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Perceptions of Probiotic Use Among Commercial Fish Farmers: Evidence From Jamalpur District, Bangladesh

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Abstract

Probiotics in aquaculture have gained recognition as a sustainable alternative to antibiotics, offering notable benefits such as improved fish health, enhanced water quality, and increased overall productivity. Despite these advantages, the adoption of probiotics mainly depends on farmers' perceptions. This study primarily aimed to assess commercial fish farmers' perceptions of probiotic use in aquaculture. Additionally, it identified influential factors affecting these perceptions. The research was conducted purposively in seven unions and one Pourashava of Jamalpur Sadar Upazila in Jamalpur District, Bangladesh, for its higher number of commercial fish farmers. Data were collected through face-to-face interviews with 114 randomly selected farmers using a structured questionnaire. Farmers' perceptions were measured using 18 statements rated on a 5-point Likert scale. The response options and corresponding scores were 'strongly disagree' (1), 'disagree' (2), 'no opinion' (3), 'agree' (4), and 'strongly agree' (5). Positive statements were scored as assigned, while negative statements were reverse-coded to ensure consistency in interpretation. Multiple linear and stepwise regression analyses were used to identify key influencing factors and their contributions. The findings revealed that all respondents expressed a positive perception of probiotics, with 92.1% showing a strongly favorable view and 7.9% a favorable one. Four socio-economic factors, educational level, fish farming experience, training exposure, and extension media contact, significantly influenced perception, with education being the most influential one. Based on these findings, it is recommended that the Department of Fisheries (DoF), the Bangladesh Fisheries Research Institute (BFRI), and Non-Governmental Organizations should prioritize farmer education by providing access to training and extension services to encourage the effective and widespread adoption of probiotics in aquaculture across other regions.

Categories: Aquaculture for sustainable food production, Aquatic animal health management
Keywords: aquaculture, bangladesh, commercial fish farmers, perceptions, probiotics

Introduction

Aquaculture has emerged as one of the most dynamic and rapidly expanding sectors within global animal-based food production. Currently, it contributes approximately 50% of the world's food fish supply, playing a critical role in meeting the escalating nutritional demands of a growing global population [1,2]. Bangladesh, endowed with abundant water resources and favorable agroclimatic conditions, is recognized as a global leader in freshwater aquaculture [3-5]. Ranked as the fifth-largest aquaculture-producing country in the world, Bangladesh produced 4.76 million metric tons of fish during the 2021-2022 fiscal year [6] and has achieved self-sufficiency by providing 63 g of fish per person per day, exceeding the national dietary requirement of 60 g [1,7]. Aquaculture, particularly fish farming, plays a vital role in Bangladesh's economy, contributing 3.5% to the national GDP and 25.7% to the agricultural GDP, while also serving as a crucial source of employment and food security [7]. However, with the expansion and intensification of aquaculture, the use of antibiotics to prevent and treat bacterial diseases has increased significantly [8-10]. While these approaches may be practical in the short term, their long-term use has led to concerns about the development of antimicrobial resistance, residual accumulation in aquatic habitats, and deleterious effects on fish health and human safety [11,12]. As a result, there is a growing emphasis on identifying sustainable alternatives to antibiotics for maintaining aquatic animal health [13,14]. To address the issue, probiotics have emerged as one of the most promising eco-friendly alternatives in aquaculture [15,16].

Probiotics play an essential role as environmentally sustainable agents that support the long-term success and ecological stability of aquaculture systems [16,17]. These beneficial microorganisms are typically part of the host's natural microbiota [18], including lactic acid bacteria, various *Bacillus* species, and yeasts such as *Saccharomyces* spp. They are widely applied in aquaculture to enhance growth performance, immune function, disease resistance, hematological parameters, and overall physiological condition of fish [19-21]. Furthermore, probiotics contribute to optimizing gut microbial composition, thereby facilitating the digestion and absorption of vital nutrients by enhancing enzymatic activity and nutrient bioavailability [22,23]. In terms of reproductive performance, probiotics have also been shown to significantly improve parameters such as egg output, fecundity, and fertilization success [24,25], as well as increase the survival and quality of hatched fry [26]. In Bangladesh, species such as tilapia (*Oreochromis niloticus*), rohu (*Labeo rohita*), catla (*Catla catla*), and shrimp have benefited from the use of probiotics, including *Bacillus* spp., *Lactobacillus* spp., and *Saccharomyces* spp. [27].

Despite their proven benefits, the practical use of probiotics among fish farmers mainly depends on their awareness, knowledge, and perception of these products. Studies show that many farmers either lack sufficient knowledge or hold misconceptions about different aqua drugs [7,28]. Decisions are often influenced by peer advice or informal sources rather than formal extension services, leading to inconsistent use and less effective results [29]. While extensive research has examined the technical effectiveness of probiotics in Bangladesh [7,15,30-38], little attention has been given to understanding fish farmers' perspectives, which are vital for successfully promoting and integrating probiotics into daily aquaculture practices.

Given aquaculture's vital role in rural livelihoods and national food security, understanding farmers' perspectives on probiotics is essential. Their willingness to adopt such practices depends not only on product availability but also on perceived benefits, ease of use, and the quality of information and training provided. If misconceptions or knowledge gaps exist, targeted training and extension programs can help address these issues and encourage sustainable farming. Recognizing the potential of probiotics in sustainable aquaculture and the gap between scientific advances and practical application, this study aims to explore fish farmers' perceptions of probiotics in selected areas of Jamalpur District. Specifically, it addresses the following research questions:

1) What is the current status of probiotic use in commercial fish farming?

2) What is the level of farmers' perception of probiotic use in aquaculture, and which socio-economic and farm-related factors are associated with this perception?

Materials And Methods

Study area

Jamalpur Sadar Upazila in Jamalpur District was purposively selected for this study due to its status as a leading fish-producing area with a high concentration of commercial fish farmers [37]. The upazila comprises 15 Union Parishads and 1 Pourashava, of which one Pourashava and seven unions - Meshta, Sharifpur, Ranagachha, Narundi, Ghoradhap, Sreepur, and Banshchara - were selected based on their relatively higher number of commercial fish farmers. The selection was guided by the recommendations from the Senior Upazila Fisheries Officer (SUFO) and local Extension Agent for Fisheries (LEAF).

Population and sampling

The study population included all commercial fish farmers living in Jamalpur Pourashava and the unions of Meshta, Sharifpur, Ranagachha, Narundi, Ghoradhap, Sreepur, and Banshchara under Jamalpur Sadar Upazila. The focus was on commercial fish farmers because they typically operate larger farms and produce more fish for the market, meaning their activities have a greater economic and environmental impact. A list of 162 commercial fish farmers was created with assistance from SUFO, LEAF of Jamalpur Sadar Upazila, and model farmers from the selected areas. Using the Qualtrics sample size calculator, a sample of 114 commercial fish farmers was determined, based on a 95% confidence level and a 5% margin of error [39]. Finally, a simple random sampling method was employed to select respondents from the identified population.

Data collection

The data collection process was carried out in three sequential phases: Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and structured household surveys. In the first phase, four KIIs were conducted with SUFO, LEAF, a hatchery owner, and a model fish farmer to gather contextual insights and expert opinions. These interviews helped identify local trends in probiotic use and informed the development of relevant, context-specific perception statements for the survey. In the second phase, three FGDs - each involving five fish farmers - were conducted to validate and refine the draft questionnaire in terms of clarity, relevance, and cultural appropriateness. In the final phase, face-to-face interviews were conducted with 114 randomly selected commercial fish farmers using the finalized structured questionnaire. Additionally, secondary data were collected from books, journals, theses, reports, online sources, and official documents from the Upazila Fisheries Office.

Assessment of the present status of probiotic application in fish farming

To assess the extent of probiotic use among commercial fish farmers, the structured questionnaire comprised two dedicated sections. The first section sought to identify the specific probiotic products applied by respondents, including their trade names and manufacturing companies. The second section examined the purposes of probiotic use. Farmers were provided with a set of predefined options, such as reducing gas accumulation in ponds, enhancing fish growth, improving water quality, stimulating natural food production, increasing disease resistance, and strengthening immune response, along with an “Other” category to capture additional purposes. These predefined responses were developed through preliminary consultations with fisheries extension agents and aquaculture professionals who have long-term experience working with commercial fish farmers in the study area. Multiple responses were permitted to reflect the diverse and multifunctional roles of probiotics in aquaculture.

Measurement of personal and socio-economic characteristics of fish farmers

In this study, 10 selected personal and socio-economic characteristics were considered as independent variables to investigate their potential influence on fish farmers’ perceptions of using probiotics. These variables were measured using appropriate scales and techniques suited to each characteristic, as outlined in Table *1*. Descriptive statistics - mean, standard deviation, and percentages - were used to summarize the data, as these metrics effectively highlight respondent traits and trends [40].

Farmers’ characteristics	Measuring unit
Age	Years
Educational level	‘1’ for each year of schooling; ‘0’ for no schooling
Household size	Numbers (No)
Fish farming experience	Years
Area under fish farming	Hectare (Ha)
Annual family income	Bangladeshi Taka (BDT)
Credit received	Bangladeshi Taka (BDT)
Training exposure in fish farming	Days
Organizational participation	Scale score
Extension media contact	Scale score (0-42)

TABLE 1: Measurement of the socio-economic and personal characteristics of the farmers

Measurement of commercial fish farmers’ perception of probiotics use

Perception refers to the cognitive process through which individuals organize and interpret sensory information [41]. To assess farmers’ perceptions of using probiotics, a scale was developed based on the summated rating method proposed by Likert and Edwards [42,43]. Eighteen carefully crafted statements were created to address different aspects of probiotic use. Nine of these statements were positively worded, while nine were negatively worded. Each statement was rated on a five-point Likert scale to measure the respondents’ level of agreement. The response options and their scores for positive statements were Strongly Agree (5), Agree (4), No Opinion (3), Disagree (2), and Strongly Disagree (1) [44-47]. For negative statements, the scoring was reversed [42]. The internal consistency of the scale was tested using Cronbach’s alpha, and a value of 0.79 indicated acceptable reliability.

The overall perception score for each respondent was calculated by summing the scores across all 18 items, yielding a possible range from 18 to 90, where 18 indicated strong disagreement and 90 indicated strong agreement. To facilitate interpretation, respondents were categorized into five groups based on their perception scores: "strongly unfavorable" (18 to 35), "unfavorable" (36 to 53), "no opinion" (54), "favorable" (55-72), and strongly favorable" (above 72) based on their perception score. The categorical classification of perception scores was used solely for descriptive interpretation, whereas inferential analyses were performed using the continuous total score. Additionally, the perception score for each statement was calculated by using the following formula [48,49]:

$$\text{Total score of a statement} = PSA \times 5 + PA \times 4 + PNO \times 3 + PDA \times 2 + PSDA \times 1$$

where,

PSA = Number of respondents who selected “Strongly Agree”

PA = Number of respondents who selected “Agree”

PNO = Number of respondents who selected “No Opinion”

PDA = Number of respondents who selected “Disagree”

PSDA= Number of respondents who selected “Strongly Disagree”

For negative statements, the same formula was applied with reversed scoring to ensure consistency in interpretation [42]. The internal consistency of the perception scale was not assessed using Cronbach’s alpha. As the scale was self-developed and intended to capture multiple aspects of farmers’ perceptions regarding probiotic use, the analysis primarily relied on descriptive and inferential statistics. This represents a methodological limitation of the study.

Measurement of factors influencing commercial fish farmers’ perception of using probiotics

Multiple linear regression analysis was conducted to determine the socio-economic factors that significantly influence farmers’ perceptions of probiotic use. In addition, stepwise regression was employed to determine the most influential factors by removing non-significant variables, thereby highlighting the contribution of each significant predictor [50]. The total perception score derived from the 18 Likert-scale statements was used as a continuous dependent variable in the multiple linear regression analysis. Prior to analysis, all relevant regression assumptions were examined and found to be satisfactory. The multiple regression analysis equation is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + e$$

where,

Y = Dependent variable (fish farmers’ perception of using probiotics), β_0 = Regression coefficient, X = Independent variables, viz. X_1 = Age, X_2 = Educational level, X_3 = Household size, X_4 = Area under fish farming, X_5 = Fish farming experience, X_6 = Annual family income, X_7 = Organizational participation, X_8 = Training exposure in fish farming, X_9 = Credit received, X_{10} = Extension media contact, and e = Error term.

Analysis of data

Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) was used to encode and process the information gathered from the questionnaire surveys. Descriptive statistics, including frequency, mean, percentage, and standard deviation, as well as inferential statistical analyses, such as stepwise multiple-linear regression, were employed using the Statistical Package for the Social Sciences (SPSS, v. 25).

Results And Discussion

Use of probiotics in fish farming by the fish farmers

Commercial fish farmers in the study area reported using a range of probiotic products, with seven prominent brands identified. Pond Care, manufactured by SK+F, was the most widely used product, adopted by 68.4% of respondents. This was followed by Ecorich (57%) by Opsonin, Gasonil (47.3%) by SK+F, Soil Care (35%) by SK+F, and Safegut (33.3%) also by SK+F. Additionally, Bio Aqua (30.7%) by EON and Yucca Plus (21.9%) by ENOK were reported as the most commonly used products (Figure *1*). These usage patterns reflect farmers’ preferences, primarily shaped by personal experience and their perception of product effectiveness. Consistent with these findings, Hossain et al. [7] reported that SK+F’s Pond Care and Safegut were among the most widely used probiotics in their study. The active ingredients and primary functions of these probiotic products, as stated on their packaging labels, are presented in the following Table *2*.

FIGURE 1: Most commonly used probiotics by the fish farmers

Trade name	Active ingredients	Functions
Pond Care	*Bacillus subtillis*, *Bacillus licheniformis*, *Bacillus polymyxa*, *Bacillus pumillus*, *Bacillus megaterium*, *Bacillus coagulans*, *Bacillus amyloliquefaciens*, *Aspergillus niger*, *Aspergillus oryzae*	Facultative probiotics are highly effective and exhibit strong potency in aquaculture systems by reducing water hardness, increasing dissolved oxygen levels, controlling excessive plankton proliferation, and lowering turbidity. Their application minimizes the need for frequent pond water exchange. Moreover, *Bacillus* spp. serve as an important food source for zooplankton and aquatic larvae, thereby contributing to improved pond ecology and enhanced aquatic productivity
Ecorich	Zeolite, probiotics, yucca	Increases the production of plankton, balances soil and water pH levels, inhibits the growth of harmful microorganisms, and reduces the release of toxic gases
Gasonil	*Bacillus subtillis*, *Bacillus licheniformis*, *Bacillus polymyxa*, *Bacillus megaterium*, *Bacillus coagulans,* Yucca30%	Prevents the growth of detrimental microorganisms, used as a growth promoter, increases disease resistance, prevents bacterial and viral diseases in fish, removes stress and ammonia, and acts as a buffering agent to control pH. It also improves the immunity of fish, shrimp, and crab
Soil Care	Comprising super potassium humate, fulvic acid, carboxylic acid, carbohydrates, seaweed extract, active l-amino acids, natural plant hormones, and enzymes	Bad-smelling black clay removes odorous, harmful gases and reduces the growth of harmful bacteria
Safegut	Non-antibiotic, eco-friendly bioproducts, probiotics, vitamins, and enzymes	Used as a growth promoter and for rapid digestion
Bio Aqua	*Rhodopseudomonas* spp., zeolite	Creation of favorable conditions in the water body, and breakdown of complex components
Yucca Plus	Yucca, Schidigera plant extract	Ammonia gas remover

TABLE 2: Commonly used probiotics with composition and functions mentioned on the label of the packet

However, in most cases, farm owners did not have a clear understanding of the specific functions of these probiotics. Although many farmers could not accurately identify the intended role of individual probiotic products, they generally knew the overall benefits and outcomes associated with their use. Typically, when problems occurred, company representatives - often working with local dealers or traders - recommended different probiotic formulations. Notably, all farm owners (100%) reported using probiotics to reduce gas buildup in ponds (Figure *2*). Additionally, a significant number of farmers mentioned other reasons for probiotic use, including promoting fish growth (75.40%), improving water quality (64.90%), enhancing natural food production (51.70%), increasing disease resistance (35%), boosting immune response (35%), and addressing other needs (26.30%) such as improving production and managing soil conditions.

FIGURE 2: Purpose of using probiotics in fish farming

Socio-economic and personal characteristics of the respondents

Table *3* presents the personal and socio-economic characteristics of the respondents. Among the respondents, the vast majority (86.3%) were in the middle-aged category, followed by younger farmers (10.8%). Regarding educational attainment, the largest proportion of farmers (29.8%) had completed higher secondary education, while 28.1% had pursued education beyond that level. This suggests that most respondents had a relatively strong educational background. Education is crucial in enabling farmers to understand technical procedures and effectively address challenges in aquaculture [51].

Characteristics	Possible (observed) score	Categories	Respondents (n=114)		Mean	SD
			Number	Percentage		
		Young (18-35)	11	10.8		

Age	Unknown (29-62)	Middle (36-55)	88	86.3	48.92	7.35
		Old (above 55)	3	2.9		
		Illiterate (0)	6	5.3		
		Primary (1-5)	11	9.6		
Level of education	Unknown (0-18)	Secondary (6-10)	31	27.2	11.15	4.59
		Higher secondary (10-12)	34	29.8		
		Higher education (>12)	32	28.1		
		Small (2-4)	38	33.3		
Household size	Unknown (3-11)	Medium (5-7)	71	62.3	5.23	1.35
		Large (above 7)	5	4.40		
		Small (0.2-1.00 ha)	8	7.00		
Area under fish farming	Unknown (0.2-8.0)	Medium (1.01-2.00 ha)	81	71.1	2.24	1.25
		Large (above 2 ha)	25	21.9		
		Low (up to 11)	19	16.7		
Fish farming experience	Unknown (5-37)	Medium (11-22)	49	43.0	20.40	7.84
		High (above 22)	46	40.3		
		Low (up to 400)	0	0		
Annual family income (‘000’ Taka)	Unknown (1,000-7,000)	Medium (400-1,000)	2	1.2	2581	1057
		Large (above 1,000)	112	98.8		
		No participation (0)	17	14.9		
		Low (1-3)	97	85.1		
Organizational participation	Unknown (0-6)	Medium (4-6)	0	0	1.89	1.39
		High (above 6)	0	0		
		No training (0)	17	14.9		
		Short duration (1-2 days)	6	5.3		
Training exposure in fish farming	Unknown (0-20)	Medium duration (3-4 days)	32	28.1	11.81	9.78
		Long duration (above 4 days)	59	51.8		
		Not received (0)	8	7.0		
		Low (1-150)	77	67.5		
Credit received (‘000’ Taka)	Unknown (0-500)	Medium (150-300)	24	21.1	128.64	102.01
		High (above 300)	5	4.4		
		Low (up to 14)	88	77.2		
Extension media contact	0-42 (8-28)	Medium (15-28)	26	22.8	13.42	4.13
		High (above 28)	0	0		

TABLE 3: Socio-economic and personal characteristics of the respondents

SD, Standard Deviation

Regarding household size, over half (62.3%) of the respondents were from medium-sized households, followed by 33.3% from small households. Most farmers (71.1%) managed medium-sized fish farms averaging 2.24 hectares, while nearly a quarter (24.9%) had larger farm holdings. In assessing farming experience, 43% of the farmers had medium experience, while 40.3% had high experience. Experience is a critical factor in successful aquaculture management, as it enables farmers to anticipate better production trends and market demands [51,52]. The vast majority of commercial fish farmers (98.8%) fall into the large income category, earning above 1,000 thousands BDT annually, suggesting overall economic stability among the fish farmers. In terms of access to financial support, a majority (67.5%) received a low amount of credit, and only a small number (7.0%) had not accessed any credit at all. Organizational participation was generally limited, with 85.1% of respondents reporting low involvement and none reporting medium or high levels of participation. Training exposure data revealed that most respondents (85.1%) had participated in some form of training, with over half (51.8%) having attended long-duration programs lasting more than four days. Training is essential for enhancing farmers' capabilities in managing aquaculture practices efficiently and improving productivity [53]. Finally, 77.2% of respondents had low levels of contact with extension media, and no farmers reported high contact.

Respondents’ perception of probiotics use in fish farming

The primary focus of the study was to assess fish farmers’ perception of using probiotics in fish farming. Perception scores among the respondents ranged from 63 to 76, within a possible score range of 18 to 90. The mean perception score was 68.56 with a standard deviation of 3.08, indicating a generally favorable perception across the sample (Table *4*).

Categories of farmers	**Respondents (n=114)**		**Mean**	**SD**
	Number	Percent		
Strongly unfavorable (18-35)	0	0	68.56	3.08
Unfavorable (36-53)	0	0		
No opinion (54)	0	0		
Favorable (55-72)	105	92.1		
Strongly favorable (73-90)	9	7.9		

TABLE 4: Distribution of respondents based on their perception of probiotics use in fish farming

SD, Standard Deviation

The findings revealed that a vast majority of fish farmers (92.1%) had a favorable perception of probiotic use, while 7.9% had a strongly favorable perception. Notably, none of the respondents fell into the unfavorable, strongly unfavorable, or neutral perception categories. Several factors may account for the overwhelmingly positive perception of probiotic use among the respondents. One possible explanation might be their prior positive experiences with probiotics, which likely led to tangible benefits in fish health, growth, and overall farm productivity [7]. In addition, several socioeconomic and personal characteristics of the respondents, such as most respondents having strong educational backgrounds, substantial training exposure, extensive farming experience, moderate to large farm sizes, and overall economic stability of the majority of respondents, may have collectively contributed to their favorable perceptions [54].

Research on farmers’ perceptions of probiotic use in aquaculture remains limited. However, Hossain et al. [7], in a survey of 200 commercial fish farmers across four regions of Bangladesh, found that while some confusion existed about the specific functions of probiotics, most respondents used them to enhance fish growth. Many also reported benefits such as reduced mortality, improved water quality, and decreased gas accumulation - indicating an overall favorable perception. Similarly, Rasul et al. [55] found that a significant number of farmers were using probiotics as alternatives to antibiotics, reporting approximately 20% higher fish growth, up to 30% lower production costs per cycle, and fewer disease outbreaks compared to non-users. These findings suggest that an increasing number of fish farmers are adopting probiotics due to their perceived benefits.

The overwhelmingly favorable perceptions observed in this study reflect farmers’ positive experiences and expectations regarding probiotic use. However, as the present study focused on perceptions rather than measured performance, it is important to note that the literature reports several practical challenges associated with probiotic application. For example, the effectiveness of probiotics can vary by species, strain, and environmental conditions, making outcomes less predictable in diverse aquaculture systems [56]. Additionally, variability in dosing strategies and inconsistent quality control of commercial products remains a major bottleneck for large-scale adoption [57]. Finally, gaps in knowledge about appropriate application methods and limited technical guidance can hinder effective use at the farm level [58]. Acknowledging these aspects provides important context for interpreting producers' perceptions. Therefore, while the respondents' perceptions are highly positive, extension services and targeted training may be necessary to ensure effective use and to manage expectations regarding potential limitations.

Fish farmers' perceptions of using probiotics in fish farming were evaluated and ranked based on their Perception Index (PI) scores (Table *5*). The statement "Probiotics help to improve water quality and reduce harmful bacteria in fishponds", with 114 farmers strongly agreeing, ranked first. This result aligns with the findings of Hossain et al. [7], who reported that many farmers recognized probiotics as effective in enhancing water quality. Probiotics contribute to water quality improvement by reducing toxic compounds and stabilizing environmental parameters. Supporting this, Ogello et al. [59] found that lactic acid bacteria decreased ammonia and nitrate levels by 35%, thereby improving water clarity. Angoua et al. [60] also demonstrated that *Bacillus subtilis* and *Saccharomyces cerevisiae* reduced organic waste by 25% and helped stabilize pH and oxygen levels.

Sl. No.	Statements	No. of respondents					PI	Rank order
		Strongly agree	Agree	No opinion	Disagree	Strongly disagree		
1 (+)	Probiotics help to improve water quality and reduce harmful bacteria in fishponds.	114	0	0	0	0	570	1
2 (+)	Probiotics use on regular interval enhanced digestion results in better feed conversion rates, leading to faster fish growth.	106	8	0	0	0	562	3
3 (+)	Reducing disease outbreaks decreases mortality rates, leading to higher yields.	89	25	0	0	0	545	7
4 (+)	The use of probiotics boosts the immune system, helping fish resist diseases caused by pathogens.	60	54	0	0	0	516	9
5 (+)	Probiotics reduce toxic gases such as ammonia and nitrites in fishponds and reduces the risk of water pollution and eutrophication.	100	14	0	0	0	556	6
6 (+)	Lower levels of harmful bacteria lead to a healthier aquatic environment.	63	49	2	0	0	517	8
7 (+)	The use of probiotics can help maintain optimal pH levels and improve water clarity in fishponds.	53	58	3	0	0	506	10
8 (+)	Probiotics improve fish reproductive performance, leading to better seed production	1	34	76	3	0	375	12
9 (+)	Reduce the need for antibiotics, lowering the risk of antibiotic resistance.	110	4	0	0	0	566	2
10 (-)	Some probiotics may not work as expected in all farming systems.	31	45	0	37	1	274	14
11 (-)	Quality probiotic products can be expensive, increasing operational costs for small-scale farmers.	29	67	1	14	3	237	16
12 (-)	Continuous use is needed to maintain benefits, adding to long-term expenses	3	61	2	38	10	333	13
13 (-)	Poor-quality probiotics or improper handling can introduce harmful bacteria instead of beneficial ones.	20	43	42	9	0	268	15
14 (-)	Excessive use of probiotics may disrupt the natural microbial balance in water and fish intestines.	49	64	1	0	0	180	18
15 (-)	Contaminated probiotics may lead to disease outbreaks rather than preventing them.	0	10	29	24	51	485	11
16 (-)	Many probiotics require specific storage conditions (e.g., refrigeration) to remain effective.	0	0	0	10	104	570	4
17 (-)	Probiotics are not widely available in local markets.	0	0	0	12	102	558	5
18 (-)	Farmers expecting immediate disease control may be disappointed.	2	108	1	1	2	235	17

TABLE 5: Rank order of the statements related to farmers' perception of using probiotics in fish farming

PI, Perception Index

The second-highest ranked statement was "Probiotics reduce the need for antibiotics, lowering the risk of antibiotic resistance", with 110 farmers strongly agreeing and four agreeing. This perception is consistent with the findings of Pereira et al. [61], who reported that the application of probiotics in aquaculture can significantly reduce dependency on antibiotics, thereby mitigating the risk of antibiotic resistance. In addition, Maisey et al. [62] noted that probiotic-fed fish exhibited lower stress and stronger immune responses during handling and transport, indicating their role in alleviating immune suppression caused by environmental stressors. Akhter et al. [63] further emphasized that probiotics such as *Bacillus subtilis* and *Lactobacillus plantarum* reduce harmful bacterial populations through competitive exclusion, thereby improving fish health.

The third-ranked statement was "Regular use of probiotics enhances digestion, resulting in better feed conversion rates and faster fish growth". This finding aligns with the studies by Rasul et al. [55] and Hossain et al. [7]. Aini et al. [64] found that *Bacillus subtilis* and *Lactobacillus casei* significantly improved growth and survival rates in *Clarias gariepinus* under conditions of challenge by *Aeromonas hydrophila*, with a 40% increase in growth and a 35% higher survival rate. Similarly, Aslam et al. [65] reported that the inclusion of probiotic-supplemented fermented soybean meal in the diet of *Labeo rohita* reduced the feed conversion ratio by 20%, thereby enhancing feed efficiency and promoting faster growth.

Factors influencing respondents' perception of probiotics use in fish farming

The regression results, along with the collinearity diagnostics, are presented in Table 6. Since all variance inflation factor values were below the threshold of 10, multicollinearity was not a concern in the model. The multiple regression analysis identified four variables as statistically significant predictors of farmers' perception: level of education ($t = 6.769$, $p < 0.05$), fish farming experience ($t = 2.118$, $p < 0.05$), training exposure on fish farming ($t = 2.229$, $p < 0.05$), and extension media contact ($t = 3.412$, $p < 0.05$). The model yielded an adjusted R^2 of 0.575, indicating that these variables collectively explained 57.5% of the variation in farmers' perceptions. The overall regression model was significant ($F = 16.289$, $p < 0.001$), confirming a good fit to the data.

Explanatory variables	Unstandardized co-efficient		Standardized co-efficient	t value	Sig.	Collinearity statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	59.036	1.651		35.753	.001	.434	2.303
Age	.018	.039	.043	0.466	.642	.738	1.354
Level of education	.325	.048	.483	6.769	.001*	.847	1.181
Household size	.037	.152	.016	0.243	.808	.424	2.358
Fish farming experience	.085	.040	.199	2.118	.037*	.598	1.673
Area under fish farming	.013	.196	.005	0.066	.948	.586	1.708
Annual family income	.000	.000	.041	.514	.608	.835	1.198
Credit received	.000	.000	-.130	-1.935	.056	.768	1.302
Training exposure on fish farming	.051	.022	.161	2.299	.024*	.784	1.275
Organizational participation	.142	.153	.064	0.929	.355	.766	1.306
Extension media contact	.178	.052	.239	3.412	.001*	.434	2.303

TABLE 6: Summaries of the linear multiple regression analysis

n = 114, R = 0.783, R2 = 0.613, Adjusted R square = 0.575, F-value = 16.289

VIF, Variance Inflation Factor

* indicates significance at 5 percent level.

Level of education was positively and significantly associated with farmers' perception of using probiotics. Specifically, for each additional year of education, the perception score increased by 0.325 units. Education enhances farmers' awareness and openness toward adopting probiotics [66]. Educated farmers may better understand the benefits, application methods, and long-term advantages of probiotics in improving fish health and productivity. Kumar et al. [67] similarly identified education as a key factor influencing the adoption of technology in aquaculture.

Fish farming experience also showed a strong and positive link with perception. The analysis revealed that each additional year of experience was tied to a 0.085-unit rise in perception score. This implies that experienced farmers are more open toward using probiotics in their practices. It could be due to better understanding, increased exposure to probiotics, and a greater appreciation for their benefits over time. This finding aligns with the results of Islam et al. [38,68], who stated that farming experience significantly influences the adoption of modern aquaculture practices.

Training exposure was found to be another significant and positively related factor. An increase of one unit in training exposure corresponded to a 0.051-unit increase in farmers' perception scores. Training often includes real-life case studies, demonstrations, or success stories [69]. This exposure may increase farmers' awareness of the practical benefits of probiotics, leading to a more positive attitude toward their use. Additionally, training can help shift traditional mindsets and foster openness to new, sustainable practices [70]. Obeiro et al. [54] found that attendance at extension training was a significant positive predictor of adoption of improved fish farming practices in Kenya.

The extension media contact also emerged as a significant and positive predictor, with each unit increase associated with a 0.178-unit rise in the perception score. Extension media serve as critical channels for disseminating reliable, up-to-date information about aquaculture technologies, including the use of probiotics. Consistent exposure to such media helps reinforce positive attitudes, fosters behavioral change, and enhances the credibility and acceptability of new practices among farmers. Chowdhury et al. [71] found that fish farmers who maintained contact with public fisheries extension services showed significantly better attitudes toward sustainable practices, greater knowledge levels, and higher farm incomes compared to those without such contact.

A stepwise multiple regression analysis was conducted to evaluate the key variables affecting fish farmers' perceptions of using probiotics (Table 7). The results revealed that education level was the most significant factor, explaining 42% of the variation in perception. Adding fish farming experience increased the explained variance by an additional 9.9%, highlighting its important role. Including contact with extension media contributed another 4.4%, while exposure to training in fish farming added a modest 1.4% to the model. These findings suggest that education is the most important factor in shaping farmers' understanding and perceptions of probiotics. Educated farmers are more likely to recognize the benefits of probiotics and be better able to process and apply relevant information, as supported by Mardy et al. [72].

Model	Combination of the factors	Co-efficient of determination	Adjusted R^2	Percent of increase in adjusted R^2
1	Constant + Level of education	.652	.420	42
2	Constant + Level of education + Fish farming experience	.726	.519	9.9
3	Constant + Level of education + Fish farming experience + Extension Media contact	.758	.563	4.4
4	Constant + Level of education + Fish farming experience + Extension Media contact + Training exposure on fish farming	.769	.577	1.4

TABLE 7: Step-wise multiple regression analysis for the perception of fish farmers of using probiotics

Conclusions

The commercial fish farmers in the study area generally held strongly favorable perceptions toward the use of probiotics in aquaculture. Most respondents acknowledged the positive effects of probiotics, while many disagreed with statements expressing negative views, reinforcing their overall positive outlook. This positive attitude may be attributed to the perceived benefits that farmers consistently experience through using probiotics in their farming operations. These benefits include improved fish health and survival rates, better water quality, faster growth, more efficient feed use, and improved overall pond management. Such outcomes not only boost productivity and profitability but also strengthen farmers' confidence in probiotics, leading to their continued and regular use in aquaculture. The most common probiotic products used were Pond Care (68.4%), Ecorich (57%), Gasonil (47.3%), Soil Care (35%), Safegut (33.3%), Bio Aqua (30.7%), and Yucca Plus (21.9%). While farmers used these products for various reasons, all respondents (100%) reported applying probiotics mainly to reduce gas buildup in ponds. Although many farmers could not specify the specific functions of each probiotic product, they showed a general awareness of their wider benefits. To improve efficiency and maximize benefits, targeted training and clear guidance on the specific functions and proper use of each probiotic are recommended.

The multiple regression analysis identified four key socio-economic factors that significantly influenced farmers' perceptions of probiotic use: level of education, fish farming experience, training exposure in fish farming, and extension media contact. These factors together explained 57.5% of the variation in farmers' perceptions. Among them, education (42%) proved to be the most influential factor, indicating that more educated farmers are more likely to understand and recognize the benefits of probiotics quickly and effectively. The findings emphasize the importance of strengthening farmer education by expanding training opportunities and improving extension outreach, such as regularly distributing informational leaflets, organizing awareness campaigns, conducting method demonstrations and result demonstrations, and holding field days to educate farmers regarding probiotic use. Relevant authorities, including the Department of Fisheries and NGOs, should prioritize these factors when designing and implementing programs to promote probiotic adoption in other regions of Bangladesh. Future research could build on these findings by exploring the actual effectiveness and cost-benefit outcomes of different probiotic products under diverse aquaculture conditions. Longitudinal studies assessing the long-term impacts of probiotic use on fish health, growth performance, and pond ecosystem quality would help validate farmers' perceptions. In addition, investigations into barriers to adoption, optimal dosing strategies, and species-specific effects could provide practical guidance for improving probiotic use. Comparative studies across different regions and production systems would further enhance understanding of how socio-economic and environmental factors influence farmers' perceptions and adoption of probiotics in aquaculture.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Data Availability Statements

The datasets (and/or code) supporting this study are available from the corresponding author upon reasonable request.

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