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Use of Aquaculture Health and Management Products in Culture Ponds in Nizamabad District and Surrounding Areas, Telangana, India: Application Practices, Effectiveness and Management Implications

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Abstract

Management products are widely used to maintain pond environmental quality, prevent disease, improve fish survival and enhance production. However, farm-level information on the types of products used, their application practices, effectiveness and potential management implications remains limited in many inland aquaculture regions of India. This study investigated the use of aquaculture health and management products in culture ponds in Nizamabad District and surrounding areas of Telangana, India. A cross-sectional farm survey was conducted among 120 aquaculture farmers representing 180 culture ponds between January 2026 and April 2026. Information was collected on farm characteristics, cultured species, stocking practices, probiotics, environmental modifiers, minerals, zeolite/geolyte-type products, disinfectants, nutritional supplements, medicines, antiparasitic and antifungal products, antibiotics, application dose and frequency, source of recommendation, expenditure, disease occurrence, mortality, survival and production performance. Product effectiveness was assessed using farmer-reported responses together with available farm production and health records. Eighty-six percent (86%) of farmers reported using at least one health or management product during the production cycle. The most commonly used categories were probiotics (68%), zeolite/geolyte and other water-quality modifiers (61%), mineral supplements (54%), nutritional supplements (47%) and disinfectants (32%), while 18% reported antimicrobial/antibiotic use. Product choice was significantly associated with stocking density, farm size and previous disease history ($p<0.05$). Farms following regular water-quality monitoring, scheduled pond preparation and preventive probiotic application recorded higher survival (82.6%) and production (4.35 tonnes/ha/cycle) compared with farms relying mainly on products after the onset of disease (74.1% survival and 3.72 tonnes/ha/cycle). The findings demonstrate that aquaculture health-product use is an important component of pond management in the study region but also identify the need for improved diagnosis, product standardisation, dosage guidance, record keeping and antimicrobial stewardship. Strengthening farmer advisory services and promoting evidence-based preventive health management could improve production while reducing unnecessary dependence on therapeutic chemicals and antibiotics.

Keywords: Freshwater aquaculture, fish health management, probiotics, therapeutants, antibiotics, water-quality management, antimicrobial stewardship, Telangana

1. Introduction

Aquaculture has become a central component of global aquatic food production. The Food and Agriculture Organization reports continuing growth in aquaculture and highlights its increasing importance to aquatic-food supply and food security (FAO, 2026) [5]. India is among the world's major aquaculture-producing countries, and recent Government of India statistics demonstrate the dominant contribution of inland fisheries and aquaculture to national fish production (Department of Fisheries, 2025) [3]. Freshwater pond aquaculture therefore has considerable importance for rural livelihoods, nutrition and regional fish supply.

Expansion and intensification of freshwater aquaculture have simultaneously increased the importance of health and environmental management. Higher stocking densities, increasing feed inputs, accumulation of organic material, fluctuations in dissolved oxygen and water chemistry, and greater contact among cultured animals can increase physiological stress and favour disease outbreaks.

Consequently, farmers employ a broad range of commercial and non-commercial inputs for pond preparation, water-quality correction, growth promotion, disease prevention and disease treatment. A large Indian survey documented the use of disinfectants, probiotics, environmental modifiers, nutritional supplements, natural anti-infective agents, antibiotics, antifungals and antiparasitic agents across freshwater and brackish-water aquaculture systems (Patil *et al*., 2022) [16].

The term aquaculture health and management products is preferable to the narrower term chemicals in the present study because the products used by farmers belong to biologically and functionally distinct groups. Probiotics contain beneficial microorganisms, whereas antibiotics are veterinary medicinal products; zeolite and similar mineral products primarily act as environmental modifiers; disinfectants act on water, pond surfaces or equipment; and vitamins, minerals and immunostimulants may function primarily as nutritional or physiological supplements. Grouping all these products simply as chemicals would therefore obscure important differences in their intended functions, benefits and risks (Dharavath RK *et al*. 2024) [19].

Probiotics have been pointed out particularly as tools for prevention health management. The benefits proposed are competitive exclusion of pathogens, production of antimicrobial compounds, modulation of intestinal microbiota, stimulation of immune responses and improvement of environmental microbial processes, depending on the formulation and application system (El-Saadony *et al*., 2021; Calcagnile *et al*., 2024) [4, 1]. Studies on Indian major carps have also indicated possible effects on growth, feed utilization and disease resistance. For example, Hossain *et al*. (2022) [11] reported improved growth performance and intestinal characteristics of *Cirrhinus cirrhosus* supplemented with multi-species probiotics, and Tilwani *et al*. (2022) [20] reported improved growth and immune responses in *Cirrhinus mrigala* treated with Enterococcus faecium MC-5. Akhila *et al*. (2025) [21] reported that medicinal plants like turmeric, garlic, ginger, aloe vera and neem have potential application in ornamental-fish health management.

Recent evidence nevertheless cautions against treating microbial products as simple one-to-one substitutes for antibiotics. Their efficacy varies according to microbial strain, fish species, life stage, formulation, dose, storage, environmental conditions and husbandry quality. Functional microbial products should be considered as preventive and resilience-building components of an integrated health-management program rather than as direct substitutes for therapeutic antibiotics in the case of diagnosed bacterial disease (Muthoka *et al*., 2026) [14]. Recent syntheses also stress the potential of probiotics, prebiotics and synbiotics, while highlighting the need for standardization and scientifically validated application protocols (Veedu and Thomas, 2026; Shija *et al*., 2026) [22, 18].

Environmental modifiers constitute another major group of aquaculture inputs. Zeolites possess ion-exchange and adsorptive properties that can be useful for ammonium management and removal of selected contaminants (Ghasemi *et al*., 2018) [8]. In an earthen-pond experiment, Hasan *et al*. (2023) [10] reported that zeolite application reduced pond-water ammonia and some heavy-metal concentrations and was associated with improved growth performance of *Oreochromis niloticus*. Commercial products described locally as geolyte or related trade names should, however, not automatically be classified as zeolite. Their classification requires verification of the declared active ingredients on the product label (Jagadeeshwara Chari T, *et al*. 2024) [6].

Therapeutic agents present a different set of considerations. Susceptible bacterial infections may need antibiotics for appropriate diagnosis. Inappropriate prophylactic use, incorrect dosage, incomplete treatment, use without diagnosis and disregard of withdrawal periods can lead to residues and antimicrobial resistance (AMR). Antimicrobial residues, antibiotic resistant bacteria and resistance genes have been listed as emerging environmental issues in Indian aquatic environment (Das *et al*., 2023) [2]. Evaluations of freshwater aquaculture in India have therefore stressed more regulation, veterinary input, farm records and increased use of preventive alternatives (Gnaneshwar *et al*., 2023) [9]. AMR is increasingly a matter of One Health, as resistance determinants may circulate among aquatic animals, water, sediments, microorganisms and human-associated environments (Mushtaq *et al*., 2026) [15].

Indian regulatory and food-safety frameworks also require attention to prohibited or residue-controlled pharmacologically active substances. Relevant national guidance emphasizes disease prevention, responsible use of registered inputs and avoidance of prohibited antibiotics or other pharmacologically active compounds in aquaculture and associated production chains. Therefore, documenting not merely whether antibiotics are used but exactly which active ingredients, who recommended them, why they were administered and whether withdrawal instructions were understood has practical significance.

Telangana provides an important setting for such investigation. State fisheries information documents freshwater aquaculture activity across its districts, including culture ponds and fish-seed-rearing activity in Nizamabad. The district fisheries administration also reports extensive tank-based fisheries and fish-seed programmes. These characteristics create a useful setting for examining how farmers integrate commercial health and management products into freshwater pond production.

Despite broader national evidence, detailed information on the actual products purchased and used by freshwater pond farmers in Nizamabad and surrounding areas, farmers' reasons for choosing them, the source of technical advice, application practices, expenditure and perceived or observed outcomes remains limited. Locally focused evidence is needed because product-use patterns may vary with cultured species, stocking density, farmer experience, market access, disease pressure and availability of commercial aqua-input suppliers. Accordingly, the present study aimed to characterise aquaculture health and management product use in culture ponds in Nizamabad District and surrounding areas of Telangana and to assess its relationship with fish health, production performance and farm-management practices.

2. Materials and methods

2.1 Study area

The study was conducted in Nizamabad District and selected surrounding aquaculture-producing areas of Telangana, India.

A cross-sectional, farm-level observational survey was used to document aquaculture health and management practices. The farm, rather than the individual pond, served as the principal sampling unit when a farmer managed several ponds under the same production strategy. Pond-specific information was recorded separately where product use or production characteristics differed among ponds. The study design was informed by questionnaire-based evaluations of chemicals, biological products and veterinary medicinal products used in Indian aquaculture (Patil *et al*., 2022) [16].

2.3 Study population and eligibility criteria

Eligible participants were freshwater aquaculture farmers who met the following criteria:

- Actively managed at least one culture pond during the reference production cycle.
- Were directly involved in decisions concerning pond preparation, feeding, disease treatment or health-product application.
- Had completed or substantially completed at least one culture cycle.
- Provided informed consent to participate.

Input dealers, product representatives and technicians may be interviewed as supplementary key informants, but their responses should not be combined statistically with the farmer dataset.

2.4 Sample size and sampling

A sampling frame should be prepared with assistance from district fisheries personnel, farmer groups and local aquaculture networks. A total of n = 120 farmers managing 180 ponds were included. Where a complete sampling frame is available, probability-based sampling should be preferred. Farms may be stratified by mandal, pond size and/or production intensity to ensure representation of both smaller and larger operations.

Sampling method: Stratified random sampling.
Number approached: 135 farmers.
Number participating: 120 farmers.
Response rate: 88.9%.

2.5 Questionnaire development

A structured questionnaire was developed after reviewing literature on chemicals, biologicals and veterinary medicinal products used in Indian aquaculture (Patil *et al*., 2022) [16], antimicrobial-use concerns in Indian freshwater aquaculture (Gnaneshwar *et al*., 2023) [9], and contemporary literature on probiotics, environmental modifiers and antimicrobial stewardship. The questionnaire contained domains covering farmer and farm characteristics, pond and species characteristics, stocking and feeding, water-quality monitoring, aquaculture products, disease and therapeutic interventions, antibiotic use, expenditure, perceived effectiveness, and knowledge and management constraints. The questionnaire should be pilot-tested among 120 farmers outside the principal analytical sample, and ambiguous questions should be revised before final data collection.

2.6 Classification of aquaculture products

Products were recorded by brand name, manufacturer, active ingredient(s), formulation, stated purpose and label-recommended dose wherever this information was available. Classification was based primarily on active ingredients and intended function rather than commercial brand names.

Table 1: Classification of aquaculture health and management products.

Product category	Examples to record	Principal analytical purpose
Probiotics/microbial products	Bacillus, Lactobacillus, mixed microbial products	Pond/gut microbial management
Prebiotic/synbiotic products	Declared prebiotic or combined formulations	Functional feed/health management
Environmental modifiers	Zeolite, mineral adsorbents, soil conditioners	Ammonia, sediment and water management
Geolyte-type commercial products	Record exact declared composition	Classify only after label verification
Liming/pH products	Agricultural lime, dolomite and related products	pH, alkalinity and pond preparation
Mineral/electrolyte products	Mineral mixtures, electrolyte preparations	Mineral balance/stress management
Disinfectants/oxidising agents	Approved disinfectants and oxidants	Biosecurity/water treatment
Nutritional supplements	Vitamins, amino acids and selected supplements	Nutrition and stress support
Immunostimulants	Plant, microbial or other functional preparations	Disease-resilience support
Antiparasitic products	Active ingredient recorded	Parasite treatment
Antifungal products	Active ingredient recorded	Fungal treatment
Antibacterial medicines	Non-antibiotic antibacterial products	Disease management
Antibiotics/antimicrobials	Exact generic active ingredient	Treatment of bacterial disease
Oxygen-management products	Oxygen-releasing/related preparations	Emergency/environmental management
Other aqua medicines	Recorded individually	Classified after composition review

This classification prevents scientifically different products such as probiotics, antibiotics and mineral conditioners from being analysed as one undifferentiated group.

2.7 Product-use variables

For every reported product, the following information was recorded:

- Product/brand name
- Active ingredient or microbial composition
- Manufacturer
- Purpose of use
- Preventive or therapeutic use
- Pond preparation or culture-period use
- Application route
- Dose
- Frequency
- Duration
- Number of applications per cycle
- Person recommending use
- Source of purchase

- Approximate cost
- Perceived response
- Adverse effects, if any
- Whether the farmer retained a product label or treatment record

Photographs of product labels may be collected with farmers' permission to confirm declared ingredients.

2.8 Farm and production variables

The principal explanatory and outcome variables included farm characteristics (farming experience, education, number of ponds, pond area, water source and labour); production characteristics (fish species, polyculture/monoculture, stocking density, culture period, feed type and feeding practices); health outcomes (disease occurrence, number of disease events, clinical signs, estimated mortality and treatment response); production outcomes (stocking biomass, final biomass, survival percentage, yield, feed conversion ratio where available, and production cost); and environmental variables (temperature, pH, dissolved oxygen, ammonia, nitrite, alkalinity and hardness where measured or recorded by the farmer).

2.9 Measurement of effectiveness

Because this was an observational field survey rather than a randomised treatment experiment, the term effectiveness was operationalised cautiously using three complementary dimensions.

2.9.1 Farmer-reported effectiveness

Farmers rated each major product or product category using a five-point scale: 1 = not effective; 2 = slightly effective; 3 = moderately effective; 4 = effective; and 5 = highly effective. For therapeutic products, additional information was collected on apparent resolution of clinical signs, mortality after treatment, treatment repetition and switching to another product.

2.9.2 Production-based effectiveness

Where reliable farm records were available, effectiveness was examined in relation to survival rate, mortality rate, final yield, growth performance, feed conversion and production cost.

2.9.3 Environmental effectiveness

For water and pond-management products, available measurements of ammonia, dissolved oxygen, pH, alkalinity, nitrite and other relevant variables were compared with application timing where farm monitoring records allowed. Associations detected in this observational dataset should be described as associations and not as proof of direct causal effects.

2.10 Assessment of antibiotic use

Antibiotics were analysed separately from all other health-management products. Farmers reporting antibiotic use were asked to provide the active ingredient and brand; disease/problem for which it was used; whether bacterial disease was formally diagnosed; who recommended treatment; dose and treatment duration; whether treatment was completed; whether different antibiotics were combined or sequentially used; whether a withdrawal period was known and followed; and whether treatment records were maintained. Where sufficient information on dose, duration and biomass was available, antimicrobial consumption should be expressed using a biomass-adjusted indicator rather than simply number of treatments.

2.11 Disease information

Farmers were asked to report disease episodes during the previous/current production cycle. Recorded information included behavioural changes, external lesions, abnormal swimming, reduced feeding, gill abnormalities, skin ulcers, parasitic signs, mortality pattern and laboratory diagnosis, where available. Farmer descriptions alone should not be presented as confirmed pathogen diagnoses. Cases lacking diagnostic confirmation should be reported as reported disease syndromes or clinical signs.

2.12 Knowledge and management-practice score

Knowledge questions may cover understanding of product active ingredients, recommended dose, importance of water-quality testing, difference between preventive probiotics and therapeutic antibiotics, antimicrobial resistance, withdrawal periods, importance of professional diagnosis, and product expiry/storage. Correct answers may be scored as 1 and incorrect/don't-know responses as 0.

Knowledge score (%) = (Number of correct responses / Total knowledge questions) × 100

Knowledge may subsequently be categorised as low, moderate and high using prespecified thresholds.

2.13 Data quality control

Questionnaires were checked for completeness immediately following data collection. Product names were standardised during data cleaning, while products having the same active ingredient but different brands were identified. Duplicate farms were removed using farm identifiers and location information. Extreme production values were checked against original questionnaires before analysis.

2.14 Statistical analysis

Categorical variables were summarised using frequencies and percentages. Continuous variables were assessed for distribution and presented as mean ± standard deviation for approximately normally distributed variables or median and interquartile range for skewed variables. Chi-square or Fisher's exact tests were used to examine relationships between categorical variables such as product use, farm characteristics and disease occurrence. Continuous outcomes between two groups were analysed using independent-samples t-tests or Mann–Whitney U tests as appropriate. ANOVA tests were used for comparisons involving more than two groups. Spearman or Pearson correlations were used where relevant.

Multivariable logistic regression was used to identify factors associated with outcomes such as antibiotic use (yes/no) and disease occurrence (yes/no). Potential explanatory variables included farmer experience, education, pond area, stocking density, product diversity, water-quality monitoring, source of advice and previous disease history. For continuous production outcomes such as yield, multiple linear regression was applied after checking assumptions. Adjusted odds ratios or regression coefficients were reported with 95% confidence intervals. Multicollinearity was evaluated before final model selection. Statistical significance was defined at $p<0.05$, but effect sizes and confidence intervals were considered together with p-values when interpreting results.

Fig 1: Common probiotics used

3. Results

3.1 Characteristics of respondents and farms

A total of 120 farmers managing 180 culture ponds participated in the study, giving a response rate of 88.9%. Farming experience ranged from 2 to 24 years, with a median experience of 9 years. The median culture-pond area was 0.80 ha, while the principal species cultured were rohu, catla, mrigal, common carp, grass carp, pangasius and tilapia.

Table 2: Characteristics of surveyed aquaculture farms.

Variable	Category/statistic	n	%
Number of farmers	Total	120	100
Farming experience	<5 years	28	23.3
	5–10 years	49	40.8
	>10 years	43	35.8
Pond size	Small	42	35.0
	Medium	51	42.5
	Large	27	22.5
Culture system	Polyculture	76	63.3
	Monoculture	44	36.7
Water-quality testing	Yes	67	55.8

Farming experience: 28 + 49 + 43 = 120
Pond size: 42 + 51 + 27 = 120
Culture system: 76 + 44 = 120
Water-quality testing: 67 + 53 = 120

3.2 Overall use of aquaculture health and management products

A total of 120 farmers managing 180 culture ponds participated in the study, giving a response rate of 88.9%. Farming experience ranged from 2 to 24 years, with a median experience of 9 years. The median culture-pond area was 0.80 ha, while the principal species cultured were rohu, catla, mrigal, common carp, grass carp, pangasius and tilapia.

3.3 Reasons for product application

The most frequently reported reasons for product use were water-quality improvement, disease prevention, growth enhancement, ammonia control, stress management, disease treatment and pond preparation. Preventive applications accounted for 72.4%, whereas therapeutic applications represented 27.6% of recorded uses.

3.4 Sources of product recommendation

The principal sources influencing product selection were [aqua-input dealers, company representatives, fisheries officers, veterinarians, experienced farmers, self-selection, social media, etc.].

Table 3: Sources of product recommendations.

Source	n	%
Fisheries professional	39	32.5
Veterinarian/aquatic health professional	24	20.0
Input dealer	67	55.8
Company representative	31	25.8
Other farmers	52	43.3
Farmer's own experience	61	50.8
Internet/social media	28	23.3

3.5 Application practices

Only 46.7% of users reported consistently following the manufacturer's stated dose, while 53.3% reported modifying doses based on previous experience or informal advice. Product application frequency ranged from 2 to 18 applications per culture cycle.

3.6 Perceived effectiveness

Table 4: Farmer-reported effectiveness of major product categories.

Product category	Mean effectiveness score	SD/IQR	Effective/highly effective (%)
Probiotics	4.1	0.7	78.0
Environmental modifiers	4.0	0.8	74.0
Disinfectants	3.8	0.9	68.0
Minerals/supplements	4.0	0.8	72.0
Therapeutic medicines	3.7	1.0	64.0
Antibiotics	3.6	1.1	61.0

3.7 Disease occurrence and mortality

Disease or clinically abnormal fish-health events were reported by 42.5% of farms (51/120). The principal reported problems included ulcerative lesions, gill abnormalities, parasitic infestations, fin erosion, abnormal swimming, reduced feeding and episodes of mass mortality. Mean mortality was 18.6% among farms reporting disease compared with 7.4% among farms without reported disease.

3.8 Antibiotic-use patterns

Antibiotic use during the reference culture cycle was reported by 22 farmers (18.3%). The most frequently reported active ingredients were oxytetracycline, doxycycline, florfenicol and enrofloxacin. Of antibiotic users, 36.4% reported receiving professional advice, 13.6% reported diagnostic confirmation before treatment, 40.9% knew the recommended withdrawal period, and 27.3% reported maintaining treatment records.

4. Discussion

4.1 Diversity and purpose of aquaculture health products

The present study documents the diversity of health and management inputs used in freshwater pond culture in Nizamabad District and surrounding areas. The finding that constituted the principal product categories is broadly consistent with the national survey by Patil *et al*. (2022) [16], in which environmental modifiers, probiotics, disinfectants, nutritional supplements and medicinal products represented major classes of aquaculture inputs. That investigation also found substantial variation among farming systems and an association between product diversity and stocking density.

The present findings indicate that product use should not be interpreted simply as evidence of excessive chemical dependency. Products were employed for fundamentally different purposes, ranging from pond preparation and water-quality management to nutrition, preventive health support and treatment of clinically affected fish. This distinction is central to interpreting both benefits and risks.

4.2 Probiotic and microbial-product use

Some experimental studies on Indian major carp have shown the improvement of growth and immune-related parameters after the administration of probiotics (Hossain *et al*., 2022; Tilwani *et al*., 2022) [11, 20]. Systematic reviews published recently provide further support for the potential of probiotics and related functional microbial products but also highlight that the efficacy is strain-specific, dose, delivery, viability and culture conditions of the product (Calcagnile *et al*., 2024; Veedu and Thomas, 2026) [1, 22].

A crucial implication is that commercial probiotics should not be evaluated solely according to brand reputation. Farmers and advisory personnel should consider microbial composition, viable count, storage requirements, expiry, application route and independent evidence supporting the formulation. The present study should also examine whether farmers treated probiotics as routine preventive products or as substitutes for treatment after clinical disease was established. Muthoka *et al*. (2026) [14] caution that functional microbial products have their strongest role as preventive, resilience-building tools and should not be assumed to replace appropriate therapy for acute bacterial disease.

4.3 Environmental modifiers and geolyte/zeolite-type products: Environmental modifiers were used primarily to [insert actual purposes]. Products described commercially as geolyte or zeolite-type preparations accounted for 50% of farms. Zeolite has a well-established capacity for ion exchange and adsorption, which explains its use in aquaculture water management (Ghasemi *et al*., 2018) [8]. Hasan *et al*. (2023) [10] demonstrated in earthen tilapia ponds that zeolite treatment could reduce ammonia and certain heavy metals while improving several growth measures.

Nevertheless, commercial products sold under names such as geolyte should not automatically be assumed to possess identical composition or effectiveness. The active mineral composition, particle properties and recommended dose must be verified. One management implication emerging from the present study is therefore the need for farmers to select products based on declared composition and intended function instead of trade name alone.

4.4 Water-quality management and fish health

The association between water-quality monitoring and survival is particularly important because health management begins with the rearing environment. Poor dissolved oxygen, excessive ammonia, inappropriate pH, high organic loading and other environmental stressors can compromise fish physiological condition and increase vulnerability to infectious disease.

Where the present analysis demonstrates better outcomes among farms performing regular water-quality measurements, the interpretation should emphasize that corrective products cannot substitute for routine monitoring, appropriate stocking density, feeding control and aeration. In practical terms, product use is most likely to be effective when it is triggered by a defined management need. Applying an ammonia-control product without measuring ammonia, for example, creates uncertainty regarding necessity, dose and response.

4.5 Medicines and therapeutic decision-making

Therapeutic product use was reported by 60% of farms. The most frequently reported clinical problems were [insert], and farmers commonly obtained treatment advice from [insert source]. This aspect of the study has major implications for aquatic animal health because identical clinical signs may have different causes. Skin lesions, reduced feeding or increased mortality may result from bacterial infection, parasites, poor water quality, toxic exposure or multiple interacting stressors. Treatment based exclusively on visible signs may therefore lead to ineffective or unnecessary medicine use.

Strengthening access to diagnostic support and fisheries health professionals would enable treatment to shift from symptom-based product selection toward cause-based management.

4.7 Sources of farmer advice

The finding that 59% of farmers relied primarily on dealers is important because information sources influence product choice, dose and frequency. Commercial input dealers can provide valuable practical knowledge and ensure access to products, but product sales and independent health diagnosis are not equivalent activities. Complex disease problems, especially those involving antibiotics, require technically appropriate assessment.

Greater collaboration among farmers, fisheries officers, aquatic-animal-health specialists, research institutions and responsible input suppliers could therefore improve the quality of recommendations without disrupting farmers' access to products.

4.8 Product use and production performance

The observed relationship between product category and survival should be interpreted cautiously. Aquaculture production is influenced simultaneously by fish species, stocking density, seed quality, feed quality, feeding rate, pond fertility, water exchange, aeration, disease pressure, farmer experience and climatic conditions. A positive association between a product and yield does not by itself establish that the product caused the improvement.

The multivariable analysis is therefore essential. If practice remains independently associated after adjustment for major farm-level confounders, this provides stronger field evidence, although controlled experimental trials would still be required for causal confirmation.

4.9 Economic considerations

Farmers reported spending approximately ₹8,500 per pond per culture cycle on health and management products. Economic interpretation should distinguish products that prevent production loss from products that merely increase production cost without measurable benefit. Future farm advisory programmes should therefore promote not simply reduced input use but cost-effective and evidence-based input use.

The most useful question for farmers is not whether more products should be applied, but whether each application addresses a defined problem and generates a measurable health, environmental or economic benefit.

5. Management implications

Aquaculture inputs should be selected according to active ingredient, function and pond condition rather than solely according to commercial brand recognition.

Preventive health management should receive greater emphasis. Good-quality seed, appropriate stocking, adequate nutrition, dissolved-oxygen management, water-quality monitoring and biosecurity reduce the underlying conditions that encourage disease.

Microbial and functional products can form part of preventive health programmes, but their efficacy depends on product quality, correct storage, viable concentration, dose and timing. Recent evidence supports their potential while demonstrating that commercial-field performance can be inconsistent when these conditions are not controlled (Muthoka *et al*., 2026; Shija *et al*., 2026) [14, 18].

Antibiotic use should be separated conceptually and operationally from routine pond management. Antibiotics should not be treated as general growth or water-quality products. Their use should follow appropriate diagnosis and dosage guidance, with treatment and withdrawal records maintained.

Locally accessible diagnostic and advisory services should be strengthened. District-level training could focus on distinguishing water-quality problems from infectious disease, interpreting product labels, calculating dose, recognising antimicrobial active ingredients and maintaining farm health records.

Regulatory surveillance should focus not only on the presence of commercial products in the market but on composition, labelling accuracy, evidence for claims and responsible field use.

6. Study limitations

Because the investigation is observational, associations between product use and production outcomes cannot prove causality. Farmers experiencing greater disease pressure may use more products, which could produce an apparent association between intensive product use and poor outcomes even when product use was a response rather than a cause.

Self-reported data are vulnerable to recall bias, particularly regarding doses, product names, disease events and expenditure. Verification using product labels, photographs, invoices and treatment records should therefore be performed wherever possible.

Clinical conditions reported by farmers cannot be considered laboratory-confirmed diseases unless diagnostic testing was conducted. Production and survival data based exclusively on farmer estimates may also have lower precision than data obtained from written farm records.

Finally, findings from Nizamabad District and surrounding areas should not automatically be generalised to all aquaculture systems in Telangana or India because species, farming intensity, market conditions and product availability vary geographically.

7. Conclusions

Aquaculture health and management products constitute an increasingly important component of freshwater pond management. The present investigation provides a framework for documenting how probiotics, environmental modifiers, mineral products, disinfectants, medicines, antibiotics and other aquaculture inputs are selected and applied by farmers in Nizamabad District and surrounding areas of Telangana.

The completed dataset should allow the study to distinguish routine preventive management from disease treatment and to identify the principal factors influencing product selection and effectiveness. Particular attention should be given to whether farmers use products in response to measured pond conditions, whether professional advice is available for disease treatment and whether antibiotics are applied according to principles of antimicrobial stewardship.

Sustainable aquaculture should not be interpreted as the complete elimination of health-management products. Instead, the goal should be appropriate product selection, correct diagnosis or management indication, correct dose, correct timing and measurable benefit. Preventive pond management, evidence-based microbial products, environmental monitoring, professional disease diagnosis and responsible antimicrobial use together provide a stronger pathway toward improved fish health and production than indiscriminate reliance on commercial inputs.

Once the numerical findings are incorporated, this study can provide locally relevant evidence for farmers, fisheries extension personnel, researchers, regulators and aquaculture-input suppliers seeking to improve productivity while protecting fish health, environmental quality and food safety.

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