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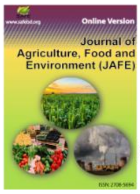

Research Article

Impact of silica nanoparticles on the digestibility and growth efficiency of rohu (*Labeo rohita*)

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ABSTRACT

The research was conducted to evaluate the effect of silica nanoparticle (NP) on the growth and digestibility of rohu (*Labeo rohita*) in the Wet Laboratory, Department of Aquaculture, Bangladesh Agricultural University. Highly pure, activated silica NP at different levels 0, 1, 2, 3 mg/kg were incorporated into different treatments T_0, T_1, T_2, T_3 possessing three copies. Thirty fish with a mean weight (± SD) of around 2.62 ± 0.02 g were assigned in a recirculatory aquaculture system, maintained in each treatment and fed with their respective diets in 12 tanks. Feeds were supplied at the rate of 10% for 4 weeks and 5% of the body weight for the rest of the experimental period. Water quality parameters were within the acceptable range during the study period. Results showed that growth parameters and feed efficiency dramatically increased as silica NP levels rose at 2 mg/Kg and then decreased. The highest final weight (9.25 ± 0.07) g, percent weight gain (252.99 ± 2.6) %, final length (8.6 ± 0.14) cm, length gain (3.2 ± 0.13) cm, SGR (2.1 ± 0.01) %/day, FCE (71.67 ± 0.21), apparent protein digestibility (87.17 ± 2.6) %, dry matter digestibility (78.17 ± 1.18) % and survival rate (97.5 ± 0.71) % were found in T_2 and the highest FCR (1.56 ± 0.02) was found in T_0. The current investigation found that the growth performance was optimal of *L. rohita* found at the level of silica up to 2 mg/kg and then decreased. The findings could be incorporated in fish feed producing practices for increased fish production.

Introduction

The fish species *Labeo rohita*, also referred to as rohu, is extensively farmed and eaten throughout the world. It contributes significantly to aquaculture and is essential to the economies of Bangladesh, India, Pakistan, and Nepal. With a yield of almost 3.4 million tonnes in 2018, *L. rohita* is the most widely grown freshwater fish species worldwide (FAO, 2020). Because of its flavor, nutritional content and comparatively quick development rate, this species is widely prized. The versatile vegetable rohu can be eaten grilled, fried, or curried. Additionally, for many individuals, especially in poor nations, the production of *L. rohita* is a vital source of income and employment. *L. rohita* plays a major role in Bangladesh's aquaculture sector, which is a vital aspect of the nation's economy. In the nation, rohu farming is commonplace in ponds and rice fields, giving many small-scale farmers a source of income and employment. *L. rohita* is responsible for about half of Bangladesh's entire fish production, according to the Department of Fisheries (DoF, 2022). The aquaculture business worldwide depends heavily on the production of *L. rohita*, which offers several advantages like as better nutrition, reduced poverty, enhanced food security, and environmental sustainability. Bangladesh's rohu aquaculture is expensive due to the usage of commercial food. Consequently, scientists have been trying to find sustainably produced and locally sourced feed ingredients. To cut down on feed waste and encourage sustainability, it is essential to make sure that the diet's protein and fat levels don't surpass the fish's needs. Working with molecules or ions, which are often between 0.1 and 100 nanometers in size, is the focus of nanotechnology. The ratio of surface area to volume is large in nanoparticles and unusual physiochemical properties, especially catalytic activities, because to their tiny size, purity, and atypical aggregation behavior. They therefore frequently offer more benefits than bulk materials in a variety of applications (Parveen *et al*., 2010 and Agarwal *et al*., 2017). According to Arora *et al.* (2011), there are currently over a thousand nanoproducts available on the market, making nanotechnology one of the world's most thriving and rapidly expanding technologies. Particles that range in size from one to one hundred nanometers are known as nanoparticles. In recent years, there has been a significant level of enthusiasm for the application of nanoparticles in a variety of industries, including fish farming. It has been demonstrated that applying nanoparticles, such as zinc (Zn), selenium (Se), silver (Ag), and silica (SiO_2), to fish production improves the fish's growth, immunity, and general health. These nanoparticles are also used in aquaculture waste water treatment to lessen the negative environmental effects of aquaculture (Jarvie *et al*., 2009). The food production business acknowledges nanoparticles (NP) for their distinct physicochemical characteristics that stem from their nano size. Both medicinal and nutritional uses are made of them (Vidya *et al*., 2016; Khosravi-Katuli *et al*., 2017; Rodrigues *et al*., 2018). Because of their high specific surface area functionalization property, nanoparticles can be used as catalysts to help both terrestrial and aquatic animals absorb micronutrients from the intestine into the bloodstream. This results in an ideal feed conversion ratio, improved growth, and nutrient digestibility at the lowest possible cost of production (Huang *et al*., 2015; Khosravi-Katuli *et al*., 2017; Pieszka *et al*., 2019). Since they have special qualities like biodegradability and reduced toxicity, silica nanoparticles are one of the most commonly employed types of nanoparticles in biological systems and have been approved by the FDA for use in the manufacture of food and pharmaceuticals. Although silica nanoparticles are most frequently linked to medical applications, aquaculture is one application for which they may be useful. El-Gazzar *et al*.'s recent study from 2021 has shown that feeding fish silica nanoparticles may have favorable impacts on their immune-related gene expression, hematological parameters, growth, and antioxidant capacity. Still unknown, nevertheless, are the effects of food addition of silica nanoparticles on fish growth outcomes as well as nutritional digestibility. Because of its exceptional adsorption and optical qualities, silica nanoparticles can also be employed. Digestive enzymes break down proteins, carbs, and fats into smaller components that can be absorbed by the microvilli of the fish gut (García- Meilán *et al*., 2016). The greater infrared emissivity of water molecules in the intestines may become triggered by silica NP when it is present (Faisal *et al*., 2021). Through improved nutrient absorption and utilization, improved digestion, and increased feed conversion efficiency, silica nanoparticles can improve the growth performance and survival rate of a number of fish species. The results of this study could be used to improve fish production methods for fish feed.

Materials and Methods

Experimental site

A 60-day experiment was performed using a two-tier recirculating aquaculture setup consisting of twelve fiberglass rectangular tanks (0.8 m x 0.5 m x 0.5 m) at the Wet Laboratory which is next to Bangladesh Agricultural University, Fisheries Faculty in Mymensingh. The tanks were continuously aerated by a 0.5 HP electric blower (one for every 3 tanks) with a 0.4 m of water depth was maintained during the experiment.

Experimental design

Solid trash was removed from the tanks using cheesecloth with a mesh size of 100 µm and fine screens. Pebbles, gravel, and mollusk shells weighing 25 kg were placed in six 50 L drums to create a biofilter (Plate 1). After passing through a mechanical filter and a biofilter, the effluent water was filtered into a 300 L settling tank. Water was moved from the settle tank to an overhead tank by means of two 1 HP pumps and it was then supplied to each tank by means of a half-inch diameter intake pipe, each with a controlled flow rate of 1.5 L per minute. Every two to three days, depending on the water quality, 15% fresh water was added. There was an automatic water level controller installed, which would trigger the water pump upon reaching a predetermined level of water in the settle tank. Two control tanks (T_0) and two duplicates for each of the three treatment groups (T_1, T_2, and T_3) were used in the investigation. The experimental tanks were kept at a consistent 28.42 to 30.12 °C temperature range.

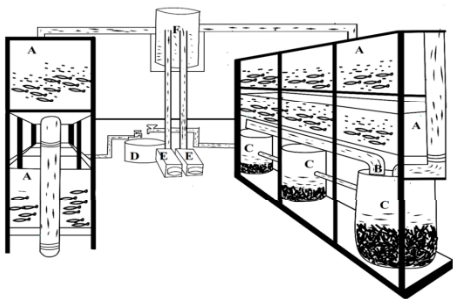

Plate 1. Layout of recirculatory aquaculture system outline show in fish tanks (A) to hold fish, mechanical filters (B) to screen out particulate wastes, drum biofilter (C) for facilitating the bacterial actions, settle tank (D) to hold effluent water, water pumps (E) to lift water from settle tank and overhead tank (F) from where water was fed to fish tanks (Bashar *et al*., 2021).

Collection of ingredients and diet formulations

The experiment used highly pure, ionized, soluble, and 100% natural silica nanoparticles (Silica+ by Ceresco Nutrition Ltd.), composed of over 98% silicon dioxide (SiO_2), 0.08% Al_2O_3, 0.5% K_2O, 0.05% Fe_2O_3 and 0.10% TiO_3.

Using common elements found in fish feed, Pearson's Square technique was used to produce four isonitrogenous diets with 30% crude protein to simulate varying quantities of silica NP. Four trial diets comprising 35 percent protein and varying quantities of silica NP were developed. Fishmeal was substituted with silica NP at concentrations of 0 mg/kg (T_0), 1 mg/kg (T_1), 2 mg/kg (T_2), and 3 mg/kg (T_3). To soften the mixture and form dough, water was added. After that, the pellets were made with a 0.6 mm diameter manual meat grinder, dried for 48 hours at ambient temperature, and then frozen within plastic bags until needed. Commercial fine power feeds from the "Quality Fish Feed Limited" brand were selected for this investigation. The following table lists the feed mix and formulation for this "quality fish feed Ltd (Table. 1).

Table 1. Feed formulation of "Quality Fish Feed Ltd." (Dry matter basis).

Ingredients	Amounts (%)
Fish meal	45.0
Soybean meal	17.0
Soybean	10.0
Corn flour	7.0
Shrimp meal	5.0
Rice bran	5.0
Full fat soybean	5.0
Mustered	4.0
Salt	1.0
Vitamins and premix	1.0
Total	100

In the Nutrition Lab, the feed was properly dried after processing. Table shows (Table 2) the proximate composition of the experimental feed after it has been analysed.

Table 2. Analyzing the approximate composition of prepared feed (moisture basis).

Treatments	Moisture (%)	Crude Lipid (%)	Crude Protein (%)	Ash (%)	Crude Fiber (%)	Carbohydrate (%)
T_0	12.56	6.88	34.30	10.50	4.16	31.60
T_1	13.45	6.76	33.55	10.10	3.39	32.25
T_2	13.38	6.56	33.74	11.37	4.56	30.39
T_3	13.74	7.16	33.69	10.65	4.28	30.48

Experimental fish

With no symptoms of illness or anomalies, 2.62 g of Rohu (*L. rohita*) fish fries from a single breeding batch were purchased from the Mymensingh's Bangladesh Fisheries Research Institute and brought to the study site in an aerated polythene bag.

Acclimatization of fish fry

After being collected, the fry spent seven days becoming used to the testing lab. A consistent supply of oxygen was maintained throughout this time by continuous aeration, and the fish were fed a basic diet devoid of nanoparticles.

Socking of fish fry

Following a period of seven days for adaption, a random stocking density in one cubic meter of 188 (12 in each tank) was applied to the about 2.62 ± 0.02 fry. Before being stocked, the tanks were cleaned with a 0.25 ppm potassium peroxide solution. Throughout the investigation, the following conditions were maintained: ideal temperature (27 ± 0.8° C), pH (7.6 ± 0.3), dissolved oxygen (7.23 ± 0.5 ppm), free carbon dioxide (6.45 ± 0.17 ppm), ammonia (>0.1 ppm), nitrate (>15 ppm), and a 12-hour light photoperiod.

Feeding trial

Following final stocking, Fish received two meals a day (at 09:00 and 14:00) with their individual diets until they appeared satiated (Abd El-Naby *et al.*, 2020). Using finely powdered feed, the rate of feeding was initially set at 15% of their body weight. Gradually, 10% and 5% pellets were introduced. Feed according to satiation and growth. Taking into account their weight and desire to eat more, the amount was changed.

Sampling procedure

Samples of at least 20% of each treatment's fish were taken every 10 days to track growth. Prior to and following each sample, the fish were starved for 12 hours, and the daily mortality was noted. Fish that were dead were removed. A fine mesh scoop net was used to gather the samples, and before the fish was weighed on a digital balance, the water was gently blotted from its body with blotting paper.

Method of analysis

The Nutrition Laboratory of the Department of Aquaculture, BAU, performed analyses on the approximate composition of prepared feeds and individual elements after adopting the association of Officials Analytical Chemists edited by AOAC (2005) methodologies.

Growth and feed-utilization metrics

These formulas were used to calculate growth indices:

Weight gain (g)

The term "weight gained" describes the variation between one's starting and ultimate weights. The formula:

Weight gain (g) = mean final weight (g) – mean initial weight (g)

Percent weight gain (%)

$$\text{Percent weight gain (\%)} = \frac{\text{mean final fish weight} - \text{mean initial fish weight}}{\text{mean initial fish weight}} \times 100$$

Specific growth rate (%/day)

Fish growth was measured in terms of weight by deducting the fish's original weight (at the time of release) from its ultimate weight. The precise growth rate or SGR was determined using the algorithm below:

$$\text{Specific growth rate (\%/ day)} = \frac{Ln\,W2 - Ln\,W1}{T2 - T1} \times 100$$

Where

W_1 = Initial live body weight (g) at time T_1

W_2 = Final live body weight (g) at time T_2

T_2-T_1 = No. of days of the experiment

Feed conversion ratio (FCR)

A measurement of the amount of food needed to increase an animal's live weight by one unit.

$$FCR = \frac{\text{Amount of dry feed (g)}}{\text{Live weight gain (g)}}$$

Feed conversion efficiency (FCE)

A ratio that shows how much feed must be added in order to increase an animal's live weight by one unit.

$$FCE = \frac{Live\ weight\ gain\ (g)}{Amount\ of\ dry\ feed\ (g)}$$

Digestibility

After the experiment lasted for 28 and 56 days, fish feces were collected and their nutritional content and chromic oxide (Cr_2O_3) measured. The amount of Cr_2O_3 in the diet and faces was measured using the optical density of a spectrophotometer (model: T60 UV, PG Instrument, UK) operating at 440 nm wave length. Next, the following formula was used to determine the digestibility:

$$\text{Dry matter digestibility (\%DMD)} = 100\text{-}100\ \frac{\%Cr2O3\ in\ diet}{\%Cr2O3\ in\ faeces}$$

$$\text{Apparent Protein digestibility (\%APD)} = 100\text{-}100\ \left(\frac{\%Cr2O3\ in\ diet}{\%Cr2O3\ in\ faeces} \times \frac{\%Cr2O3\ in\ faeces}{\%Cr2O3\ in\ diet}\right)$$

$$\text{Amount of } Cr_2O_3 \text{ (mg)} = \frac{Y - 0.0032}{0.2089}$$

Where, Y= Optical density,

% Chromic oxide was determined using the formula below

$$\%Cr_2O_3 = \frac{\text{Amount of Cr2O3 (mg)}}{\text{Amount of sample (mg)}} \times 100$$

Crude protein content of feed and faeces were estimated in Nutrition Laboratory in line with AOAC (2005).

Statistical analysis

Microsoft Excel and the SPSS analytical program were used to evaluate the gathered data and carry out statistical analyses like ANOVA. To ascertain the significance of variations between treatment means, the means of the various therapies were contrasted using the Duncan Multiple Range test. Microsoft Excel was used to create the graphs (Zar, 1984).

Results and Discussion

Growth Performance of rohu

The goal of the current study was to assess the relationship between Rohu survival rate and growth performance. The experiment's growth performance for Rohu was computed at the end. Table 3 displays the growth characteristics of fish fed diets that were experimental and control. The findings demonstrate that silica NP significantly affected all growth metrics ($p<0.05$). Individual rohu under various treatments had a starting average weight of 2.62 ± 0.02 g (Table 3). In various treatments, the average ultimate weight of each rohu varied from 7.3 ± 0.14 g to 9.25 ± 0.07 g. The ultimate weight mean (g) in T_2 was found in highest followed by T_3, T_1, T_0, respectively (Table 3). The percent weight gain (%) of fish in different treatments ranged from 178.57 ± 5.32 to 252.99 ± 2.6 %. The highest percent weight gain (%) was found in treatment T_2 followed by T_3, T_1 and T_0, respectively. There was significant (P<0, 05) variation of percent weight gain among T_3, T_2, T_1 and T_0 (Table 3). The initial average length of individual rohu in different treatments was 5.41 ± 0.01 cm. (Table 3). The mean final length of individual rohu in various treatments differed from 7.57 ± 0.1 to 8.6 ± 0.14 cm. The mean length gain (cm) in T_2 was found in highest followed by T_3, T_1, T_0, respectively (Table 3). The mean length gain (cm) of individual rohu in different treatments ranged from 2.17 ± 0.09 to 3.2 ± 0.13 cm. The highest mean length gain of experimental fish was found in T_2 followed by T_3, T_1 and T_0, respectively (Table 3). Fish raised under controlled conditions with low protein basal diets and higher stocking densities (nearly six times higher than conventional methods of pond farming in Bangladesh) demonstrated improved growth performance than alternative cultural frameworks, including the cultures of raceways, tanks, and aquariums (El-Naby *et al.*, 2019, 2020), biofloc culture (Da Silva *et al.*, 2018; Martins *et al.*, 2019), and semi-intensive and intense pond cultivation (Kabir *et al.*, 2019; Dawood *et al.*, 2020). Fish welfare may improve and overall yield benefits may increase in RAS systems with effective management of nitrogenous waste and controlled environmental conditions. The impact of silica NP on rohu growth was studied during the experimental phase. The enhanced growth performance seen in this study can be attributed to the potential of nano-sized silica as a nutrient carrier, particularly for amino acids. By carefully encapsulating and releasing nutrients from the gastrointestinal system into the bloodstream, these transported nutrients may also enhance the process of breaking down and absorbing nutritional molecules (Bahabadi *et al.*, 2017). This rise may possibly be associated with improved gut bacteria and DNA and RNA production, both of which are encouraged by nanoparticles (Onuegbu *et al.*, 2018). In T_2, rohu's growth performance was 9.25 ± 0.07 g, statistically considerably ($p<0.05$) greater than the other treatments. The effects of organic selenium on *L. rohita* growth performance were observed by Baidya and Murthy (2017) at graded selenium levels containing four diets (1, 2, 3, and 4) with (0, 1, 2, and 3 g kg-1 diet) and 30% protein, respectively. They discovered that T_1 had the largest weight gain, 3.51 g. Compared to the last study, the current one revealed a greater weight gain. An eight-week experiment was conducted to investigate the effects of silica nanoparticles (NP) on the physiology and nutrition of *Oreochromis niloticus*, the Nile tilapia, as reported by Bashar *et al*. in 2021. Highly pure activated silica nanoparticles (0, 1, 2, and 3 mg/kg diet) were added to a meal that contained 30% protein. The feed efficiency and growth metrics (WG, PWG, SGR, and DGC) were much improved up to 2 mg/kg of silica NP before declining, according to the results. The largest weight gain he discovered was 44.70 ± 1.77 g in T2. Comparing the current trial to the prior one, there was less weight gain. It could be the result of a healthy diet.

Specific growth rate

Additionally, the SGR statistics show how silica NP enhances growth performance. The fish raised without silica NP in T_0 had the lowest SGR of 1.71 ± 0.03 to 2.1 ± 0.01 %/day (Table 3), while the maximum SGR was seen in T_2 at 2.1 ± 0.01 %. The T_2 value was found to be relatively lower than the Pavithra *et al.* (2021) observed result of 3.96 ± 0.41 %.

Feed conversion ratio (FCR) and Feed conversion efficiency (FCE)

Mean feed conversion ratio in various therapies varied from 1.56 ± 0.02 to 1.4 ± 0. The highest FCR was obtained in T_0 followed by T_1, T_3 and T_2, respectively (table 3). Mean feed conversion efficiency in various therapies varied from 64.1 ± 0.69 to 71.67 ± 0.21. The highest FCE was obtained in T_2 followed by T_0, T_1 and T_3, respectively. The mean feed conversion efficiency varied significantly (P<0.05) across the four treatments (Table 3). The FCR discovered in this investigation is significantly less than what Pavithra *et al.* (2021) found. The greater FCR value in this trial was recoded in T_0. In T_2, the reduced FCR value was noted. According to Pavithra *et al.* (2021), 1.83 ±0.24 is the lowest feed conversion ratio. The current study's FCR values were lower than those of the previously stated study. In *L. rohita*, feed containing silica NP performed better than feed containing selenium NP. Likewise, Popoola *et al.* (2023) sought to evaluate the immune stimulatory characteristics of silver nanoparticles (AgNPs) on *Labeo rohita* and comprehend the ways in which it influences the growth of the organism, the structure of its cells, and the expression of immune genes, and susceptibility to infection by *Aeromonas hydrophila*. The lowest FCR of 1.48 was discovered at T_3 15 µgKg-1 Ag NP containing diet. The current investigation found a decreased FCR of 1.4 at 2 g/kg of diet containing silica. On the other hand, Bashar *et al.* (2021) noted silica nanoparticle (NP) effects on Nile tilapia physiology and nutrition, where FCR is lower than the present one. Increasing the silica NP level up to T_2 significantly increased feed conversion efficiency. The higher FCE was recorded in T_2.

Survival (%)

One important measure of fish health is survival. The survival rate in the current study ranged from 96.5 ± 0.71 to 97.5 ± 0.71 percent (table 3). When feeding T_2 with a diet containing 2 mg/kg of silica nanoparticles, the survival rate is higher than it is in T_0. Upreti *et al.* (2021) conducted a 15-day trial with diets containing 2, 4, and 6 mgl^{-1} SiO_2 concentration, which were chosen based on the survival to mortality ratio. At the conclusion of the trial, there was no mortality seen in the *L. rohita* fingerlings. This was similar to the current investigation.

Digestibility (%)

The mean apparent protein of rohu under different treatments ranged from 75.11 ± 1.26 to 87.17 ± 2.6 %. Best apparent protein digestibility was found in T_2. Significant variation a ($P<0.05$) was found between the T_1 and T_0; T_2 and T_0, T_3 and T_0; T_1 and T_2; T_2 and T_3 (Table 3). The mean dry matter digestibility of rohu under different treatments ranged from 66.5 ± 2.12 to 78.17 ± 1.18 %. Best apparent protein digestibility was found in T_2. Significant variation a ($P<0.05$) was found between the T_1 and T_0; T_2 and T_0, T_3 and T_0; T_1 and T_2; T_2 and T_3 (Table 3). Additionally, digestibility research shows how silica NP enhances growth performance. According to GarcíaMeilán *et al.* (2016), digestive enzymes break down proteins, carbs, and fats into smaller components so that the fish intestine's microvilli can absorb them. As an omnivore fish, rohu has a rather passive stomach when it comes to breaking down proteins. Hydrochloric acid plays a major role in the digestion of proteins in the gut, which occurs shortly after the stomach. Because of size restrictions, only smaller peptides and amino acids may pass via the stomach wall and be absorbed, making them able to expand. Apart from supporting gut bacteria and preserving homeostasis, water in the gut is largely inert and plays no direct function (Laforenza, 2012; Giatsis *et al*., 2015). Eight weeks of research were planned after Bashar *et al.* (2021) observed the effects of silica nanoparticles (NP) on the physiology and nutrition of Nile tilapia, *Oreochromis niloticus*. A 30% protein-rich meal was supplemented with various dosages of highly pure, activated silica NP (diet of 0, 1, 2, and 3 mg/kg). He discovered that the highest DMD was in T2 83.41 ± 2.95 % and the highest APD was in T2 92.35 ± 1.71 %. APD and DMD were lower in this trial than in the last.

Water quality parameter

The factors of water quality are crucial in preserving a wholesome environment for aquatic life. In the experimental tank, the measured water temperature during the study period ranged from 28.43 to 30.12 ºC. The values recorded in the four treatments were quite near to Boyd's (1982) results, which ranged from 26.06 to 31.97 ºC. According to Battes *et al*. (1979), fish metabolism is significantly regulated by the temperature of the water. Maintaining the culture unit's temperature is crucial for this reason. The impact of varying ranges of water temperature on growth efficiency was examined by Kausar and Salim (2006). The water temperatures in the ponds on the BAU campus in Mymensingh were measured by Hossain (2004) and ranged from 29.4 to 33.0 ºC and 26.0 to 32.8 ºC, respectively. According to measurements made by Alam (2009) and Hossain (2009), the temperature of the water in Agro 3 Farm's ponds in Trishal, Mymensingh, ranged from 26.9 to 32.5 ºC. The water in the RAS tank was about the same temperature as the pond, according to the statement above. The current experimental study's soluble oxygen content varied between 7.85 and 8.21 mg/L. The dissolved oxygen levels in the ponds of agro-3 Farm, Trisal, Mymensingh, were measured by Alam (2009) and Hossain (2009), and they ranged from 5.5 to 6.5 mg/L, respectively. As per DoF (1996), the observed value fell within the permissible range of 6.5 to 8.5, which is necessary for fish culture. For aquatic animals, exposure to excessive pH levels can be fatal or extremely stressful.

Table 3. The impact of various treatments on rate of survival, feed utilization, and growth of (*L. rohita*) (Mean ±SD) during the experimental period.

Growth and feed utilization parameters	T_0	T_1	T_2	T_3	*p* value
Initial weight (g)	2.62 ± 0.01a	2.62 ± 0.02a	2.62 ± 0.02a	2.62 ± 0.01a	1
Final weight (g)	7.3 ± 0.14c	8.06 ± 0.23b	9.25 ± 0.07a	8.4 ± 0.14b	0.001066
Weight gain(g)	4.68 ± 0.14c	5.44 ± 0.23b	6.63 ± 0.07a	5.78 ± 0.14b	0.001048
Initial length (cm)	5.41 ± 0.01a	5.41 ± 0.01a	5.41 ± 0.01a	5.41 ± 0.01a	1
Final length (cm)	7.57 ± 0.1c	7.88 ± 0.01bc	8.6 ± 0.14a	8.1 ± 0.14b	0.003333
Length gain (cm)	2.17 ± 0.09c	2.48 ± 0.01bc	3.2 ± 0.13a	2.7 ± 0.13b	0.002681
Percent weight gain (%/day)	178.57 ± 5.32c	207.57 ± 8.55b	252.99 ± 2.6a	220.55 ± 5.31b	0.001012
Specific growth rate (%/ day)	1.71 ± 0.03c	1.87 ± 0.05b	2.1 ± 0.01a	1.93 ± 0.03b	0.001139
Survival rate	96.5 ± 0.71a	97 ± 1.41a	97.5 ± 0.71a	96.5 ± 0.71a	0.6889
Feed conversion ratio	1.56 ± 0.02a	1.48 ± 0.02ab	1.4 ± 0b	1.45 ± 0.01ab	0.001443
Feed conversion efficiency	64.1 ± 0.69c	67.47 ± 0.9b	71.67 ± 0.21a	68.8 ± 0.52b	0.001284
Apparent protein digestibility (%)	75.11 ± 1.26b	81.7 ± 1.85ab	87.17 ± 2.6a	83.22 ± 2.52ab	0.02059
Dry matter digestibility (%)	66.5 ± 2.12b	71.05 ± 1.35ab	78.17 ± 1.18a	74.11 ± 2.67ab	0.01558

The findings are displayed as mean ± SD. Significant means ($p<0.05$) are those in the same row with different superscript letters. Weight gain (g); Length gain (cm); Percentage weight gain (%); Specific growth rate (% per day); Survival rate; Feed conversion ratio; Feed conversion efficiency; Apparent protein digestibility (%); Dry matter digestibility (%).

Conclusion

The fastest-growing food production technology is aquaculture, which contributes significantly to the world's fish biomass. Encouraging sustainable aquaculture methods is essential to guaranteeing global food security, and one of the most significant challenges is managing feed sustainably. Globally, aquaculture has lessened the need for wild-caught fish as a source of protein for diets, but the feed business has increased strain on these resources, especially for protein and oils. Fish growth performance can still not be optimized due to the low digestibility of plant-based proteins, even if many replacement procedures including fishmeal have been adopted to counterbalance the high cost of fishmeal. Meeting the criterion of "feed quality" is an essential prerequisite. A well-balanced feed composition is necessary to get the maximum yield and fastest growth at the lowest expense. This is why the current experiment was conducted to find out how silica nanoparticles affected the pace of development and survival of *L. rohita*. Because of its beneficial effects on fish health and immunity, disease diagnosis and treatment (including safer and more effective vaccination administration), and growth performance, nanotechnology has emerged as a crucial tool for sustainable aquaculture. These findings have confirmed the evident benefits of silica NP for the experimental fish's capacity for growth, use of feed, and quality of final product. The results of the present investigation demonstrate that silica NP supplementation significantly affects *L. rohita* growth performance, and silica produced a good outcome. Without raising concerns about the safety of human health, one of nanotechnology's inputs, silica NP, can be creatively used as feed supplements to increase the rate of absorption and digestion in the production of *L. rohita*. Consequently, it can be said that adding silica NP to feed will increase the production of *L. rohita*.

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