AM, Bevan DJ, Simmons LA, Azevedo PA, Cho CY. Feather meals and meat and bone meals from different origins as protein sources in rainbow trout (*Oncorhynchus mykiss*) diets. *Aquaculture*. 2000; 181(3-4):281-291.
15. Bureau, D. P., Harris, A. M., Bevan, D. J., Simmons, L. A., Azevedo, P. A., Cho, C. Y. (2000): Feather meals and meat and bone meals from different origins as protein sources in rainbow trout. *Aquaculture*, 181: 281-291.
16. C. Nikapitiya, S.H.S. Dananjaya, B.C.J. De Silva, G.-J. Heo, C. Oh, M. De Zoysa, J. Lee, Chitosan nanoparticles: a positive immune response modulator as display in zebrafish larvae against *Aeromonas hydrophila* infection, *Fish Shellfish Immunol*. 76 (2018) 240–246.
17. Carrillo, Y.S., C. Hernandez, R.W. Hardy, B.G. Rodriguez, S.C. Vargasmachuca, 2012. The effect of substituting fish meal with soybean meal on growth, feed efficiency, body composition and blood chemistry in juvenile spotted rose snapper *Lutjanus guttatus*, *Aquaculture*, 364-366: 180-185.

18. Chris, U. O., Singh, N. B., & Agarwal, A. (2018). Nanoparticles as feed supplement on Growth behaviour of Cultured Catfish (*Clarias gariepinus*) fingerlings. *Materials Today: Proceedings*, 5(3), 9076-9081.
19. Cromwell, G.L., Soybean meal-an exceptional protein source, *Animal and food sciences department university of Kentucky*, pp: 1-15.
20. Dare, C., Eisler, I., Russell, G., Treasure, J., & Dodge, L. I. Z. (2001). Psychological therapies for adults with anorexia nervosa: randomised controlled trial of out-patient treatments. *The British Journal of Psychiatry*, 178(3), 216-221.
21. Davies SJ, McConnel S, Bateson RI. Potential of rape seed meal as an alternative protein source in complete diet for tilapia (*Oreochromis mossambicus*). *Aquaculture*. 1990; 87:145-54.
22. Davies, O.A., N.C. Ezenwa, 2010. Groundnut cake as alternative protein source in the diet of *Clarias gariepinus* fry, *International J. of Sci. and nature*, 1(1): 73-76.
23. Davies, S. J., Williamson, J., Robinson, M., Bateson, R. I. (1989): Practical inclusion levels of common and by products on complete diets for tilapia (*Oreochromis mossambicus*). In *proc. Third Intl. Symp. On feeding and Nutri. In Fish, Tisa Japan*. 325 - 332.
24. Devi C, Vijayaraghavan S. Biochemical composition of carcass, muscle and liver tissue of *Labeo rohita* (Hamilton) after feeding with sunflower (*Helianthus annuus*) oil cake meal. *Indian Journal of fisheries*. 1996; 43:299-302.
25. Dominy, M. G., Ako, H. (1988): The utilization of blood meal as a protein ingredient in the diet of the marine shrimp *P. vannamei*. *Aquaculture*, 70: 289 - 299.
26. Effiong BN, Sanni A, Fakunle JO. Effect of partial replacement of fishmeal with duckweed (*Lemna pauciscostata*) meal on the growth performance of *Heterobranchus longifilis* fingerlings. *Report Opin*. 2009; 1(3):76-81.
27. Elangovan A, Shim KF. The influence of replacing fish meal partially in the diet with soybean meal on growth and body composition of juvenile tin foil barb (*Barbodes Altus*). *Aquaculture*. 2000; 189(1-2):133-144.

28. El-Sayed, A. F. M. (1987): Protein and energy requirements of *Tilapia zillii*. PhD Thesis, Michigan State University, East Lansing, MI, USA. 147 pp.
29. El-Sayed, A. F. M. (1990): Long-term evaluation of cotton seed meal as a protein source for Nile tilapia, *Oreochromis niloticus*. *Aquaculture*, 84: 315 - 320.
30. El-sayed, A. F. M. (1998): Total replacement of fishmeal with animal protein sources in Nile tilapia (*Oreochromis niloticus*, L.) feeds. *Aquaculture Research*, 29: 275 – 280.
31. El-Sayed, A. F. M. (1999): Alternative dietary protein sources for farmed tilapia, *Oreochromis* spp. *Aquaculture*, 179: 149-168.
32. El-Sayed, A. F. M., Tacon, A. G. J. (1997): Fish meal replacers for tilapia: A review. In: Tacon AGJ, Basurco B. (eds). *Feeding tomorrow's fish*. Zaragoza: CIHEAM 205 - 224.
33. Enyidi UD, Pirhonen J, Vielma J. Effects of substituting soybean (*Glycine max*) meal with Bambaranut (*Voandzeia subterranea*) meal on growth performance and survival of African catfish (*Clarias gariepinus*) larvae. *International Journal of Fisheries and Aquatic Studies*. 2014; 1(3):152-157.
34. F. Ahmed, F.M. Soliman, M.A. Adly, H.A.M. Soliman, M. El-Matbouli, M. Saleh, Recent progress in biomedical applications of chitosan and its nanocomposites in aquaculture: a review, *Res. Vet. Sci.* 126 (2019) 68–82.
35. F.S. Abd El-Naby, M.A.E. Naiel, A.A. Al-Sagheer, S.S. Negm, Dietary chitosan nanoparticles enhance the growth, production performance, and immunity in *Oreochromis niloticus*, *Aquaculture* 501 (2019) 82–89.
36. Fagbenro OA. Evaluation of heat processed cocoa pod husk meal as an energy feed stuff in production diets for the clarid catfish, *Clarias Isharensis* (Sydenham). *Aquaculture Nutrition*. 1995; 1(4):221-25.
37. Fagbenro, O., 1998. Short communication apparent digestibility of various oil seed cakes/meals in African catfish diets, *Aquaculture Int.*, 6: 317-322.
38. Falaye AE. The use of hydrolysed feather meal alone or in combination with supplemental amino acids as a dietary source for tilapia (*Oreochromis niloticus*). University of Stirling, UK, 1982.
39. Fao, Aquaculture Department, *The State of World Fisheries and Aquaculture*, FAO, Rome, 2010, p. 2018.

40. Fasakin, E. A., Serwata, R. D., Davies, S. J. (2005): Comparative utilization of rendered animal derived products with or without composite mixture of soybean meal in hybrid tilapia (*Oreochromis niloticus* X *Oreochromis mossambicus*) diets. *Aquaculture* 249: 329 - 338.
41. Ferguson, L. R., Philpott, M., & Karunasinghe, N. (2006). Oxidative DNA damage and repair: Significance and biomarkers. *Journal of Nutrition*, 136, 2687S–2689S.
42. Ferozekhan S, Gupta S, Singh A, Rather M, Kumari R, Kothari D, et al. RNA-Loaded Chitosan Nanoparticles for Enhanced Growth, Immunostimulation and Disease Resistance in fish. *Current Nanoscience*.2014;10:453.
43. Fowler LG. Feather meal as a dietary protein source during Parr-Smolt transformation in fall Chinook salmon. *Aquaculture*. 1990; 89(3-4):301-314.
44. Fowler LG. Poultry by-product meal as a dietary protein source in fall Chinook salmon diets. *Aquaculture*. 1991; 99(3-4):309-321.
45. Galkanda-Arachchige HSC, Wilson AE, Davis DA.
46. GatlinIII DM, Barrows FT, Brown P, Dabrowski K, Gaylord TG, Hardy RW et al. Expanding the utilization of sustainable plant products in aquafeeds: a review. *Aquaculture research*. 2007; 38(6):551-579.
47. Grenha, A., Seijo, B., & Remuñán-López, C. (2005). Microencapsulated chitosan nanoparticles for lung protein delivery. *European Journal of Pharmaceutical Science*, 25, 427–437.
48. H.M. Abdel-Ghany, M.E.-S. Salem, Effects of dietary chitosan supplementation on farmed fish; a review, *Rev. Aquacult.* 12 (1) (2020) 438–452.
49. H.M. Abdel-Ghany, M.E.S. Salem, Effects of dietary chitosan supplementation on farmed fish; a review, *Rev. Aquacult.* 12 (1) (2020) 438–452.
50. H.M.R. Abdel-Latif, M.A.O. Dawood, S. Menanteau-Ledouble, M. El-Matbouli, The nature and consequences of co-infections in tilapia: a review, *J. Fish. Dis.* 43 (6) (2020) 651–664.
51. Hamilton, S. J. (2004). Review of selenium toxicity in the aquatic food chain. *Science of the total environment*, 326(1-3), 1-31.

52. Hasan, M. R., Akand, A. M., Siddiqua, A. (1993): Studies on poultry offal meal and silk worm pupae meal as dietary protein sources for Indian major carp, *Catla catla* (Hamilton). *Bangladesh Journal of Training and Development*, 6: 55 - 66.
53. Hill LE, Taylor TM, Gomes C. Antimicrobial Efficacy of Poly (DL-lactide-co-glycolide) (PLGA) Nanoparticles with Entrapped Cinnamon Bark Extract against *Listeria monocytogenes* and *Salmonella typhimurium*. *Journal of Food Science*. 2013; 78(4):N626–N32. <https://doi.org/10.1111/1750-3841.12069> PMID:23464835.
54. Hosnedlova, B., Kepinska, M., Skalickova, S., Fernandez, C., Ruttkay-Nedecky, B., Peng, Q., & Kizek, R. (2018). Nanoselenium and its nanomedicine applications: a critical review. *International journal of nanomedicine*, 13, 2107.
55. Hussain SM, Afzal M, Rana SA, Javid A, Iqbal M. Effect of phytase supplementation on growth performance and nutrient digestibility of *Labeo rohita* fingerlings fed on corn gluten meal-based diets. *International Journal of Agriculture and Biology*. 2011; 13(6):916-22.
56. Ibrahim, M. S., El-gendy, G. M., Ahmed, A. I., Elharoun, E. R., & Hassaan, M. S. (2021). Nanoselenium versus bulk selenium as a dietary supplement: Effects on growth, feed efficiency, intestinal histology, haemato-biochemical and oxidative stress biomarkers in Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) fingerlings. *Aquaculture Research*.
57. Izquierdo MS, Ghrab W, Roo J, Hamre K, Hernández-Cruz CM, Bernardini G, et al. Organic, inorganic and nanoparticles of Se, Zn and Mn in early weaning diets for gilthead seabream (*Sparus aurata*; Linnaeus,1758). *Aquaculture Research*. 2017; 48(6):2852–67. <https://doi.org/10.1111/are.13119>.
58. J.J. Wang, Z.W. Zeng, R.Z. Xiao, T. Xie, G.L. Zhou, X.R. Zhan, S.L. Wang, Recent advances of chitosan nanoparticles as drug carriers, *Int. J. Nanomed*. 6 (2011) 765–774.

59. Jaramillo JR F, Peng L, Gatlin DM III. Selenium nutrition of hybrid striped bass (*Morone chrysops* × *M. saxatilis*) bioavailability, toxicity and interaction with vitamin E. *Aquaculture Nutrition*. 2009; 15(2):160–5. <https://doi.org/10.1111/j.1365-2095.2008.00579.x>. *Journal of Nutrition*, 136, 172–176.
60. K. Nagpal, S.K. Singh, D.N. Mishra, Chitosan nanoparticles: a promising system in novel drug delivery, *Chem. Pharm. Bull.* 58 (11) (2010) 1423–1430.
61. Kasper CS, Watkins BA, Brown PB. Evaluation of two soybean meals fed to yellow perch (*Perca flavescens*). *Aquaculture Nutrition*. 2007; 13:431-38.
62. Kellems, R. O., Church, D. C. (1998): *Livestock Feeds and Feeding*. 4th edition, Prentice Hall, Upper Saddle River, New Jersey, USA 146 pp
63. Keramat Amirkolaie A, Shamsavari M, Hedayatyfard M. Full replacement of fishmeal by poultry by-product meal in rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1972) diet. *Iranian Journal of Fisheries Sciences*. 2014; 13(4):1069-1081.
64. Khelifi, S., El Hachimi, Y., Khalil, A., Es-Safi, N., & El Abbouyi, A. (2005). In vitro antioxidant effect of *Globularia alypum* L. hydromethanolic extract. *Indian Journal of Pharmacology*, 37(4), 227–237.
65. Kockisch, S., Ress, G. D., Young, S. A., Tsibouklis, J., & Smart, J. D. (2003). Polymeric microspheres for drug delivery to the oral cavity: An in vitro evaluation of mucoadhesive potential. *Journal of Pharmaceutical Science*, 92(8), 1614–1623.
66. Kou X, Gao J, Xue Z, Zhang Z, Wang H, Wang X. Purification and identification of antioxidant peptides from chickpea (*Cicer arietinum* L.) albumin hydrolysates. *LWT-Food Science and Technology*. 2013; 50(2):591-598.
67. Kumar, N., Gupta, S.K., Chandan, N.K., Bhushan, S., Singh, D.K., Kumar, P., Kumar, P., Wakchaure, G.C., Singh, N.P., 2020. Mitigation potential of selenium nanoparticles and riboflavin against arsenic and elevated temperature stress in *Pangasianodon hypophthalmus*. *Sci. Rep.* 10, 17883.

68. Kureshy N, Davis DA, Arnold CR. Partial replacement of fish meal with meat-and-bone meal, flash-dried poultry by-product meal, and enzyme-digested poultry by-product meal in practical diets for juvenile red drum. *North American Journal of Aquaculture*. 2000; 62(4):266-272.
69. Kureshy, N., Davis, D. A., Arnold, C. D. (2000): Partial replacement of fish meal with meat-and-bone meal, flash-dried poultry by product meal and enzyme digested poultry by-product meal in practical diets for juvenile red drum. *North American Journal of Aquaculture*, 62: 266 - 272.
70. Leo'n-Rodríguez L, Luzardo-A´lvarez A, Blanco-Me´ndez J, Lamas J, Leiro J. Biodegradable microparticles covalently linked to surface antigens of the scuticociliate parasite *P. dicentrarchi* promote innate immune responses in vitro. *Fish & Shellfish Immunology*. 2013; 34(1):236–43. <https://doi.org/10.1016/j.fsi.2012.10.029> PMID: 23142727
71. Li B, Liu B, Shan C, Ibrahim M, Lou Y, Wang Y, et al. Antibacterial activity of two chitosan solutions and their effect on rice bacterial leaf blight and leaf streak. *Pest Management Science*. 2013; 69(2):312–20. <https://doi.org/10.1002/ps.3399> PMID: 23129534
72. Lim C, Klesius H, Higgs DA. Substitution of canola meal for soybean meal in diets for channel catfish *Ictalurus punctatus*. *Journal of the World Aquaculture Society*. 1998; 29:161-68.
73. Lin Y, Miao L-H, Pan W-J, Huang X, Dengu JM, Zhang W-X, et al. Effect of nitrite exposure on the antioxidant enzymes and glutathione system in the liver of bighead carp, *Aristichthys nobilis*. *Fish & Shellfish Immunology*. 2018; 76:126–32. <https://doi.org/10.1016/j.fsi.2018.02.015> PMID: 29438848
74. Lovell T. Nutrition and feeding of fish. An AVI book. Published by Van Nostrand Reinhold, New York, USA, 1989.
75. M. Abdel-Tawwab, N.A. Razek, A.M. Abdel-Rahman, Immunostimulatory effect of dietary chitosan nanoparticles on the performance of Nile tilapia, *Oreochromis niloticus* (L.), *Fish Shellfish Immunol*. 88 (2019) 254–258.
76. Makinde OA, Sonaiya EB. The potential of two vegetable-carried blood meals as protein sources in African Catfish (*Clarias gariepinus*, Burchell) juvenile diets *Open Journal of Animal Science* 2012;2(1):15-18.

77. Millamena OM. Replacement of fish meal by animal by-product meals in a practical diet for grow-out culture of grouper *Epinephelus coioides*. *Aquaculture*. 2002; 204(1-2):75-84.
78. Mondal K, Kaviraj A, Mukhopadhyay PK. Effects of partial replacement of fishmeal in the diet by mulberry leaf meal on growth performance and digestive enzyme activities of Indian minor carp *Labeo bata*. *International Journal of Aquaculture Science*. 2012; 3(1):71-83.
79. Moutinho S, Martínez-Llorens S, Tomás-Vidal A, Jover-Cerdá M, Oliva-Teles A, Peres H. Meat and bone meal as partial replacement for fish meal in diets for gilthead seabream (*Sparus aurata*) juveniles: Growth, feed efficiency, amino acid utilization, and economic efficiency. *Aquaculture*. 2017; 468:271-277.
80. Muzinic LA, Thompson KR, Metts LS, Dasgupta S, Webster CD. Use of turkey meal as partial and total replacement of fish meal in practical diets for sunshine bass (*Morone chrysops* × *Morone saxatilis*) grown in tanks. *Aquaculture Nutrition*. 2006; 12(1):71-81.
81. N. Younus, A. Zuberi, T. Mahmood, W. Akram, M. Ahmad, Comparative effects of dietary micro- and nano-scale chitosan on the growth performance, non-specific immunity, and resistance of silver carp *Hypophthalmichthys molitrix* against *Staphylococcus aureus* infection, *Aquacult. Int.* 28 (6) (2020) 2363–2378.
82. N.M. Abu-Elala, S.H. Mohamed, M.M. Zaki, A.E. Eissa, Assessment of the immune-modulatory and antimicrobial effects of dietary chitosan on Nile tilapia (*Oreochromis niloticus*) with special emphasis to its bio-remediating impacts, *Fish Shellfish Immunol.* 46 (2) (2015) 678–685.
83. Navas-Acien, A., Bleys, J., & Guallar, E. (2008). Selenium intake and cardiovascular risk: What is new? *Current Opinion Lipidology*, 19, 43–49.
84. Nengas, I., Alexis, M. N., Davies, S. J. (1999): High inclusion levels of poultry meals and related by products in diets for gilthead sea bream, *Sparus aurata* L. *Aquaculture*, 179: 13 - 23.
85. Niamat R. Studies on the nutrition and growth of teleostean fishes. PhD thesis. Aligarh Muslim University, Aligarh, 1985.

86. Ogunji JO, Wirth M. Alternative protein sources as substitutes for fishmeal in the diet of young tilapia *Oreochromis niloticus* (Linn.), 2001.
87. Opiyo MA, Marijani E, Muendo P, Odede R, Leschen W, Charo-Karisa H, et al. A review of aquaculture production and health management practices of farmed fish in Kenya, International Journal of Veterinary Science and Medicine 2019;6(2):141-148.
88. Ovie S, Ovie S. The effect of replacing fish meal with 10% of groundnut cake in the diets of *H. longifilis* on its growth, food conversion and survival. Journal of Applied Science and Environment Sciences. 2007; 11:87-90.
89. Penglase S, Hamre K, Sweetman JW, Nordgreen A. A new method to increase and maintain the concentration of selenium in rotifers (*Brachionus* spp.). Aquaculture. 2011; 315(1):144–53. <https://doi.org/10.1016/j.aquaculture.2010.09.007>.
90. Quartararo, N., Allan, G. L., Bell, J. D. (1998): Replacement of fish meal in diets for Australian snapper, *Pagrus auratus*. Aquaculture, 166: 279 - 295.
91. R. Harikrishnan, J.-S. Kim, C. Balasundaram, M.-S. Heo, Immunomodulatory effects of chitin and chitosan enriched diets in *Epinephelus bruneus* against *Vibrio alginolyticus* infection, Aquaculture 326–329 (2012) 46–52.
92. Rajesh Kumar S, Ishaq Ahmed VP, Parameswaran V, Sudhakaran R, Sarath Babu V, Sahul Hameed AS. Potential use of chitosan nanoparticles for oral delivery of DNA vaccine in Asian sea bass (*Lateolabrax niloticus*) to protect from *Vibrio* (*Listonella*) *anguillarum*. Fish & Shellfish Immunology. 2008; 25(1):47–56. <https://doi.org/10.1016/j.fsi.2007.12.004> PMID: 18479939
93. Ramachandran S, Singh SK, Larroche C, Soccol CR, Pandey A. Oil cakes and their biotechnological applications-A review. Bioresource technology. 2007; 98(10):2000-2009.
94. Rathore, S. S., Murthy, H. S., Abdullah-Al Mamun, M., Nasren, S., Rakesh, K., Kumar, B. T. N., ... & Khandagale, A. S. (2020). Nano-selenium Supplementation to Ameliorate Nutrition Physiology, Immune Response, Antioxidant System and Disease Resistance Against *Aeromonas hydrophila* in Monosex Nile Tilapia (*Oreochromis niloticus*). Biological Trace Element Research, 1-16.

95. Rawles, S.D., M. Riche, T.G. Gaylord, J. Webb, D.W. Freeman, M. Davis, 2006. Evaluation of poultry by-product meal in commercial diets for hybrid striped bass (*Morone chrysops* x *M. saxatilis*) in recirculated tank production, *Aquaculture*, 259: 377-389.
96. Ray, A. L., Semba, R. D., Walston, J., Ferrucci, L., Cappola, A. R., Ricks, M. O., et al. (2006). Low serum selenium and total carotenoids predict mortality among older women living in the community: The women's health and aging studies.
97. Robinson, E.H., M.H. Li, 2007. Catfish protein nutrition: revised. *Bulletin*, 1159: 1-22.
98. S. Saffari, S. Keyvanshokoo, M. Zakeri, S. Johari, H. Pasha-Zanoosi, Effects of different dietary selenium sources (sodium selenite, selenomethionine and nanoselenium) on growth performance, muscle composition, blood enzymes and antioxidant status of common carp (*Cyprinus carpio*), *Aquacult. Nutr.* 23 (3) (2017) 611–617.
99. S.E. Fadl, G.A. El-Gammal, W.S. Abdo, M. Barakat, O.A. Sakr, E. Nassef, D.M. Gad, H.S. El-Sheshtawy, Evaluation of dietary chitosan effects on growth performance, immunity, body composition and histopathology of Nile tilapia (*Oreochromis niloticus*) as well as the resistance to *Streptococcus agalactiae* infection, *Aquaculture. Res.* 51 (3) (2020) 1120–1132.
100. H. Wang, J.-C. Chen, The protective effect of chitin and chitosan against *Vibrio alginolyticus* in white shrimp *Litopenaeus vannamei*, *Fish Shellfish Immunol.* 19 (3) (2005) 191–204.
101. Sadiku, S. O. E., Jauncey, K. (1995a): Soybean flour–poultry meat meal blends as dietary protein source in practical diets of *Oreochromis niloticus* and *Clarias gariepinus*. *Asian Fisheries Science*, 8 (2): 159 –168.
102. Sarkar, B., Bhattacharjee, S., Daware, A., Tribedi, P., Krishnani, K. K., & Minhas, P. S. (2015). Selenium nanoparticles for stress-resilient fish and livestock. *Nanoscale research letters*, 10(1), 1-14.
103. Sarmwatanakul A, Bamrongsut B. Aquarium Fish Nutrition. Extension paper, 2000, 1.1. Sato T, Kikuchi K. Meat Meal as a Protein Source in the Diet of Juvenile Japanese Flounder. *Fisheries science*. 1997; 63(6):877-880.

104. Shah BR, Mraz J. Advances in nanotechnology for sustainable aquaculture and fisheries. *Reviews in Aquaculture*. 2020; 12(2):925–42. <https://doi.org/10.1111/raq.12356>.
105. Shah, S., Pal, A., Kaushik, V. K., & Devi, S. (2009). Preparation and characterization of venlaxine hydrochloride-loaded chitosan nanoparticles and in vitro release of drug. *Journal of Applied Polymer Science*, 112, 2876–2887.
106. Siddiqui, M.I., M.A. Khan, M.I. Siddiqui, 2013. Effect of soybean diet: growth and conversion efficiencies of fingerling of stinging catfish, *Heteropneustes fossilis* (bloch), *J. Of King Saud university-science*, pp: 1-5.
107. So, O., O. Si, 2007. The effect of replacing fish meal with 10% of groundnut cake in the diets of *H. Longifilis* on its growth, food conversion and survival, *J. Appl. Sci. Environ. Manage.*, 11(3): 87-90.
108. Sogbesan AO, Ugwumba AAA. Nutritional values of some non-conventional animal protein feedstuffs used as fish meal supplement in Aquaculture practices in Nigeria, *Turkish Journal of Fisheries and Aquatic Sciences* 2008;8(1):159-164.
109. Srivastava B, Reddy PB. Evaluation of groundnut oil cake as a substitute of fishmeal for tilapia, 2018.
110. Steffens, W. (1994): Replacing fish meal with poultry by product meal in diet for rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, 124: 27- 34.
111. Success of fishmeal replacement through poultry by-product meal in aquaculture feed formulations- A meta-analysis, *Reviews in Aquaculture* 2020;12(3):1624-1636.
112. T. Kean, M. Thanou, Biodegradation, biodistribution and toxicity of chitosan, *Adv. Drug Deliv. Rev.* 62 (1) (2010) 3–11.
113. Tacon, A. G. J. (1993): Feed ingredients for warm water fish. Fish meal and other processed feedstuffs, *FAO Fisheries Circular* 856: 64.
114. Tacon, A. G. J., Jackson, A. J. (1985): Protein sources in fish feeds. In: Cowey CB, Nackie AM, Bell JG. (eds). *Nutrition and Feeding in Fish*. Academic Press, London, U.K 120 – 145.

115. Tacon, A. G. J., Jackson, A. J. (1985): Utilization of conventional and unconventional protein sources in practical fish feeds. In Nutrition and Feeding in Fish, Cowey CB, Mackie AM, Bell JG. (eds). Academic Press, London, 119 - 145.
116. Tacon, A. G. J., Jauncey, K., Falaye, A. E., Pantha, M., MacGowon, F., Stafford, A. E. (1983): The use of meat and bone meal, hydrolysed feather meal and soybean in practical fry and fingerling diet for *Oreochromis niloticus*. In Fishelson L.(ed) proceedings of International Symposium on tilapia in Aquaculture, Nazareth, Israel, 8-13 May, 356 - 365.
117. Thiessem DL, Maenz DD, Newkirk RW, Classen HL, Drew MD. Replacement of fish meal by canola protein concentrate in diets fed to rainbow trout (*Oncorhynchus mykiss*). Aquaculture Nutrition. 2004; 10:379-88.
118. Thomson, C. D. (2004). Assessment of requirements for selenium and adequacy of selenium status: A review. European Journal of Clinical Nutrition, 58, 391–402.
119. Tian J, Yu J, Sun X. Chitosan microspheres as candidate plasmid vaccine carrier for oral immunisation of Japanese flounder (*Paralichthys olivaceus*). Veterinary Immunology and Immunopathology.2008;126(3):220–9. <https://doi.org/10.1016/j.vetimm.2008.07.002> PMID: 18722672.
120. Viola, S., Arieli, Y., Zohar, G. (1988): Animal-protein-free feeds for hybrid tilapia (*Oreochromis niloticus* X *O. aureus*) in intensive culture. Aquaculture, 75: 115 – 125.
121. Viola, S., Zohar, G. (1984): Nutrition studies with market size hybrids of tilapia (*Oreochromis niloticus*) in intensive culture. Israel Journal of Aquaculture, 36: 3 –15.
122. Wang C, Lovell RT. Organic selenium sources, selenomethionine and selenoyeast, have higher bioavailability than an inorganic selenium source, sodium selenite, in diets for channel catfish (*Ictalurus punctatus*). Aquaculture. 1997; 152(1):223–34. [https://doi.org/10.1016/S0044-8486\(96\)01523-2](https://doi.org/10.1016/S0044-8486(96)01523-2).
123. Wang, L., Wang, L., Zhang, D., Li, S., Yin, J., Xu, Z., Zhang, X., 2021. Effect of dietary selenium on postprandial protein deposition in the muscle of juvenile rainbow trout (*Oncorhynchus mykiss*). Br. J. Nutr. 125, 721–731.

124. Watanabe, T. (2002): Strategies for further development of aquatic feeds. *Fisheries Science* 68: 242 – 252.
125. Yang Y, Xie S, Cui Y, Lei W, Zhu X, Yang Y, et al. Effect of replacement of dietary fish meal by meat and bone meal and poultry by-product meal on growth and feed utilization of gibel carp, *Carassius auratus gibelio*. *Aquaculture Nutrition*. 2004; 10(5):289-294.
126. Yang, Y., Xie, S., Cui, Y., Lei, W., Zhu, X., Yu, Y. (2004): Effect of replacement of dietary fish meal by meat and bone meal and poultry by-product meal on growth and feed utilization of gibel carp, *Carassius auratus gibelio*. *Aquaculture Nutrition*, 10: 289 – 294.
127. Yigit NO, Olmez M. Canola Meal as an Alternative Protein Source in Diets for Fry of Tilapia (*Oreochromis niloticus*). *Bamidgeh*. 2009; 61(1):35-41.
128. Yuan, Y., S. Gong, H. Yang, Y. Lin, D. Yu, Z. Luo, 2011. Effects of supplementation of crystalline or coated lysine and/or methionine on growth performance and feed utilization of the Chinese sucker, *Myxocyprinus asiaticus*, *Aquaculture*, 316: 31-36.
129. Zhang J, Wang H, Yan X, Zhang L. Comparison of short-term toxicity between Nano-Se and selenite in mice. *Life Sciences*. 2005; 76(10):1099–1109. <https://doi.org/10.1016/j.lfs.2004.08.015> PMID:15620574
130. Zheng Qingmei, Wen Xiaobo, Han Chunyan, Li Haobo, Xie Xiaohui. Effect of replacing soybean meal with cottonseed meal on growth, hematology, antioxidant enzymes activity and expression for juvenile grass carp, *Ctenopharyngodon idellus*. *Fish Physiology and Biochemistry*. 2012; 38(4):1059-69.
131. Zhou, Q.C., J. Zhao, P. Li, H.L. Wang, L.G. Wang, 2011. Evaluation of poultry-by-product meal in commercial diets for juvenile cobia (*Rachycentron canadum*), *Aquaculture*, 322-323: 122-127.

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