MANGROVE ASSOCIATE BASED SHRIMP FEED: AN INNOVATION IN THE AQUACULTURE SECTOR

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Abstract

The traditional method of shrimp culture is a common practice in Indian Sundarbans which is done without any sound scientific back-up, proper feed, and water quality management. The shrimp farmers use a traditional feed of animal origin that often results in deterioration of water quality and disease outbreaks in cultured species. The present paper highlights the effect of the total replacement of animal ingredients in shrimp feed with floral ingredients on water quality and shrimp health. Weight gain, condition index, feed conversion ratio (FCR), survival, body pigmentation (astaxanthin level) were analyzed in shrimps along with pond water quality. Higher condition index (C.I.) values, survival rate, and gain in shrimp weight were observed in the experimental pond (E) compared to the control pond (C). Low FCR values were observed in the experimental pond than in the control pond. Astaxanthin values in shrimps of the experimental pond were also higher than the control pond which points towards Suaeda maritima as the source of carotenoid in the shrimp tissue.

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I. Introduction

India has a long coastal stretch of 8085 km supporting aquaculture as the predominant activity. The culture of *Penaeus monodon* is practiced in the brackish water system of the country to increase fish production basically for human consumption. Its other benefits include employment generation, food security, and general improvement in the livelihood of the people in remote islands and deltaic complex like Indian Sundarbans (located at the apex of the Bay of Bengal). To attain its full potential in contributing to human development and social empowerment, the culture of *Penaeus monodon* requires new approaches that are realistic and achievable in the context of current environmental circumstances [LXIII]. Over the last decade, the culture of *P. monodon* in Indian Sundarbans has witnessed an exponential growth when the semi-intensive method of shrimp farming was at its peak. This type of farming, however, resulted in the deterioration of water quality and created a negative impact on the health of the coastal population as well as the mangrove ecosystem [XXXIII]. Hence, the Supreme Court of India banned the semi-intensive method of shrimp farming in December 1996 [LV]. Presently modified traditional method of shrimp farming is practiced in Indian Sundarbans, where traditional feed with the animal matter as the main ingredient is provided to the cultured species.

Shrimp feed is a significant factor in increasing productivity and profitability in the aquaculture sector [XIX]. From an economic point of view, feed cost and feed management accounts for at least 60% of the production cost and appear to be one of the major constraints against the greater expansion of aquaculture [XXIII]. Fish feed is the biggest source of nutrient loading in aquaculture production requires a clear understanding of its impact on the ambient environment for sustainable aquaculture. This will help to reduce negative impacts and improve the predictability of environmental effects. Present knowledge and understanding of the environmental impacts of shrimp feed among aquaculturists and nutritionists are very low and need further refinement. More emphasis has now been on the formulation of shrimp feed with good palatability that will enhance fast growth within a limited period without cognizance of its impact on the environment. A feed with animal ingredients generates wastes of a complex character in the culture system. The common pollutants of shrimp culture farms are phosphorous and nitrogenous substances as well as organic matter that are released into the ambient environment through the release of faecal matter and residual feed of animal origin [XXXV]. Microalgae and macroalgae have been used for years in terrestrial animal feed to replace animal ingredients [XIV], [XXVI] as a source of pigments [LIX] to increase disease resistance [LXVIII], to increase egg production [VI], etc. In aquatic animals, seaweeds have been used as a dietary supplement for sea bass [LXIX], snakehead [XVII] and shrimp [XLII], [XLVIII], [IX]. In some instances, the inclusion of algae in feed formulations has resulted in improved performance, including improved feed efficiency, pellet quality, and animal product quality. Most nutritional studies with *MN Sarker et al.*
seaweed have investigated low dietary inclusion rates (less than 80 g/kg) to establish their possible usefulness as functional (binder effect), nutritional, and nutraceutical (health protective effects) supplements [X]. The optimum inclusion level varies depending on algae or consumer species [XLVIII], [IX], [LXII]. A lot of studies demonstrated the antioxidant properties of the algal carotenoids and the role they play in preventing many pathologies linked to oxidative stress [XLVII], [LXXV]. The main carotenoids in red seaweed are the β-carotene and α-carotene and their dihydroxylated derivatives viz. zeaxanthin and lutein.

Considering the merit of floral-based shrimp feed, the present paper is an attempt to study the effect of mangrove associate-based formulated feed on water quality, shrimp production, survival rate, and FCR in a shrimp culture unit of central Indian Sundarbans. This mangrove-dominated deltaic complex is located at the apex of the Bay of Bengal and has been declared as the World Heritage Site by UNESCO (1987) on account of its rich taxonomic diversity. This is the first attempt to use Suaeda maritima as an ingredient in shrimp feed in the deltaic complex of Sundarbans. The main objective of the present study is to prove the efficacy of the feed obtained by inclusion of the mangrove associate species, Suaeda maritima in formulated feed in terms of growth performance and body pigmentation of the cultured shrimp.

II. Materials and Methods

Experimental design and layout

The study area (Fig. 1) for culturing shrimp (Penaeus monodon) was selected in the central part of Indian Sundarbans in Canning block located in South 24 Parganas district of the state of West Bengal (22°16'40.6" N latitude and 88°38'18.4" E longitude). The culture site is located on the bank of Matla River, which has an average salinity of 8.5 psu. Two ponds were selected in the study site out of which one was treated as control (C) and the other was treated as experimental (E). The cultured species (Penaeus monodon) in the experimental pond was provided with the Suaeda maritima based formulated feed and the control pond was provided with traditional feed. Good quality shrimp seeds obtained from a local shrimp farm were stocked after proper acclimatization with ambient environmental conditions. The stocking density was 5 PL-20/m² in both the control and experimental ponds. The shrimps were fed initially at 15% of the biomass in each pond and the ratio was then adjusted to actual consumption every day, thus reducing uneaten feed to a minimum.
Water quality parameters were analyzed fortnightly for a 90 days culture period (15th April to 15th July 2016). The parameters remained well within the optimum throughout the trial. The surface water salinity was recorded using an optical refractometer (Atago, Japan) in the field and cross-checked in the laboratory by employing Mohr-Knudsen method [LX]. The correction factor was found out by titrating silver nitrate solution against standard seawater (IAPO standard seawater service Charlottenlund, Slot Denmark, chlorinity 19.376 psu). Our method was applied to estimate the salinity of standard seawater procured from NIO and a standard deviation of 0.02% was obtained for salinity. The average accuracy for salinity (in connection to our triplicate sampling) is ±0.28 psu and for temperature, it is ±0.035°C. Glass bottles of 125ml were filled to overflow from collected water samples and Winkler titration was performed for the determination of dissolved oxygen. The pH was obtained via a portable pH meter (Hanna, USA), which has an accuracy of ±0.1. A Secchi disc was used to measure the transparency of the water column and the data was used to calculate the euphotic depth. Surface waters were analyzed for nutrient concentrations (nitrate, phosphate, and silicate) following the standard spectrophotometric method [LXI]. Phytopigment concentration (Chl a) was analysed as per the method [XX]. The organic carbon content of pond bottom soil was estimated by the standard titration method [LXXI].

Formulation of shrimp feed and analysis of biochemical constituents

Feed is considered the most critical input for augmenting fish production. Cultured shrimps accept a wide range of agricultural by-products in the form of pelleted or dough feed. Several studies have been carried out in the development of formulated feed for the species under controlled culture system [XL], [XLIII], [XLIV], [XV], [XXIV], [II]. The mangrove associate species *Suaeda maritima* (in dried powder form) was selected as the candidate flora (source of astaxanthin) for the

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preparation of formulated shrimp feed. A comparative account of traditional feed (commonly used in the study area at Canning) and mangrove associate-based formulated feed is given (Table 1). The proximate composition of the mangrove associate meal was determined using the methods of Lowry for protein [XXVIII], Soxhlet for lipid [LXIV], and Anthrone method for carbohydrate [LXVII]. Astaxanthin was estimated as per the standard spectrophotometric method [LIV].

Table 1: Comparative analysis of shrimp feed components

| Traditional shrimp feed          | Percentage (%) | Specially formulated shrimp feed          | Percentage (%) |
|---------------------------------|----------------|------------------------------------------|----------------|
| Trash shrimp dust               | 20             | Soybean oil cake                         | 40             |
| Dry fish dust                   | 30             |                                          |                |
| Soybean oil cake                | 10             |                                          |                |
| Rice bran                       | 12.5           | Rice bran                                | 15             |
| Flour                           | 7              | Wheat bran                               | 15             |
| Groundnut dust                  | 5              | Mustard oil cake                         | 12.5           |
| Maize dust                      | 4.5            |                                          |                |
| Coconut khail                   | 10             | Coconut oil cake                         | 12.5           |
| Vitamins and minerals mixture   | 1.0            | Suaeda maritima (as a source of carotenoid) | 5              |

Zoo-technical parameters and statistical analysis

Individual weights and lengths of shrimps were taken at the fortnightly interval for 90 days culture period and the relevant response variables were determined for each control and experimental pond. Condition Index was analyzed at fortnightly intervals during the culture period as per the expression: C.I. = W/L³ x 100, where W = weight of the cultured species (in gm) and L = length of the cultured species (in cm). Percentage weight gain was calculated as the difference in weight from the average final weight concerning the initial weight; weight gain = [(average individual final weight – average individual initial weight)/average individual initial weight] x 100. Feed consumption reported was the total of the consumption estimated for 90 days period. The survival rate was measured as a percentage of the difference of stocking number and production volume (No.) at the end of the culture period. Feed Conversion Ratio (FCR) is the weight of feed consumed per unit of weight gain and was analyzed after the harvesting of shrimps as per the expression: FCR = Δf/Δb, where, Δf = Change in feed biomass and Δb = Change in body biomass of the cultured species.

Body pigmentation was assessed for each treatment on shrimp cooked for 5 min in boiling water and comparing the orange-red colouration with Roche SalmoFan™ colour score. Analysis of variance (ANOVA) was computed between all the selected parameters (indicators of our experiment) considering both control and experimental ponds to evaluate the differences caused by inclusion of dried Suaeda maritima in the feed.

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III. Results and Discussion

Biochemical composition of *Suaeda maritima* and specially formulated feed

The proximate composition of traditional and mangrove associate-based formulated feed is highlighted in Table 2. The traditional feed showed higher protein, lipid, and carbohydrate values than mangrove associate-based feed. However, astaxanthin content was almost nil in traditional feed.

**Table 2: Proximate composition of the traditional and formulated feed**

| Parameters               | Traditional feed | Formulated feed |
|--------------------------|------------------|-----------------|
| Protein (%)              | 32±2.65          | 28.29±0.58      |
| Lipid (%)                | 4.7±2.05         | 1.62±0.03       |
| Carbohydrate (%)         | 22.1±4.08        | 17.25±0.50      |
| Astaxanthin (ppm)        | BDL              | 62.33±2.78      |

* Values are the mean±SD

**Shrimp growth and pigmentation**

Shrimps fed with the *Suaeda* diet exhibited higher final weights and better weight gain (Table 3) at the end of the experiment (25.5 gm final weight and 2450 % weight gain) in comparison to the control pond (20 gm final weight and 1900 % weight gain). Condition Index values of shrimp were also higher in experimental ponds (3.41±4.68) than in control ponds (3.08±4.52) (Table 3 and Fig. 2). The FCR value for the control pond was 1.45 and for the experimental pond was 1.39. The survival rate was found to be 55% in the control pond and 70% in the experimental pond. The production volume was also maximum in the case of the experimental pond (69.97 kg) compared to the control pond (20.10 kg) as given (Table 4). The present pilot-scale study speaks in favour of a healthy pond environment, better growth, higher survival rate, and low FCR values through the use of mangrove associate, *Suaeda* based feed.

**Table 3: Zoo-technical parameters recorded in the culture ponds**

| Parameters               | Control pond | Experimental pond |
|--------------------------|--------------|-------------------|
| Condition Index of shrimp | 3.08±4.52*   | 3.41±4.68*        |
| % weight gain            | 1900         | 2450              |
| Astaxanthin in shrimp (ppm) | 9.52±5.45* | 11.32±6.37*       |
| Roche SalmoFan™ colour score | 24          | 29                |
| Survival rate (%)        | 55           | 70                |
| Δ F                      | 27.67        | 72.65             |
| Δ B                      | 19.09        | 52.14             |
| FCR                      | 1.45         | 1.39              |

* Values are the mean±SD

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Table 4: Cost-Benefit analysis of the culture ponds

| Items                             | Control pond | Experimental pond |
|-----------------------------------|--------------|-------------------|
| Area (m²)                         | 365.40       | 784.08            |
| Stocking density @ 5 PL/m²        | 1827         | 3920              |
| Seed cost (in Rs.)                | 913.50       | 1960.00           |
| Feed given (in kg)                | 29.93        | 78.82             |
| Feed cost (in Rs.) @ Rs. 35/- per kg = 1047.55 | @ Rs. 19 per kg (excluding the cost of S. maritima) = 1497.58 |
| Labour cost (supported by the beneficiary himself) | Nil         | Nil               |
| Experimental cost (in Rs.)        | 5000         | 5000              |
| Total cost (in Rs.)               | 6961.05      | 8457.58           |
| Total unit cost (in Rs./ m²)      | **19.05**    | **10.79**         |
| Production (in kg) @ 20 gm/kg = 20.10 | @ 25.5 gm/kg =69.97 |
| Return @ Rs. 350/kg              | 7035.00      | 24,489.50         |
| Expenditure (in Rs.)              | 6961.05      | 8457.58           |
| Total profit/pond (in Rs.)       | 73.95        | 16,031.92         |
| Profit/unit area (in Rs./ m²)     | **0.20**     | **20.45**         |

An important factor governing the consumer acceptance and market value of many cultivated fish and shrimp species is the pink or red colouration of their flesh or boiled exoskeleton [VII]. In the wild, this colouration is achieved through the ingestion of carotenoid pigments particularly astaxanthin contained within invertebrate food organisms [XXI], [XVIII]. The *Suaeda* based feed in the present study resulted in higher astaxanthin values in shrimps of the experimental pond (11.32±6.37 ppm) as reflected through darker orange-red colouration of shrimp exoskeleton in comparison to the control pond (9.52±5.45 ppm). Roche SalmoFan™ colour score showed a value of 24 in the control pond, much lesser than experimental pond with a colour score of 29 (Table 3).

**Variation in environmental parameters**

The surface water temperature during the study period ranged from 29.0°C to 29.6°C with a mean value of 29.4±0.22°C in both the culture ponds (Table 5). The surface water salinity ranged from 3.72 psu to 4.45 psu with a mean value of 4.35±0.2 psu in the control pond and 4.08±0.16 psu in the experimental pond (Table 5). The surface water pH ranged from 7.10 to 8.12 with a mean value of 7.88±0.35 in the control pond and 8.08±0.03 in the experimental pond (Table 5). The DO values ranged from 3.08 mg l⁻¹ to 5.58 mg l⁻¹ with a mean value of 4.66±0.77 mg l⁻¹ in the control pond and 5.47±0.12 mg l⁻¹ in the experimental pond (Table 5). The nutrient values (nitrate, phosphate, and silicate) ranged from 15.12 µgat l⁻¹ to 21.33 µgat l⁻¹

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with a mean value of 19.5±1.21 μgat l⁻¹ in the control pond and 16.6±0.01 μgat l⁻¹ in the experimental pond (Table 5) for nitrate, from 1.53 μgat l⁻¹ to 2.28 μgat l⁻¹ with a mean value of 2.22±0.05 μgat l⁻¹ in the control pond and 2.0±0.29 μgat l⁻¹ in the experimental pond (Table 5) for phosphate and from 59.63 μgat l⁻¹ to 66.2 μgat l⁻¹ with a mean value of 64.01±2.23 μgat l⁻¹ in the control pond and 63.32±2.67 μgat l⁻¹ in the experimental pond (Table 5) for silicate. The Chl a concentration during the study period ranged from 0.97 mg m⁻³ to 2.66 mg m⁻³ with a mean value of 1.74±0.51 mg m⁻³ in the control pond and 1.92±0.16 mg m⁻³ in the experimental pond (Table 5). The organic carbon of the pond bottom soil during the study period ranged from 0.97 % to 1.35 % with a mean value of 1.18±0.16 % in the control pond and 1.07±0.10 % in the experimental pond (Table 5). The water transparency during the study period ranged from 14.35 cm to 27.5 cm with a mean value of 17.02±2.02 cm in the control pond and 24.3±2.58 cm in the experimental pond (Table 5).

Table 5: Variation in the physico-chemical parameters of the culture ponds

| Parameters                        | Control pond | Experimental pond |
|-----------------------------------|--------------|-------------------|
| Surface water temperature (°C)    | 29.4±0.22    | 29.4±0.22         |
| Surface water salinity (psu)      | 4.35±0.2     | 4.08±0.16         |
| pH                                | 7.88±0.35    | 8.08±0.03         |
| Transparency (cm)                 | 17.02±2.02   | 24.3±2.58         |
| Dissolved oxygen (mgl⁻¹)          | 4.66±0.77    | 5.47±0.12         |
| Nitrate (μgat⁻¹)                  | 19.5±1.21    | 16.6±1.01         |
| Phosphate (μgat⁻¹)                | 2.22±0.05    | 2.0±0.29          |
| Silicate (μgat⁻¹)                 | 64.01±2.23   | 63.32±2.67        |
| Chlorophyll a (mgm⁻³)             | 1.74±0.51    | 1.92±0.16         |
| Soil organic carbon (%)           | 1.18±0.16    | 1.07±0.1          |

Values are the mean±SD

Feed quality

Growth, health, and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrients through feed both in terms of quality and quantity, irrespective of the culture system in which they have grown [XXII]. Therefore, the supply of inputs (feeds, fertilizers, etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved [XVI]. The nutrient balance of feed influences feeds utilization and growth of fish. It is very essential to know the nutritional requirements particularly for protein, lipid, and energy for optimum growth of fish species as well as in formulating a balanced diet. Dietary protein and energy levels are known to influence the growth and body composition of fish [XXVII]. Improper protein and energy levels in feed increase fish production cost and deteriorates water quality. Insufficient energy in diets causes protein waste due to the increased proportion of dietary protein used for energy and the produced ammonia can reduce the water quality [XLIX], [L], [LVI]. On the contrary, excessive energy in diets can lead to increased body lipid deposition and growth reduction because of a lack of necessary nutrients for growth [XI], [LXX]. This is often the case seen in the

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case of traditional meals which has resulted in deterioration of water quality parameters in the control pond (Table 5). In the present study, the specially formulated feed prepared from *Suaeda maritima* had optimum protein, lipid, carbohydrate, and astaxanthin content and the values were also within the recommended nutrient levels for fish [XLV].

Protein is the major growth-promoting factor in feed. The protein requirement of fish is influenced by various factors such as fish size, water temperature, feeding rate, availability and quality of natural foods, and overall digestible energy content of diet [LIII], [LXXIII]. In the present study, the protein level in formulated feed was found to be 28.29±0.58 % in comparison to 32±2.65 % in traditional feed. Lipids are primarily included in the formulated diet to maximize their protein-sparing effect [XVI] by being a source of energy. Low lipid content of the specially formulated feed results in greater binding efficiency and more pellet water stability. Lipid values were found to be lower in specially formulated feed indicating the efficiency of the present feed-in maintaining water stability. Carbohydrate levels in the feed are the most suitable sources of energy for shrimps. The various carbohydrate sources of shrimp feed are those derived from low-cost practical ingredients (e.g. wheat flour, rice bran, etc.). The formulated feed in the present study also supports the above view (Tables 1 and 3). The use of *Suaeda maritima* as an astaxanthin supplement (source of carotenoid) has increased the antioxidative property of the feed and resulted in higher pigment concentration in shrimp species of the experimental pond (Tables 3 and 4).

**Growth performance of shrimp**

The present case study exhibited significant weight gain in the experimental pond compared to the control pond (p<0.05). ANOVA results showed no significant variation of C.I. values between the ponds (F<sub>obs</sub> = 1.759 < F<sub>crit</sub> = 5.987) but significant variation at 5% level was observed between the culture periods. The significant variation of C.I. with time is due to the growth in biomass with time. Feeding the shrimps (*Penaeus monodon*) supplemented with *Suaeda* meal resulted in better growth and survival rate in the present programme. The percentage increase in biomass was also higher in the experimental pond than control pond (Table 3). This was also revealed by the low FCR values for experimental pond than control pond which proves the acceptance of the specially formulated feed by the shrimp species. Cost-benefit analysis (CBA) has also confirmed a higher profit percentage (Table 4).

**Pigmentation**

Colour development depends on the carotenoid content of the feed [XLI] although it has been reported that dietary carotenoids are responsible for less than 20% of the flesh pigmentation in aquatic organisms [LXVI], [LVIII]. Carotenoid pigmentation is affected by dietary pigment source, dosage level, duration of feeding, dietary composition, degree of carotenoid esterification, etc. [XXX], [IV], [VIII], [XIII], [LXXII]. Animals including fish and shrimp are unable to synthesize carotenoids but certain aquaculture species (i.e. crustaceans, omnivorous/herbivorous fish) are capable of transforming ingested carotenoids such as α-carotene and *MN Sarker et al.*
These pond species which drastically influence their environment through excreta, feed, and other waste products. Usual astaxanthin in their tissues [LVII], [XLV]. ANOVA results showed a significant variation of astaxanthin between the ponds (p<0.05) as well as between the culture periods (p<0.05) which is due to the difference in astaxanthin level in feed types. The mangrove associate-based feed had astaxanthin of 62.33±2.78 ppm, whereas the astaxanthin level in traditional feed was BDL. *Suaeda maritima* is a rich source of carotenoid [III] and hence may be the cause for high astaxanthin levels in the species of the experimental pond. Pigmentation of muscle is a major quality attributed to shrimps [VII], [XII]. Coloration of muscles in shrimps using mangrove associates such as *Suaeda maritima* as a natural pigment source may enhance the potential of *Suaeda maritima* inclusion in shrimp feed and may perhaps replace or reduce artificial colorants currently used by the industry [I], [XLVI].

**Water quality of the cultured ponds**

Aquatic parameters of the shrimp culture ponds are a reflection of the quality of feed provided to the cultured species and the condition index values symbolize the suitability of the environment for the species [XXIX]. Surface water temperature in both the culture ponds showed a more or less parallel trend of variation throughout the study period. This is reflected in the ANOVA results which showed no significant variation of the parameter between the control and experimental ponds as well as between the culture periods. The uniformity in temperature profile is due to the location of both the ponds in the same site that experience similar weather and climate. Water temperature plays a major role in shrimp enzyme kinetics which may have a regulatory influence on their growth [XXXIV]. It also affects the process of molting during the post-larval stage of shrimps [LXXIV]. In the present study, no significant relationship was observed between the condition index of shrimp and surface water temperature.

The salinity of the Hugli-Matla estuarine complex is known to exhibit intensive variations [LI]. The selected station, Canning is located in the Matla estuarine stretch, which is known for its dynamics in tidal conditions. ANOVA results showed significant variation of salinity between the ponds (p<0.05) as well as between the culture period (p<0.05). The difference in salinity between ponds may be attributed to the different soil salinity (as the substratum of the pond) that leaches soluble salt to the pond water. Between periods the difference in salinity tally’s with the feature of Indian Sundarbans, where the salinity value oscillates with the season. In general, high salinity is recorded during the premonsoon and the value falls drastically during monsoon [XXXVII], [XXXI], [XXXVI], [XXXIX], [XXXVIII], [XXXII]. In the present study, the culture period was from 15th April to 15th July’09 which encompasses both premonsoon (April to Mid June) and monsoon (Mid-June to July) seasons. The relatively higher C.I. values in the experimental pond with less salinity (4.08±0.16 psu) proves the efficiency of formulated feed in combating the stress posed by salinity which in turn increases the astaxanthin level in the cultured species [XXV], [LXV], [XV], [V], [LII]. Shrimp culture directly affects the pH of the pond bottom through the deposition of excess feed, shrimp excreta, dead shrimps, etc. These shift the soil and overlying aquatic pH towards the acidic condition. In the

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present study, such a condition was not observed at the culture site owing to the traditional practice of liming at a regular interval of time in the lower Gangetic region. ANOVA result also confirmed the above view as no significant variations of pH between the ponds as well as between the culture periods were observed. High organic carbon load was observed in the control pond due to the use of traditional feed resulting in low pH. ANOVA result shows the significant variation of organic carbon content between the ponds (p<0.05) as well as between the culture periods (p<0.05). The excreta and animal-based feed residue being the major contributors to organic load in the shrimp pond caused such variation.

Dissolved oxygen (DO) is a vital parameter regulating aquatic life. The shrimp's health is a direct function of dissolved oxygen and its diurnal variation. Excessive organic load in the system results in lowering the D.O. value posing threat to the survival of aquatic life. In the present study, the D.O. level in the control pond showed a lower value owing to the deposition of organic carbon at the bottom of the pond. ANOVA result confirmed the significant variation of D.O. between the ponds (p<0.05) and insignificant variation between the culture period. The significant variation of D.O. between ponds may be attributed to the different growth rates of the culture species and also the use of different types of feed. The traditional feed contains dry fish dust and trash shrimp dust which lowers the D.O. due to its utilization for oxidizing the residual matter. Floral-based feed, on the other hand, generates very limited residue due to which D.O. remains almost unaltered. The uniformity in D.O. over the period is attributed to the similar meteorological hydrological features of the common site.

Transparency controls the phytoplankton standing stock in shrimp culture ponds due to their dependency on solar radiation for photosynthesis. This parameter has thus a major role in regulating the phytopigment level and coloration of shrimp pond water. The formulated feed provided in the experimental pond showed increased transparency of the water due to its unique binding property. This upgraded the water quality as reflected by the high condition index values of the shrimps in the experimental pond. The above statement was confirmed by ANOVA results which showed significant variation of transparency between the ponds (p < 0.05) but no significant variation between the culture periods. The ready acceptance of the *Suaeda maritima* based feed by the cultured species in the experimental pond may be the basis of reduced suspended particulate matter in an aquatic phase that caused variation in water transparency.

Nutrients comprising of nitrate, phosphate, and silicate in the aquatic phase of the culture ponds are generated through the excretory products of the cultured species, leftover feed, and also by the churning of the pond bed (due to run-off from the adjacent landmasses). ANOVA results showed significant variation of nitrate between the ponds (p<0.05) which may be due to the leaching of the feed ingredients (particularly from an animal component in traditional feed) in pond water and also the faecal matter that generates ammonia [XXXV]. However, no significant variations between the culture periods were observed. ANOVA results for the phosphate concentration during the study period showed no significant variation between the

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ponds as well as between the culture periods owing to the complete cut-off of using the culture pond water for washing and daily activities. ANOVA results for silicate concentration showed significant variation of silicate between the ponds (p < 0.05) as well as between the culture periods (p < 0.05). The significant variation of silicate between the ponds may be attributed to different substratum or bed compositions. Between culture periods the difference is due to the seasonal fluctuation as commonly seen in Indian Sundarbans. The monsoon run-off from adjacent landmasses churns the bed materials of ponds which alters the silicate level of the aquatic phase.

Phytopigment (Chl a) is an indicator of aquatic productivity and standing stock of phytoplankton. Although a higher concentration of phytopigment signifies the eutrophic condition of water, their presence at an optimum level is healthy for shrimp growth as the phytoplankton constitute the natural diet of shrimp. In the present study, an optimum Chl a concentration and lower nutrient values in the experimental pond prove the effective utilization of nutrients by aquatic phytoplankton. ANOVA results showed no significant variation of Chl a between the ponds as well as between the culture periods, implying a healthy ambient environment of the cultured species.

V. Conclusion

Aquaculture has become a peak industry in the present millennium, which involves seafood farming with shrimp, cuttlefish, squid, lobster, and other such culinary delights cultivated in aquatic enclosures under scientifically controlled conditions. The use of nutrient-rich feed continues to gain wide acceptance in the aquaculture industry to boost up the quality of the aquacultural products. The use of quality feed results in a substantial reduction in the overall variable cost of an operation through improved animal performance, better feed conversion ratio (FCR), and improved water quality due to a reduction in the number of nutrients and solids (i.e., feces and uneaten food) in the wastewater effluent. Suaeda maritima based formulated feed showed better growth performance of the cultured species concerning condition index values and survival rate. Body pigmentation improved in the cultured species of the experimental pond and showed a significantly higher astaxanthan level than in the controlled pond. Cost-Benefit analysis (CBA) reflects the high profitability of using floral-based feed instead of the traditional feed. Considering the sea level rise and salinity increase in this geographical locale, this programme, if replicated on a mass scale can be a befitting livelihood for the islanders.

Conflict of Interest:

The authors declare that no conflict of interest to report the present study.
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