IMPACT OF SUBSIDY ON THE ECONOMIC VIABILITY OF BIOFLOC FISH FARMING: AN ANALYSIS OF PMMSY IN KERALA

MS (Research) Thesis

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SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **IMPACT OF SUBSIDY ON THE ECONOMIC VIABILITY BIOFLOC FISH FARMING: AN ANALYSIS OF PMMSY IN KERALA** in the fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (RESEARCH)** and submitted in the **SCHOOL OF HUMANITIES AND SOCIAL SCIENCES, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from August 2021 to June 2023 under the supervision of Prof. Pritee Sharma, Professor, School of Humanities and Social Sciences, Indian Institute of Technology Indore.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

11/12/2024

AMRUTHA A A

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

December 20, 2024

Prof. Pritee Sharma
Thesis Supervisor

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DEDICATION

To Amma, Achan and Kunchechi.

Table of Contents

Table of Contents ---------- vi

Lists of Tables ---------- viii

List of Figures ---------- viii

ABSTRACT ---------- x

ACRONYMS ---------- xii

Chapter 1. INTRODUCTION ---------- 1

1.01 Introduction ---------- 1

1.02 Importance of Fisheries and Aquaculture ---------- 2

1.03 Fisheries and Aquaculture Scenario: Global Level ---------- 5

1.04 Fisheries and aquaculture scenario: India ---------- 8

1.05 Fisheries and aquaculture scenario: Kerala ---------- 12

1.06 Research Questions ---------- 17

1.07 Research Objectives ---------- 17

1.08 Organization of Thesis ---------- 17

1.09 Conclusion ---------- 19

Chapter 2. REVIEW OF LITERATURE ---------- 21

2.01 Introduction ---------- 21

2.02 Techno- economic feasibility of RAS and Biofloc Technologies ---------- 21

2.03 Consumer Preference ---------- 27

2.04 Subsidies ---------- 31

2.05 Literature Gap ---------- 35

2.06 Conclusion ---------- 36

Chapter 3. METHODOLOGY -- 37

3.01 Introduction -- 37

3.02 Study Area -- 38

3.03 Work flow of the study -- 40

3.04 Calculation of ROI -- 41

3.05 Consumer Preference -- 44

3.06 Conclusion -- 45

Chapter 4. DATA ANALYSIS -- 47

4.01 Introduction -- 47

4.02 Socio-economic Profile of the Fish Farmers -- 49

4.03 Economic Viability: Biofloc -- 53

4.04 Economic Viability: RAS -- 57

4.05 Consumer Preferences towards Farmed Fishes -- 60

4.06 Conclusion -- 67

Chapter 5. FINDINGS AND POLICY SUGGESTIONS -- 68

5.01 Introduction -- 68

5.02 Bio floc and RAS: Comparison -- 70

5.03 Summary of Data Collected From Co-Ordinator's of PMMSY Project -------- 72

5.04 Consumer's Preference towards Farmed Fish -- 73

5.05 Policy Suggestions -- 74

5.06 Conclusion -- 76

REFERENCES -- 78

Lists of Tables

Table 1-1. Fish production in Kerala from the year 1997-98 to 2015-16 (In lakh tons) (Source: Department of Fisheries, Govt. of Kerala. (Numbers in parentheses show percentage to total production). 14

Table 1-2. Share of Fisheries sector in Gross State Domestic Product from the year 2005-06 to 2016-17 (Source: Department of Fisheries, Govt. of Kerala) 15

Table 4-1. District wise distribution of fish farmers (Source: Primary Survey). 49

Table 4-2. Biofloc with subsidy (Source: Author's calculation based on Primary data). 53

Table 4-3. Biofloc without subsidy (Source: Author's calculation based on Primary data). 54

Table 4-4. RAS with subsidy (Source: Author's calculation based on Primary data). 57

Table 4-5. RAS without subsidy (Source: Author's calculation based on Primary data. 58

Table 4-6. socio economic characteristics of Consumers (Source: Primary Survey). 60

Table 4-7. Fish consumption pattern of Consumers (Source: Primary Survey). 62

Table 4-8. Preference towards various fish items (Source: Primary Survey). 64

Table 4-9. Factors affecting fish purchasing (Source: Primary Survey). 65

Table 4-10. Consumer's perception about farm raised freshwater fish (Source: Primary Survey). 66

List of Figures

Figure 1-1. World capture fisheries and aquaculture production (Source: FAO 2022) 6

Figure 1-2. Regional contribution to world capture fisheries and aquaculture production (Source: FAO 2022) 7

Figure 1-3. World aquaculture production, 1991–2020 (Source: FAO 2022) 8

Figure 1-4. Fish production in India (Source: https://dof.gov.in) 11

Figure 1-5. Fish production in India from 2005-06 to 2018-19 (Source: Ministry of Fisheries, Animal Husbandry and Dairying Govt. of India) 12

Figure 1-6. Inland fish production in Kerala (Quantity and Value) (Source: Department of Fisheries, Govt. of Kerala) 15

Figure 3-1. Study Area: Kerala (Source: Author's own compilation) 39

Figure 3-2. Workflow of the thesis (Source: author's own compilation) 41

Figure 3-3. Methodology of ROI calculation (Source: Author's own compilation). 44

Figure 4-1. Age of the farmers. 51

Figure 4-2. Gender of the farmers. 51

Figure 4-3. Religion of the farmers. 51

Figure 4-4. Caste of the farmers. 51

Figure 4-5. Occupation of the farmers 52

Figure 4-6. Annual Income of the farmers. 52

Figure 4-7. Land ownership 52

Figure 4-8. Education level of farmers. 52

Figure 4-9. Correlation matrix: Biofloc. 56

Figure 4-10. Correlation matrix: RAS. 59

ABSTRACT

Fisheries and aquaculture play a significant role in global development, providing employment, food security, and economic growth. The Indian state of Kerala, with its extensive coastline and brackish water bodies, has a thriving fisheries sector that supports the livelihoods of coastal communities. In an effort to promote sustainable development and enhance fish production, the Indian government has implemented the Pradhan Mantri Matsya Sampada Yojana (PMMSY) scheme, which includes subsidies for biofloc and Recirculating Aquaculture System (RAS) fish farming techniques. This study examines the economic viability of these techniques in Kerala under the PMMSY scheme and explores the challenges faced by fish farmers.

Primary data was collected from 293 beneficiaries of the biofloc fish farming scheme and 188 beneficiaries of the RAS fish farming scheme through a structured questionnaire. The data covered various aspects, including investment costs, operational expenses, production output, revenue, and profitability. Return on Investment (ROI) analysis was employed to evaluate the financial feasibility of these ventures.

The findings indicate that both biofloc and RAS fish farming techniques have resulted in negative ROI values, suggesting their current economic inviability. The high costs associated with infrastructure setup, equipment, and operational expenses have led to significant net losses for fish farmers. The lack of proper guidance and support from the fisheries department, as well as a lack of awareness about subsidy details, contribute to the challenges faced by farmers. Discrepancies in subsidy allocation, including the requirement of proper documentation, and the quality of seedlings provided by the fisheries department further exacerbate the economic challenges.

To address these issues and enhance the viability of fish farming, several policy recommendations are proposed. Increasing subsidy and loan support, along with technical assistance and research support, can provide the necessary financial resources and knowledge to improve infrastructure, productivity, and overall profitability. The establishment of marketing and distribution channels, including collaborations with retailers and exploring direct-to-consumer sales channels, can ensure the availability and accessibility of fresh fish products. Quality control and certification programs are crucial in building consumer trust and encouraging

demand. Setting standards for fish farming practices, certifying organic fish, and implementing labeling requirements for freshwater fish can ensure the availability of safe and high-quality fish products.

Awareness and education programs are recommended to educate the public about the nutritional value of freshwater fish and the benefits of consuming organically produced fish. Promoting local cuisine that features freshwater fish can create a demand for these products and support the livelihoods of fish farmers. Implementing these interventions can enhance the economic viability of biofloc and RAS fish farming techniques in Kerala, ultimately contributing to sustainable fisheries development, increased income generation, and improved livelihood opportunities for coastal communities.

In conclusion, this study sheds light on the economic challenges faced by biofloc and RAS fish farming techniques under the PMMSY scheme in Kerala. It provides valuable insights into the factors contributing to their economic inviability and proposes policy recommendations to address these challenges. By implementing these interventions, the fisheries sector in Kerala can overcome barriers, improve profitability, and contribute to sustainable economic growth and livelihood development in the region.

ACRONYMS

ACRONYM	FULL FORM
BFT	Bio Floc Technology
FC	Fixed Cost
OBC	Other Backward Class
PMMSY	Pradhan Mantri Matsya Sampada Yojana
RAS	Re circulatory Aquaculture System
ROI	Return On Investment
SC	Scheduled Caste
ST	Scheduled Tribe
VC	Variable Cost

Chapter 1. INTRODUCTION

1.01 Introduction

This chapter provides a comprehensive overview of fisheries and aquaculture, highlighting their importance and examining the global, national, and regional scenarios. The chapter aims to set the context for the subsequent chapters by offering insights into the significance of fisheries and aquaculture as well as the specific situation in the state of Kerala.

section 1.2 emphasizes the vital role that fisheries and aquaculture play in the global food supply, nutritional security, and socio-economic development. It explores the significance of fish as an affordable and easily digestible source of animal protein, its contribution to the diet of millions of people, and the employment opportunities it provides to coastal communities.

In section 1.3 the focus shifts to the global scenario, discussing the trends, challenges, and opportunities in fisheries and aquaculture on an international scale. The chapter examines factors such as the growing demand for seafood, the impact of climate change, and the need for sustainable practices to ensure the long-term viability of the sector.

Section 1.4 delves into the fisheries and aquaculture landscape specific to India. It explores the country's vast coastline, inland water bodies, and rich aquatic biodiversity. The chapter highlights India's efforts in meeting the growing demand for fish through capture fisheries as well as the increasing significance of aquaculture in bridging the supply-demand gap.

In section 1.5, the focus narrows down to the fisheries and aquaculture scenario in the state of Kerala. It sheds light on the unique characteristics of Kerala's coast, estuaries, and backwaters, which provide a conducive environment for aquaculture. The chapter examines the challenges faced by Kerala, such as land scarcity and water scarcity, and discusses innovative approaches like biofloc technology that are being implemented to overcome these limitations.

Section 1.6, the concluding section of this chapter summarizes the key points discussed and provides a transition to the subsequent chapters. It underscores the importance of understanding the global, national, and regional contexts of fisheries and aquaculture to comprehend the specific dynamics and potential for growth in Kerala's aquaculture sector. By providing a comprehensive overview of fisheries and aquaculture at various levels, this chapter sets the foundation for a deeper exploration of the subject matter in the subsequent chapters, which will focus on specific aspects such as production techniques, environmental sustainability, market trends, and policy frameworks.

1.02 Importance of Fisheries and Aquaculture

Fisheries and aquaculture play a critical role in global development, contributing to employment, food security, and nutrition. Small-scale fisheries are significant sources of livelihood for millions of people, especially those in developing countries. It is estimated that over 41 million individuals worldwide work in fish production, with the majority residing in developing nations. The importance of these industries becomes evident when considering that fish constitutes a crucial source of nutrients for low-income households, often being the most affordable form of animal protein available. In fact, fish consumption patterns of the poor depend more on affordability than other factors such as preference (Finegold, n.d.)

The impact of fisheries and aquaculture extends beyond providing employment and affordable nutrition. Approximately one-third of fishery commodity production in developing countries is destined for export, highlighting the economic value and potential for income generation. This export market creates opportunities for economic growth and trade, which can contribute to overall development efforts in these countries. The global demand for fish continues to rise due to factors such as population growth, rising incomes, and increasing urbanization. However, many capture fisheries are already fully exploited or overexploited, making it challenging to meet the growing demand for fish (Finegold, n.d.)

In this context, aquaculture emerges as a crucial solution for meeting fish demand sustainably. Aquaculture, which involves the farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants, has witnessed significant growth in recent decades. In fact, aquaculture production has been increasing at a rate of approximately 7-11% per year, and it now produces nearly as much fish and shellfish as fisheries. Aquaculture offers several advantages over capture fisheries. It allows for controlled and predictable production, reducing pressure on wild fish stocks and supporting conservation efforts. Additionally, aquaculture systems can be tailored to specific environmental conditions, promoting sustainable practices, and minimizing negative impacts on biodiversity and ecosystems. However, it is important to note that aquaculture can also have negative consequences, such as habitat loss, pollution, and overfishing of wild fish stocks for use as feed (Troell et al., 2017). Hence, responsible, and well-regulated aquaculture practices are essential to mitigate these environmental concerns.

Furthermore, the expansion of aquaculture production has significant implications for labour relations, rural poverty, and class formation. Unlike fishing in capture fisheries, aquaculture requires access to capital for start-up and running costs, making it less accessible to the landless poor. The higher barriers to entry in aquaculture, coupled with its higher profitability at larger scales, tend to favour larger commercial enterprises that benefit from economies of scale. As a result, shifting from activities like rice cultivation to fish farming can impact rural labour markets and limit employment opportunities for the landless poor. However, despite these challenges, aquaculture holds significant potential for pro-poor rural development (Finegold, n.d.).

In addition to economic benefits, fish and other aquatic animals contribute to improved nutrition and food security. Fish is a highly nutritious food source, providing essential animal protein, fatty acids, and micronutrients. Especially for low-income households, fish consumption plays a crucial role in meeting nutritional needs, and interventions focused on increasing fish intake and promoting aquaculture have the potential to improve overall food and nutrition security. Access to locally available and nutritious foods, including fish, can contribute to reducing micronutrient deficiencies and improving the health and well-being of vulnerable populations. Moreover, fisheries and aquaculture can have a direct impact on the nutritional status of women and children. Women often engage in fishing for household consumption, which helps meet the nutritional needs of their. Additionally, their involvement in trading and processing activities within the fisheries sector can provide them with income, contributing to their empowerment and overall well-being (The Contribution of Fish Intake, Aquaculture, and Small-Scale Fisheries to Improving Food and Nutrition Security: A Literature Review, n.d.).

Fisheries and aquaculture make critical contributions to various aspects of development, including employment, food security, and nutrition. Small- scale fisheries provide livelihood opportunities for millions of people in developing countries, while fish serves as an affordable and nutritious source of animal protein for low-income households. With the increasing demand for fish and the limited capacity of capture fisheries, aquaculture emerges as a sustainable solution. However, the expansion of aquaculture presents challenges in terms of labor relations and access to capital. Responsible and well-regulated aquaculture practices are essential to minimize environmental impacts. Nonetheless, the potential of aquaculture for pro-poor rural development and improving food and nutrition security is significant.

Aquaculture practices can be classified into three types based on the intensity of input and stocking density: extensive, semi-intensive, and intensive systems. Extensive aquaculture involves low capital investments and operating costs, making it suitable for small-scale households with limited resources. This type of farming relies on extensive and semi- intensive technologies. An example of an extensive system is the capture and culture of fish in rice fields. In extensive systems, large ponds ranging in size from 1 to 5 hectares are used, with a stocking density of no more than 5000 fish per hectare. Fish in these systems primarily rely on natural food and feedstuffs, without any supplementary feeding or fertilization. The yield per unit area is relatively low, ranging from 500 to 2 tonnes per hectare, and the survival rate is also low. These systems are labour- intensive, have minimal management requirements, and provide modest income due to their low investment costs. Semi-intensive aquaculture systems strike a balance between extensive and intensive systems. In semi-intensive systems, smaller ponds ranging from 0.5 to 1 hectare in size are used, with a higher stocking density of 10,000 to 15,000 fish per hectare. Fertilization is employed with or without additional feeding to stimulate the development of natural food sources. While natural food remains the primary source of nutrition, supplementary feeding may also be provided. The yield per unit area in semi-intensive systems ranges from 3 to 10 tonnes per hectare, and the survival rate is relatively high. These systems require moderate investment and management efforts. Intensive aquaculture is a well-managed system focused on maximizing fish production with minimal water usage. It involves the use of small ponds, tanks, or raceways with high stocking densities of 10 to 50 fish per cubic meter of water. In intensive systems, fish are provided with nutritionally complete diets and water quality is carefully controlled using aerators. The yield per unit area in intensive systems can vary from 15 to 100 tonnes per hectare or even higher. Although intensive systems require significant investment costs, the returns from higher fish output can lead to profitable returns. (Natural Resource Perspectives DFID Department for International Development AQUACULTURE, POVERTY IMPACTS AND LIVELIHOODS Peter Edwards, 2000; Naylor et al., 2000; Oddsson, 2020; Pillay, 1997)

1.03 Fisheries and Aquaculture Scenario: Global Level

Since the year 2000, aquaculture has become an integral part of the global food system, contributing significantly to the production of aquatic animals. The aquaculture sector is characterized by a high level of diversity, with both fed and extractive species being produced in roughly equal amounts worldwide. The distribution of aquaculture production varies across regions, with inland aquaculture dominating in Asia and Africa, while marine aquaculture takes precedence in the Americas, Europe, and Oceania. The growth in annual aquaculture production since 2000 can be attributed to various factors, including intensification, improved feed quality, enhanced production management practices, and increased attention to biosecurity measures. However, both fed and extractive aquaculture systems need to focus more on scaling up operations, selecting suitable sites, and ensuring the overall health of the production environment. In terms of land use efficiency, aquaculture proves to be more efficient than terrestrial animal production. Nevertheless, water usage remains a significant challenge for industry (Verdegem et al., 2023).

In 2020, the global production of aquatic animals was estimated to be around 178 million tonnes, representing a slight decline from the record high of 179 million tonnes achieved in 2018. Capture fisheries accounted for 90 million tonnes (51 percent), while aquaculture contributed 88 million tonnes (49 percent) to the total production. Of the combined output, approximately 63 percent (112 million tonnes) originated from marine waters, with 70 percent derived from capture fisheries and the remaining 30 percent from aquaculture. Inland waters contributed 37 percent (66 million tonnes), with 83 percent coming from aquaculture and the remaining 17 percent from capture fisheries. The global first sale value of this production was estimated at USD 406 billion, with capture fisheries accounting for USD 141 billion and aquaculture generating USD 265 billion. Additionally, 36 million tonnes of algae (wet weight) were produced in 2020, with 97 percent of it originating from aquaculture, primarily from marine sources (Figure 1.1) ("The State of World Fisheries and Aquaculture 2022," 2022).

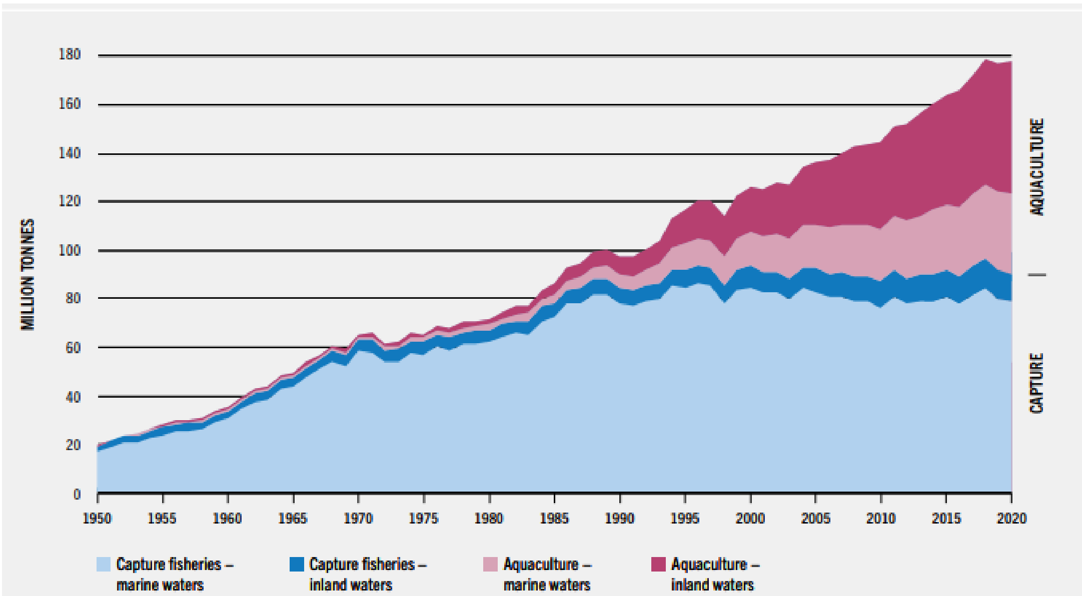

Figure 1-1. World capture fisheries and aquaculture production (Source: FAO 2022)

In 2020, Asian countries emerged as the primary producers, contributing to 70 percent of the global fisheries and aquaculture production of aquatic animals. Following closely were countries in the Americas, accounting for 12 percent, while Europe, Africa, and Oceania represented 10 percent, 7 percent, and 1 percent, respectively. Over the past few decades, fisheries and aquaculture production have experienced significant growth across all continents, except for Europe, which has witnessed a gradual decline since the late 1980s, with slight recovery in recent years before declining again. The Americas have also experienced fluctuations, particularly due to variations in anchoveta catches since the mid-1990s. Conversely, Africa and Asia have seen nearly a doubling of production over the past 20 years. However, in comparison to 2019, total aquatic animal production in 2020 decreased by 3 percent for African countries and 5 percent for countries in Oceania, likely due to the impact of COVID-19. Among the top producers in 2020, China maintained its position as the major contributor, accounting for 35 percent of the total production. India, Indonesia, Viet Nam, and Peru followed with shares of 8 percent, 7 percent, 5 percent, and 3 percent, respectively. Collectively, these five countries accounted for approximately 58 percent of the global fisheries and aquaculture production of aquatic animals in 2020 (Figure 1.2) ("The State of World Fisheries and Aquaculture 2022," 2022)

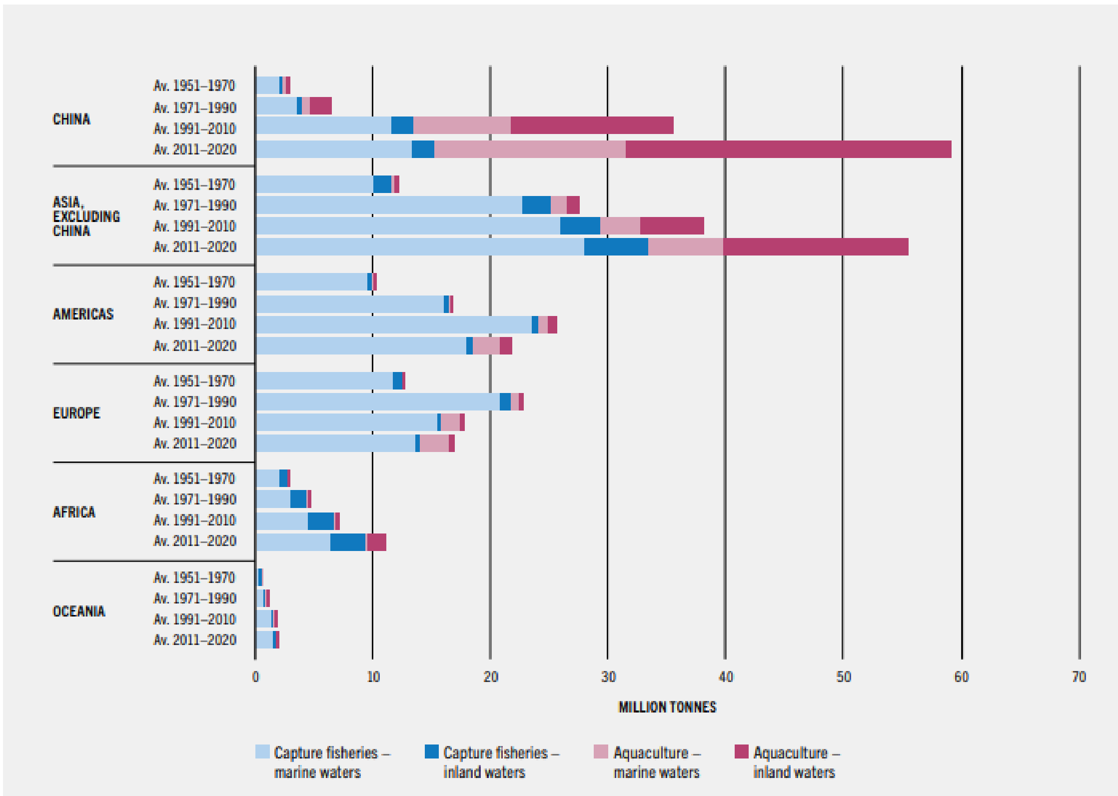

Figure 1-2. Regional contribution to world capture fisheries and aquaculture production (Source: FAO 2022)

Despite the global spread of the COVID-19 pandemic, global aquaculture production continued its growth trajectory in 2020. However, variations were observed among regions and individual countries within each region. The total aquaculture production in 2020 amounted to 122.6 million tonnes in live weight, consisting of 87.5 million tonnes of aquatic animals primarily intended for human consumption, 35.1 million tonnes of algae serving both food and non-food purposes, and 700 tonnes of shells and pearls for ornamental use. This marked an increase of 6.7 million tonnes compared to the 115.9 million tonnes recorded in 2018. The estimated farm gate value of this production in 2020 reached USD 281.5 billion, reflecting a rise of USD 18.5 billion from 2018 and USD 6.7 billion from 2019. Despite the challenges posed by the pandemic, the aquaculture sector demonstrated resilience and sustained growth during this period as shown in Figure 1.3.

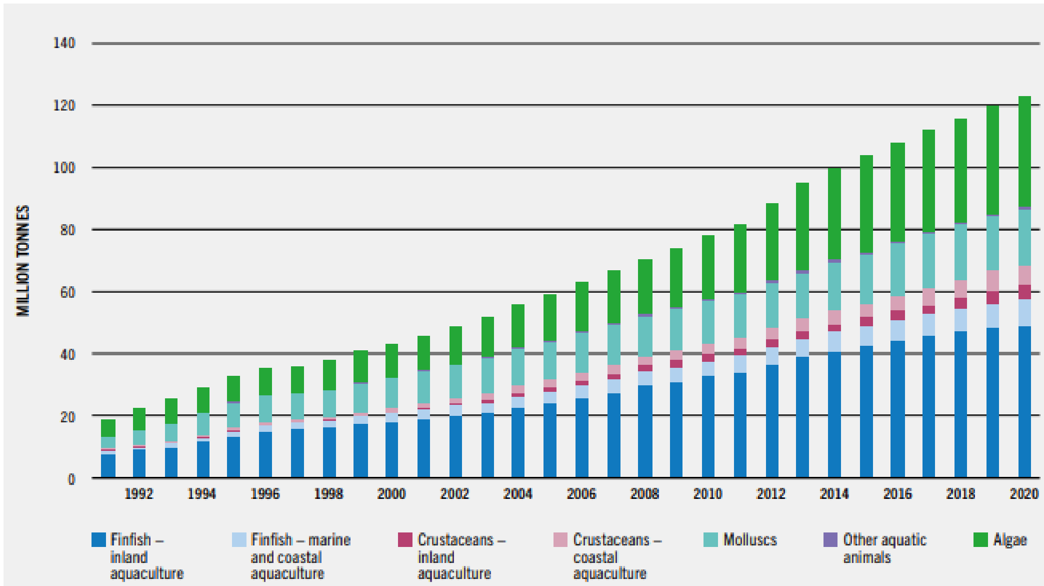

Figure 1-3. World aquaculture production, 1991–2020 (Source: FAO 2022)

1.04 Fisheries and aquaculture scenario: India

India has emerged as a significant player in the global fisheries and aquaculture sector. Currently ranking 3rd in fisheries and 2nd in aquaculture production worldwide, India contributes approximately 6.3% to the total global fish production. This underscores the country's pivotal role in meeting the growing demand for fish and seafood globally.

Fisheries and aquaculture plays crucial role in India's food production system. It emphasizes that this sector plays a vital role in ensuring nutritional security, as well as providing livelihood and employment. opportunities to millions of people across the country. The fisheries and aquaculture industry in India acts as a significant source of income and sustenance for coastal communities, supporting their economic development. To further enhance production, India has established a robust infrastructure for fish farming. With over 1,500 hatcheries spread throughout the country, India has created a conducive environment for breeding and cultivation. These hatcheries have been instrumental in producing over 32 billion carp fry, which contributes to the overall aquaculture production in the country. India's achievements in the fisheries and aquaculture sector underscore its commitment to meeting the growing demand for fish, while also prioritizing food security and livelihood development. With its continued focus on sustainable practices and technological advancements, India is poised to make even greater strides in the future, consolidating its position as a key player in the global fisheries and aquaculture industry (Ngasotter et al., 2020)

In line with its objectives, the National Policy of the Government of India has placed a strong emphasis on increasing output in the fisheries and aquaculture sector. This focus on enhancing production has been consistent across various plan periods, reflecting the government's commitment to utilizing the country's abundant resources to stimulate economic growth. The scientific policy adopted by the Government of India recognizes the immense potential of India's fisheries and aquaculture resources in driving economic progress. By harnessing these resources effectively, the country aims to achieve several important outcomes. Firstly, it seeks to raise the per capita income of its population, which will contribute to overall economic prosperity. Additionally, increased output will lead to higher levels of consumption, benefiting both producers and consumers within the sector. Beyond economic considerations, the National Policy also acknowledges the broader socioeconomic impact of a thriving fisheries and aquaculture industry. By promoting higher production levels, the policy aims to improve the overall well-being of the population. This includes addressing issues such as malnutrition and vulnerability, which can be alleviated through increased access to nutritious seafood and enhanced livelihood opportunities. The Government of India recognizes that boosting output in the fisheries and aquaculture sector requires a comprehensive approach. This entails implementing strategies and measures that support sustainable practices, technological advancements, and efficient resource management. By doing so, the government aims to strike a balance between maximizing productivity and ensuring the long-term viability of the sector.

Through its commitment to increasing output, the National Policy demonstrates the Government of India's recognition of the significant role that fisheries and aquaculture can play in driving economic growth, improving living standards, and addressing social challenges. By leveraging the country's resources potentials effectively, India is working towards a future where the fisheries and aquaculture sector serves as a catalyst for inclusive development and a better quality of life for its citizens (Rath, 2000).

The fish production sector in India has experienced remarkable growth over the years, transitioning from a production level of 0.75 million metric tonnes (MT) during 1950-51 to the current production of 14.1 million MT. This significant increase in production is a testament to the country's commitment to the development of its fisheries industry (Figure 1.4). Traditionally, marine fish production held a dominant position in India's total fish production until the turn of the millennium. However, the implementation of science-based fisheries practices has led to a remarkable transformation in the inland fisheries sector. Presently, inland fisheries contribute approximately 70% of the country's total fish production, signifying a remarkable shift in focus. Recognizing the immense potential of inland fisheries, the holistic approach adopted under the Prime Minister's Matsya Sampada Yojana (PMMSY) aims to leverage this sector's opportunities and capabilities for further production enhancement. By adopting optimal utilization of fisheries resources, incorporating technology infusion, and emphasizing capacity building, the PMMSY seeks to unleash the full potential of inland fisheries. The PMMSY recognizes that inland fisheries present a vast opportunity for augmenting fish production in India. By employing sustainable practices and harnessing the benefits of scientific advancements, the sector can experience further growth and contribute significantly to the country's overall fish production. Through the optimal utilization of fisheries resources, which include rivers, reservoirs, ponds, and other water bodies, the PMMSY envisions a comprehensive approach to enhance production in inland fisheries. This involves employing innovative techniques, promoting effective fish breeding and rearing practices, and integrating modern technology into various aspects of the sector. Capacity building is also a key focus of the PMMSY, as it recognizes the importance of equipping stakeholders in the inland fisheries sector with the necessary knowledge and skills. By providing training programs, knowledge dissemination, and technical support, the government aims to empower fishery communities and enhance their productivity and income- generating potential. The holistic approach adopted under the PMMSY underscores the commitment of the Indian government to further develop the inland fisheries sector. By capitalizing on the immense opportunities and potential offered by inland fisheries, the country can achieve significant growth in fish production. Through sustainable practices, technological advancements, and capacity building, India is poised to harness the full potential of its inland fisheries and drive the continued growth and development of its fisheries industry.

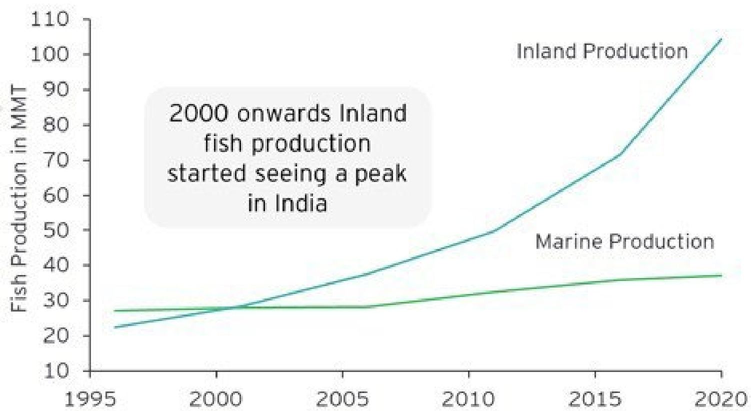

Figure 1-4. Fish production in India (Source: https://dof.gov.in)

India has emerged as a significant player in the global fish production arena, securing the second position with an impressive output of 13.4 million tonnes in 2018-19. This noteworthy achievement comprises 3.7 million tonnes from the marine sector and 9.7 million tonnes from the inland sector (Figure 1.5). The thriving fisheries industry in India not only contributes substantially to the agricultural sector but also plays a vital role in the country's overall gross domestic product (GDP). With a contribution of 6.58 percent to the agriculture sector's GDP, the fisheries industry holds significant economic significance. This sector's growth and productivity positively impact the broader agricultural landscape, creating a symbiotic relationship between fisheries and other agricultural activities. Furthermore, the fisheries industry contributes 1.03 percent to India's overall GDP, further highlighting its importance in the country's economic framework. The remarkable progress of India's fish production sector can be attributed to a range of factors, including favorable geographical conditions, technological advancements, and sustainable practices. The marine sector, with its abundant coastal resources, and the inland sector, utilizing various water bodies such as rivers, reservoirs, and ponds, collectively drive the country's impressive fish production figures. The substantial contribution of the fisheries sector to India's GDP underscores its role in providing livelihood opportunities and supporting rural economies. Fishery communities, including fishermen, fish farmers, and associated industries, rely on the sector for their sustenance and income generation. By fostering growth and development in the fisheries industry, India simultaneously promotes rural development, poverty alleviation, and improved livelihoods for millions of people. Recognizing the importance of the fisheries sector, the Indian government has implemented various initiatives and policies to support its sustainable growth. Investments in infrastructure, technology, and research have been made to enhance production, promote responsible fishing practices, and ensure the sector's long-term viability. Additionally, the government has focused on capacity building, skill development, and providing financial support to empower fishery communities and strengthen their resilience. The remarkable achievements of India's fisheries industry, as reflected in its second- ranking global position and substantial contributions to GDP, highlight the sector's significance for the nation's economic prosperity and food security. As the industry continues to evolve, leveraging technological advancements and sustainable practices, it is poised to further strengthen its position, uplift rural communities, and contribute to India's overall socio-economic development. (Lakra & Gopalakrishnan, 2021).

Figure 1-5. Fish production in India from 2005-06 to 2018-19 (Source: Ministry of Fisheries, Animal Husbandry and Dairying Govt. of India)

1.05 Fisheries and aquaculture scenario: Kerala

Kerala, known as "God's Own Country," possesses a unique natural feature that sets it apart from other coastal regions: an extensive network of estuaries and backwaters that span almost its entire coastline. These water bodies, combined with abundant inland water resources and the biodiversity-rich rivers originating from the Western Ghats, make Kerala an ideal environment for aquaculture. With a declining trend in production from capture fisheries due to various factors such as anthropogenic influences and the effects of climate change, the growth of aquaculture has emerged as a prominent solution to meet the ever-increasing demands for food supply. By focusing on aquaculture, Kerala can not only alleviate pressure on threatened wild stocks but also enhance its ability to provide food and nutritional security for its people. Fish, being a vital component of the local diet, holds immense significance in Kerala's culinary traditions. Furthermore, the thriving aquaculture industry also contributes to employment opportunities for coastal inhabitants, stimulating economic growth and improving livelihoods. In addition to its socio-economic benefits, fish stands out as one of the most affordable and easily digestible sources of animal protein, making it a crucial dietary staple for the people of Kerala.

The state of Kerala is bestowed with abundant resources that make it highly conducive for the development of aquaculture. The inland water areas in Kerala cover an estimated extent of approximately 360,535 hectares. Among these, brackish water areas span over 242,600 hectares, while freshwater areas encompass 117,935 hectares. However, currently, only a small proportion of this vast potential is being utilized. Aquaculture in Kerala has evolved into a high-value activity, engaging not only small and marginal farmers but also commercial entrepreneurs. This transformation is particularly evident in coastal aquaculture, where shrimp farming constitutes a significant component both in terms of the area under cultivation and the value of output. The rivers and streams originating from the Western Ghats in Kerala are renowned for their remarkable biodiversity, which includes various freshwater fish species. In total, there are 210 primary fish species found in inland waters, excluding marine migrants, with 53 species being endemic. Many of these fish species also possess ornamental value, adding to their appeal. In the brackish waters of Kerala, there are 75 fish species, including 57 fish species, 6 species of shrimp, 1 species of prawn, 5 species of crabs, and 6 species of bivalves. Among them, 28 species hold commercial significance. These include mullets, catfishes, perches, pearl spot, shrimp, prawn, green mussels, brown mussels, the Indian backwater oyster (locally known as 'Kadalmuringa'), and mud crabs such as Scylla Serrata and Scylla tranquibarrica. Many of these species are well-suited for aquaculture. Additionally, Kerala's inland waters harbor around 106 species of fish that have ornamental value. Some notable ornamental fish species in Kerala include the Redline torpedo fish, Aurulibarb, Rosy barb, Tiger barb, Tictobarb, Kooliebarb, Melon barb, Glass fish, Yellow catfish, and many others. The rich diversity of fish species, both for commercial purposes and ornamental trade, presents significant opportunities for aquaculture development in Kerala. By harnessing this potential, the state can not only boost its economic growth but also contribute to the sustainable utilization of its water resources while meeting the increasing demand for fish and ornamental species. (Inland Fisheries Statistics in Kerala, 2017).

Table 1-1. Fish production in Kerala from the year 1997-98 to 2015-16 (In lakh tons) (Source: Department of Fisheries, Govt. of Kerala. (Numbers in parentheses show percentage to total production).

Year	**Marine**	**Inland**	**Total**
1997-98	5.11	0.58 (10.19)	5.69
1998-99	5.82	0.66 (10.19)	6.48
1999-00	5.94	0.74 (11.08)	6.68
2000-01	5.67	0.85 (13.04)	6.52
2001-02	5.94	0.78 (11.61)	6.72
2002-03	6.03	0.75 (11.06)	6.78
2003-04	6.09	0.76 (11.09)	6.85
2004-05	6.02	0.76 (11.21)	6.96
2005-06	5.59	0.78 (12.24)	6.37
2006-07	5.98	0.80 (11.80)	6.78
2007-08	5.86	0.91 (13.44)	6.67
2008-09	5.83	1.03 (15.01)	6.86
2009-10	5.7	1.17 (17.03)	6.87
2010-11	5.6	1.21 (17.77)	6.81
2011-12	5.53	1.40 (20.00)	6.93
2012-13	5.31	1.49 (21.91)	6.8
2013-14	5.22	1.86 (26.27)	7.08
2014-15	5.24	2.02 (27.82)	7.26
2015-16	5.17	2.10 (28.00)	7.27

Table 1.1 shows the fish production in Kerala from the year 2010-11 to 2015-16, in lakh tons. According to this table, there has been a steady increase in inland fish production from 1.21 lakh tons in 2010-11 to 2.10 lakh tons in 2015-16. The percentage of inland fish production to total fish production has also increased from 17.77% in 2010-11 to 28.00% in 2015-16. Marine fish production, on the other hand, has decreased slightly from 5.60 lakh tons in 2010-11 to 5.17 lakh tons in 2015-16.

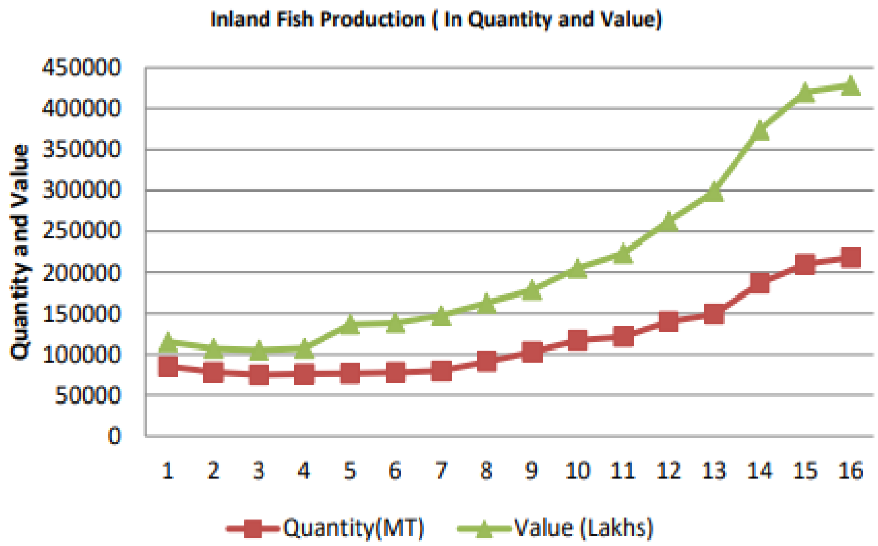

Figure 1-6. Inland fish production in Kerala (Quantity and Value) (Source: Department of Fisheries, Govt. of Kerala)

Figure 1.6 shows the change in the quantity and value of inland fish production in Kerala during the period from 2001 to 2016. The blue line represents the quantity of inland fish production in metric tons, while the orange line represents the value of inland fish production in lakhs. According to this figure, both the quantity and value of inland fish production have increased over time. The quantity increased from 85234 metric tons in 2001 to 218130 metric tons in 2016, showing an increase of 2.6 times. The value of the product per metric ton in the year 2001 was 0.35 lakh, whereas in the year 2016, the value raised to 1 lakh. The figure also shows that the growth rate of the value of the product is faster than that of the quantity.

Table 1-2. Share of Fisheries sector in Gross State Domestic Product from the year 2005-06 to 2016-17 (Source: Department of Fisheries, Govt. of Kerala)

Year	Share of Fisheries Sector (%)
2005-06	1.3
2006-07	1.27
2007-08	1.17
2008-09	1.1
2009-10	1.06
2010-11	1.11
2011-12	1.12
2012-13	1.06
2013-14	1.07

2014-15	1.09
2015-16	1.01

Table 1.2 shows the share of the fisheries sector in the Gross State Domestic Product (GSDP) of Kerala from the year 2005-06 to 2015-16. According to this table, the share of the fisheries sector in GSDP has decreased over time. In 2005-06, the share was 1.30%, and it decreased to 1.01% in 2015-16. This suggests that the contribution of the fisheries sector to the GSDP of Kerala has declined over time.

As Kerala continues to experience rapid urbanization and population growth, it is increasingly being considered as an urban region. This urban character presents unique challenges for the expansion of aquaculture in the state, particularly due to the limitations in available land for building additional ponds and the scarcity of water resources. In light of these constraints, sustainable exploitation of aquaculture resources through innovative technologies that are suitable for urban settings becomes crucial. One such innovative approach that holds significant potential for fish production in Kerala is the utilization of biofloc technology. Biofloc fish farming allows for the cultivation of fish in a high-density system within a small space while maintaining regulated environmental conditions.

This method relies on the development of a microbial community known as biofloc, which helps in nutrient recycling and water quality management. By harnessing the characteristics of the biofloc method, fish production can be significantly increased even in urban areas where land and water resources are limited. Recognizing the benefits of biofloc technology for aquaculture in Kerala, the government has taken proactive steps to promote its adoption. Under the Pradhan Mantri Matsya Sampada Yojana (PMMSY), a project has been implemented to establish biofloc systems for fish farming. The PMMSY is a program aimed at revolutionizing the fisheries sector in India through sustainable and responsible growth. It addresses critical areas such as fish production and productivity, quality, technology, post-harvest infrastructure, value chain modernization, fisheries management, and fisher welfare. The implementation of PMMSY in Kerala, specifically focusing on biofloc technology, is expected to play a vital role in bridging the gaps in fish production and productivity. The program is set to span five years, from FY 2020-21 to FY 2024-25, covering all states and union territories. With this initiative, Kerala aims to enhance its fish production capabilities, improve the quality of fish products, upgrade technology and infrastructure, strengthen the value chain, ensure traceability, implement effective fisheries management practices, and enhance the welfare of fishers.

By embracing innovative approaches like biofloc technology and implementing comprehensive programs such as PMMSY, Kerala is paving the way for sustainable and responsible growth in its aquaculture sector. These initiatives will not only contribute to increased fish production but also promote environmental sustainability and socioeconomic development in urban settings.

1.06 Research Questions

• What is the economic viability of biofloc fish farming in Kerala, and how does the PMMSY subsidy program impact its profitability and sustainability?

• How does the economic viability of biofloc fish farming compare to that of RAS, and what factors contribute to the differences in profitability and sustainability between these two practices?

• What policy recommendations can be made to support the growth of the biofloc fish farming sector in Kerala while ensuring its long-term economic viability and sustainability?

1.07 Research Objectives

• To analyze the economic viability of bio floc fish farming in Kerala given that farmers are getting subsidy for setting up bio floc fish farm

• To compare the economic viability of bio floc fish farming with RAS (Re circulatory Aquaculture System)

• Develop policy recommendations that can support the growth of the sector, while ensuring long-term economic viability and sustainability.

1.08 Organization of Thesis

The chapter scheme of the thesis is as follows.

- Chapter 1: Introduction

Chapter 1 provides an overview of the thesis, introducing the research topic, its significance, and the objectives to be addressed. The importance of studying aquaculture practices and consumer preferences is emphasized, setting the stage for the subsequent chapters. The chapter outlines the scope and themes that will be explored throughout the thesis.

- Chapter 2: Review of Literature

Chapter 2 conducts a comprehensive review of relevant literature in the field of aquaculture, consumer preferences, and policy implications. The discussion includes theories, concepts, and previous studies, highlighting their significance and identifying any gaps or limitations. This chapter provides the foundation for the analysis and findings by establishing the context of the research.

- Chapter 3: Research Methodology

Chapter 3 describes the research methodology employed in the study. The research design, data collection methods, and sampling techniques are outlined to ensure transparency and reliability in gathering the necessary information. By presenting the research methodology, the chapter establishes the credibility and validity of the study.

- Chapter 4: Data Analysis

Chapter 4 presents the findings of the data analysis. Various statistical techniques, qualitative analysis, or other appropriate methods are used to analyze the collected data. The objective is to identify patterns, trends, and relationships within the data, drawing meaningful conclusions and insights that contribute to the research objectives.

- Chapter 5: Findings and Policy Suggestions

Chapter 5 summarizes the key findings of the study and offers policy suggestions based on those findings. The main results are highlighted, emphasizing significant findings or emerging patterns. Recommendations and policy suggestions are presented to improve and sustain aquaculture practices, taking into account consumer preferences and broader policy implications.

By following this chapter scheme, the thesis provides a well-structured analysis of aquaculture practices, consumer preferences, and policy implications. The chapters collectively contribute to the existing knowledge in this field, fostering a deeper understanding of the subject matter.

1.09 Conclusion

Fisheries and aquaculture play a crucial role in meeting the global demand for food, providing nutritional security, and supporting the livelihoods of millions of people. The significance of fish as a valuable source of affordable protein cannot be understated. As we examined the global scenario, it is evident that fisheries and aquaculture face various challenges, including climate change impacts, overfishing, and unsustainable practices. However, there are also immense opportunities for sustainable growth and innovation in the sector.

At the national level, India has recognized the importance of fisheries and aquaculture and has made substantial efforts to meet the growing demand for fish through both capture fisheries and aquaculture. The rich coastal and inland water resources of India, including those in Kerala, provide a fertile ground for the development of aquaculture.

In the context of Kerala, the state's unique abundance of estuaries, backwaters, and inland water resources offer an ideal environment for aquaculture. However, the densely populated and urban nature of Kerala presents specific challenges, such as limited land availability and water scarcity. In response, the government of Kerala has taken initiatives to promote sustainable exploitation and innovative technologies suitable for urban settings, such as biofloc technology.

The implementation of the Pradhan Mantri Matsya Sampada Yojana (PMMSY) in Kerala, with a focus on biofloc technology, holds great promise for enhancing fish production, improving quality, upgrading infrastructure, and strengthening the value chain. This five-year program aims to revolutionize the fisheries sector and ensure responsible and sustainable growth.

In conclusion, this chapter has provided an overview of the importance of fisheries and aquaculture globally, nationally in India, and specifically in Kerala. It has highlighted the challenges and opportunities faced by the sector and the efforts being made to address them. Understanding the global and national contexts is essential for comprehending the unique dynamics and potential for growth in Kerala's aquaculture sector.

Chapter 2. REVIEW OF LITERATURE

2.01 Introduction

The second chapter of this thesis presents a comprehensive literature review of the related studies. This chapter is subdivided into five. Section 2.1 gives an introduction to the chapter. Section 2.2 delves into the technical feasibility of RAS and Biofloc Technologies in the context of fish farming. It explores the potential of these systems to create controlled and high-density environments for fish growth, highlighting their effectiveness in year-round maturation of broodstock, seed production, and nursery rearing. By examining the advancements and successful adoption of these technologies in different coastal states, this section establishes the technical viability of RAS and Biofloc Technologies as promising alternatives in the aquaculture industry. Section 2.3 focuses on consumer preferences and their influence on the adoption of biofloc fish farming in Kerala. It examines studies that analyze customer attitudes towards organic food, highlighting the growing popularity of organic agricultural produce, including organic fruits, vegetables, meat, and meat products. By understanding consumer preferences for healthier and higher-quality food options, this section underscores the relevance and potential demand for biofloc fish farming, which aligns with the principles of organic and sustainable farming practices. Section 2.4 investigates the role of subsidies in promoting the adoption and economic viability of biofloc fish farming in Kerala. It examines the initiatives and programs introduced by the Indian government, specifically the Pradhan Mantri Matsya Sampada Yojana, which aims to enhance fish production, create critical infrastructure, and generate employment opportunities in the fisheries sector. By analyzing the impact of these subsidies on the development of biofloc fish farming, this section sheds light on their significance in improving economic viability and efficiency.

2.02 Techno- economic feasibility of RAS and Biofloc Technologies

Aquaculture is an essential industry in addressing the increasing global demand for seafood. However, conventional aquaculture practices have encountered obstacles concerning water usage, waste management, and environmental impact. To overcome these challenges, novel technologies such as Biofloc Technology (BFT) and Recirculating Aquaculture Systems (RAS) have emerged as sustainable alternatives.

Biofloc technology (BFT) is an emerging biotechnology that promotes eco-friendly and sustainable production of aquatic species. Djurstedt and Berg define BFT as a system in which carbohydrates are added to the fish tank, triggering the growth of heterotrophic microorganisms. These microorganisms convert ammonia into microbial protein, resulting in improved growth performance, feed utilization, and reduced water usage. The aggregation of microorganisms, including bacteria, protozoa, and algae, bound together in a matrix by mucus and organic material, forms bioflocs. This aggregation not only improves water quality but also provides protection against harmful pathogens in aquaculture production systems (Djurstedt & Berg, n.d.). Shinde (n.d.) further elaborates that bioflocs consist of autotrophic bacteria responsible for nitrification processes and heterotrophic bacteria that aid in ammonia removal from the water.

In contrast, Recirculating Aquaculture Systems (RAS) have gained recognition as a technology that minimizes water usage and reduces the ecological impact of fish farming. RAS operate by continuously filtering and recycling water within the system, creating a controlled environment for aquatic food production. Rurangwa and Verdegem (2015) define RAS as systems in which water is recirculated between the culture and water treatment stages. This approach provides a solution to environmental concerns associated with conventional aquaculture practices by enabling fish production in relative isolation from the surrounding environment.

RAS systems offer advantages such as reduced water usage, improved waste management, enhanced biosecurity, and increased control over water quality (Rurangwa & Verdegem, 2015). Van Rijn (2013) emphasizes the importance of water quality control and waste management in these highly contained systems.

Furthermore, Faizullah et al. (2019) highlight that BFT and RAS technologies complement each other in aquaculture. BFT utilizes the growth of microorganisms in the culture medium, forming bioflocs that improve water quality and serve as a source of microbial protein. This results in improved feed conversion ratio and reduced feed costs. Additionally, the biomass of bioflocs can be utilized as an ingredient in compounded feeds.

RAS, on the other hand, provides a controlled and environmentally secure production system by recirculating and filtering water, minimizing water consumption and waste discharge. These technologies contribute to the economic viability and sustainability of the aquaculture industry by reducing water usage, improving waste management, and enhancing overall productivity (Faizullah et al., 2019).

Biofloc Technology (BFT) and Recirculating Aquaculture Systems (RAS) are innovative approaches that offer sustainable solutions to the challenges faced by traditional aquaculture practices. BFT utilizes the aggregation of microorganisms in the form of bioflocs to improve water quality, increase feed utilization, and reduce water consumption. RAS enables controlled fish production through the continuous recycling and filtration of water, leading to improved waste management, biosecurity, and reduced environmental impact. These technologies present potential opportunities for the aquaculture industry to become more economically viable and environmentally sustainable.

Biofloc technology is a method that promotes nutrient recycling and minimizes water exchange by utilizing suspended microbial aggregates, known as bioflocs, as a natural food source. This approach has been successfully applied to species such as Litopenaeus vannamei and tilapia, with promising results (Ulloa Walker et al., 2020). The use of biofloc technology offers several advantages, including water quality control, pathogen resistance, and nutritional supplementation. Additionally, it presents a cost-effective alternative for feed production, as bioflocs can be utilized as a complementary and permanent food source for aquatic organisms (Crab et al., 2012).

Recirculating Aquaculture Systems (RAS) are characterized by their high structural and technological complexity, aiming to propagate high-density animal cultures with reduced water requirements. However, the success of RAS is hindered by poor system design and management, lack of skilled personnel, and inadequate knowledge sharing (Badiola et al., 2012). Improvements in equipment performance, conducting research at a commercial scale, and enhancing knowledge sharing and education programs are identified as key priorities for the future development of RAS. Overcoming these challenges would contribute to optimizing system design and management, ultimately improving the performance and efficiency of RAS operations.

Comparatively, biofloc technology provides an economical and sustainable approach to water quality control in aquaculture. The technology's ability to balance carbon and nitrogen in the system, minimize water exchange, and produce proteinaceous feed in situ makes it an attractive option for aquaculture operations. Furthermore, biofloc technology offers the potential to decrease nutrient discharge into adjacent water bodies, thus reducing environmental impacts. This could help alleviate the depletion of wild fish stocks, lower fish production prices, and improve social welfare for both farmers and consumers (Crab et al., 2012).

The techno-economic feasibility of biofloc technology and RAS relies on various factors. Challenges for biofloc technology include selecting suitable aerators, integrating the technology into existing systems, optimizing floc characteristics and composition, and determining the impact of carbon source type on biofloc properties. On the other hand, addressing issues such as system design, management, and knowledge sharing is crucial for the successful implementation of RAS (Badiola et al., 2012). These challenges highlight the need for further research, technological advancements, and improved education and training programs to enhance the feasibility and effectiveness of both techniques.

Biofloc technology and RAS offer promising approaches for sustainable aquaculture practices. The techno-economic feasibility of biofloc technology lies in its potential for water quality control, nutrient recycling, and low-cost feed production. Meanwhile, the feasibility of RAS depends on addressing issues related to system design, management, and knowledge sharing.

The adoption of biofloc technology (BFT) and recirculating aquaculture systems (RAS) in different parts of the world has been the subject of extensive research. BFT, which involves the growth of beneficial microorganisms in water to improve water quality and animal health, has been studied in the context of shrimp aquaculture. Factors affecting shrimp production in BFT systems, integration with other farmed species, nutritional value of bioflocs, application in different rearing phases, and its use as a natural probiotic have been explored (El-Sayed, 2021).

In the case of RAS, its advantages were demonstrated in the soft-shelled crab industry in Louisiana, where it allowed geographic expansion and reduced dependence on specific water conditions. However, the adoption of RAS has faced challenges, and factors influencing its adoption, such as trust in price premiums, access to finance, and uncertainty about performance, have been identified (Caffey & Kazmierczak, 1993). Similar constraints on RAS adoption have been observed in Vietnamese pangasius farming, including lack of trust, inadequate finance, and uncertainty about system performance (Thi & Ngoc, n.d.).

The integration of BFT with hydroponics in FLOCponics has been explored as an alternative type of aquaponics, enabling nutrient recycling and waste minimization (Pinho et al., 2022). In Bangladesh, biofloc technology has been proposed as a cost-effective and sustainable practice to improve aquaculture productivity, with potential benefits for farmers and consumers. However, challenges such as information exchange, infrastructure development, and government support need to be addressed for its successful implementation (Rahaman, n.d.).

The use of vertical substrates as an alternative to suspended biofloc has been investigated, offering advantages in intensifying shrimp and fish production. Vertical substrate systems provide an environment for the development of microbial biomass, which offers similar benefits to suspended biofloc, such as ammonia control and natural food items. Trials conducted in India showed higher survival, average shrimp weight, and production in ponds with vertical substrates (Adapting Biofloc Technology for Use in Small Scale Ponds with Vertical Substrate, n.d.)

Biofloc technology originated in the United States and was commercially implemented in Central America, specifically in the cultivation of Litopenaeus vannamei. It has been shown to enable higher densities, improve biosafety, reduce food consumption and water pumping, and require smaller cultivation areas (Betanzo-Torres et al., 2020).

The adoption of advanced fish farming techniques, such as Recirculating Aquaculture Systems (RAS) and Biofloc Technology (BFT), in India has gained significant attention in recent years. Mariculture, as a subsector of aquaculture, has been recognized for its potential to contribute to global food fish aquaculture production, and India has recognized this potential as well. The Indian government has been making efforts to address the institutional and commercial needs of mariculture development in the country, including the development of RAS facilities for broodstock and seed production (Gopalakrishnan et al., 2022). In Kerala, specifically, the government is planning to provide financial support to interested individuals for implementing advanced aquaculture production systems like RAS and BFT as part of their climate change mitigation efforts (Tharanath et al., 2021).

Fish farming methods have been diversifying in Kerala, with various techniques being adopted by farmers. Among these methods, pond fish farming and biofloc fish farming have gained popularity. Pond fish farming is the most common method among farmers in the study area, while biofloc fish farming has emerged as a female-dominated area. Biofloc fish farming is a high-density fish farming technique that addresses the challenges of growing demand for fish and limited available space for farming. It involves the cultivation of floc, a composition of bacteria and flora and fauna, along with fish, which naturally purifies the water and serves as fodder for the fish. The Subiksha Kerala Scheme has been introduced in Kerala to promote biofloc fish farming, offering a 60 percent subsidy for starting such a system (Plamoottil & Kumar, 2022).

Tilapia production has also been recognized for its potential in meeting global food demand and achieving sustainable development goals in India. Tilapia farming practices, including the use of BFT and RAS, have been promoted through government schemes, missions, subsidies, projects, and funding. BFT, which utilizes microbial communities to break down waste particles and produce protein-rich biomass, has been shown to improve yields and reduce costs, ensuring sustainable tilapia production. RAS, on the other hand, provides optimum environmental conditions year-round and offers an eco-friendly approach to fish farming (Arumugam et al., 2023).

In the context of the COVID-19 pandemic, the fisheries community in India, including coastal districts in Kerala, has faced significant challenges and economic impacts. The government has launched initiatives like the Pradhan Mantri Matsya Sampada Yojana (PMMSY) to support the fisheries sector, enhance fish production, create critical infrastructure, and generate employment opportunities (Ramakrishnan et. al.,). These initiatives aim to protect the livelihoods of fishermen and promote sustainability in the fisheries sector.

The adoption of advanced fish farming techniques, such as RAS and BFT, in India, including the state of Kerala, has gained attention due to their potential for improving productivity, addressing environmental challenges, and supporting sustainable aquaculture. The government has taken steps to support mariculture development and promote the adoption of these techniques through financial assistance and initiatives. The diversification of fish farming methods in Kerala, including the popularity of pond fish farming and the emergence of biofloc fish farming, reflects the need to meet the growing demand for fish and overcome space limitations. Furthermore, the promotion of tilapia farming and the use of BFT and RAS highlight India's commitment to sustainable aquaculture

2.03 Consumer Preference

Consumer demand and consumer preference are closely interconnected concepts in the field of economics. Consumer demand refers to the behavior of individuals in allocating their expenditures on commodities based on their preferences. On the other hand, consumer preference refers to the ordered set of preferences that an individual has for different commodities.

Traditionally, the assumption in economic theory has been that consumers have a unique ordinal utility index function, representing their preferences, which they seek to maximize given their income and the prices of commodities. However, the relationship between consumer preferences and demand becomes more complex when considering factors such as advertising and selling efforts.

In a seminal article by Basmann (1956), a theory of consumer demand is presented that accounts for changes in consumer preferences due to advertising and other forms of selling effort. The author replaces the assumption of a unique ordinal utility index function with the idea that consumers have a family of ordinal utility functions. The specific ordinal utility function to be maximized is determined by the advertising expenditures made by sellers of commodities. This theory provides a framework for understanding how changes in consumer preferences, influenced by advertising, can impact consumer demand.

Furthermore, in his article "The Recoverability of Consumers' Preferences from Market Demand Behavior," Mas-Colell (1977) explores the relationship between consumer demand and consumer preferences. The paper addresses the question of whether a given demand function can uniquely identify a specific set of consumer preferences. In other words, can we recover consumers' preferences solely from their observed market demand behavior? This inquiry highlights the intricate connection between consumer demand and the underlying preferences that drive it. Consumer demand is influenced by consumer preferences, which are represented by ordinal utility functions. Changes in consumer preferences, influenced by factors such as advertising, can impact the consumption behavior and choices made by individuals. Understanding the relationship between consumer preference and demand is crucial for comprehending consumer behavior and making informed decisions in various economic contexts.

Consumer preferences play a significant role in shaping consumer behavior towards perishable commodities. Perishable products, such as bakery bread, present unique challenges and opportunities in understanding customer preferences and their impact on inventory performance. Research by Van Woensel et al. (2007) focuses on customer behavior when faced with out-of-stocks (OOS) of perishable products. The study reveals that customers exhibit distinct behavior when it comes to perishables, particularly a high willingness to substitute. This finding highlights the importance of considering customer preferences and substitution behavior when managing inventory and supply chains for perishable goods.

Furthermore, consumer preferences for organic agricultural produce have gained attention in recent years. The research conducted in the Czech Republic by Zámková et al. (2021) explores customer attitudes towards organic food. The study finds an increasing number of respondents considering organic food and perceiving it to be of better quality. Notably, organic fruits, vegetables, meat, and meat products witnessed higher popularity in 2019 compared to 2016. These findings indicate a growing preference among consumers for organic agriculture produce, emphasizing the significance of understanding and catering to these preferences within the perishable food sector.

In the context of perishable food production planning, consumer purchasing behavior plays a crucial role. The paper titled "Influence of consumer purchasing behavior on the production planning of perishable food" by Amorim et al. (2014) addresses this relationship. The research builds on previous studies on the effects of expiry dates and develops mathematical formulae to model age-dependent demand for different categories of perishable products. These demand expressions incorporate customer willingness to pay and product quality risk. By considering consumer preferences and behavior, companies operating in the fast- moving consumer goods industry can enhance their production planning and better align their offerings with customer demands. Consumer preferences towards perishable commodities exhibit distinctive characteristics that differ from those associated with non-perishable items. Customers demonstrate a high willingness to substitute in the face of out- of-stocks for perishable products. Additionally, the increasing popularity of organic agricultural produce reflects evolving consumer preferences for healthier and higher-quality food options. Understanding and incorporating consumer preferences into production planning and supply chain management are vital for optimizing inventory performance and meeting customer demands in the perishable food industry.

Wongprawmas et al. (2022) investigated how information influences consumers' perceptions and purchasing intentions for farmed and wild fish. Their findings reveal that consumers generally have a more positive perception of wild fish compared to farm fish. However, when provided with specific information about farming practices, nutritional content, and environmental sustainability, consumers' preferences showed variations. Positive information about sustainable and environmentally friendly farming methods increased consumers' preference for farmed fish, along with nutritional information such as omega-3 fatty acid content.

On the other hand, Hoque and Myrland (2022) analyzed consumer responses to a regulatory scheme for safe seafood in Bangladesh. The study highlighted that consumers value fish safety inspection highly in their affective reaction, particularly for farmed fish with local authority safety certification. Lack of authorized food safety inspection significantly decreased utility, suggesting a positive market potential for farmed fish with safety certifications.

Furthermore, Kaimakoudi et al. (2013) conducted a study in Greece to classify consumers based on their attitudes towards fisheries products. They identified two distinct clusters: low-potential aquaculture consumers and high-potential aquaculture consumers. While both clusters showed a preference for catches over aquaculture products, the study suggested that marketing strategies aiming to increase public awareness could improve the value of aquaculture products in the Greek market.

Additionally, Claret et al. (2012) explored consumer perception of different factors in the decision-making process when choosing sea fish. The study revealed that country of origin was the most important factor for consumers, followed by obtaining method, storage conditions, and purchasing price. Effective information strategies were identified as crucial to support and increase farmed fish consumption, thereby reducing the impact of unsustainable fishing practices.

Consumer preference towards fish is influenced by various factors, including social, cultural, economic, and health considerations. In the Indian scenario, studies have highlighted the demand for value-added fish products among consumers. Research conducted in Odisha revealed that consumers showed interest in consuming different forms of value-added fish products, with fish cutlets being the preferred choice for 50% of consumers. Factors such as price, taste, and health benefits were perceived as significant attributes influencing consumer preferences for value-added fish products. However, consumers in states outside Odisha were hesitant to pay prevailing market rates for these products (Tanuja et al., 2020).

In Kerala, consumer preference for fish is influenced by several factors. A study conducted in Palakkad District found that quality was the most important attribute influencing consumer behavior, and consumers in the young and earning age group were willing to pay a premium for quality- assured fish products. Additionally, the study emphasized the importance of certified quality labels in establishing the superiority and acceptability of value-added fish products in the market (Geethalakshmi et al., n.d.). Another study conducted across 14 districts of Kerala revealed that consumers frequently purchased fish from retail markets, way-side stalls, and vendors while traveling. Fish consumption rates varied among respondents, with a significant proportion consuming fish daily or on alternative days (S. S. Salim et al., 2023).

These studies highlight the significance of understanding consumer preferences and behaviors towards fish in both the Indian and Kerala contexts. The demand for value-added fish products indicates potential opportunities for enterprise development and alternative livelihood options, particularly for marginalized groups such as fisherwomen (Tanuja et al., 2020; Tanuja et al., 2022). Promoting awareness about the health benefits of consuming fresh fish, ensuring quality and food safety, and establishing market and credit linkages are crucial for increasing fish consumption and market opportunities (Tanuja et al., 2020; Geethalakshmi et al., n.d.; Tanuja et al., 2022). Additionally, the development of digital marketing platforms and the implementation of policies supporting transparency and accountability in the fish marketing system can further enhance consumer access and market efficiency (S. Salim et al., 2018; S. S. Salim et al., 2020). consumer preferences towards fish in India and Kerala are influenced by factors such as price, taste, health benefits, and quality assurance. Understanding these preferences is essential for promoting value-added fish products, creating alternative livelihood opportunities, and ensuring sustainable fisheries development and management. Further research and policy interventions are needed to address challenges and capitalize on the potential of the fish market in meeting consumer demands while benefiting fisherfolk and consumers alike.

2.04 Subsidies

A subsidy is a concept defined by Robinson (1967) as an intentional intervention by the government to increase the demand for a particular output or to reduce the production costs associated with that output. Unlike changes driven by market forces or natural factors such as consumer preferences, production techniques, or resource availability, subsidies result from deliberate actions taken by the subsidy giver.

Understanding and measuring government subsidies pose challenges, as discussed in the paper by Schwartz and Clements (n.d.). The paper examines the complexities of defining and quantifying subsidies, explores their role as a fiscal policy tool, analyzes their economic implications in terms of real welfare costs and distributional effects, and evaluates international empirical evidence on subsidies. Additionally, the paper presents options for reforming subsidies, with a focus on enhancing their cost-effectiveness. The research underscores that subsidies serve as a significant instrument within government expenditure policy. At a domestic level, subsidies exert a range of effects on resource allocation decisions, income distribution, expenditure productivity, and overall economic flexibility. Moreover, subsidies can impact structural and sectoral adjustments, influencing the ability of the economy to adapt to changing circumstances.

On an international scale, the increased integration of economies through trade and the proliferation of multilateral and bilateral agreements raise questions about the potential distortions caused by subsidies in the allocation of global resources. Subsidies can affect competitiveness among nations, thereby influencing international trade dynamics.

subsidies play a crucial role in government interventions, with their definition and measurement posing challenges. Their impact extends to domestic resource allocation, income distribution, expenditure productivity, and structural adjustments. Internationally, subsidies can affect competitiveness and resource allocation, particularly in the context of global trade. Understanding and reforming subsidies are important considerations for policymakers aiming to optimize their effectiveness and minimize potential distortions in both domestic and international economic systems (Schwartz & Clements, n.d.; Robinson, 1967). Governments play a crucial role in making policy decisions that impact the welfare of their societies. In a paper by De Gorter et al. (1992), the authors propose that governments face a trade-off between research expenditures, which enhance social welfare, and production subsidies, which incur deadweight losses. This decision-making process involves considering the distribution of income between producers and consumers and taking into account the interplay between research and subsidy expenditures. The paper also explores the reasons behind underinvestment in research and examines the circumstances in which research and subsidy policies complement each other.

Shifting our focus to the Indian agricultural sector during the 1980s, Ashok Gulati (1989) conducted a comprehensive analysis of input subsidies across different states. The study encompassed four key inputs in modern agriculture: fertilizers, irrigation, electricity, and credit. Gulati defines the concept of subsidies on these inputs in a more economically meaningful manner, deviating from the conventional delineation found in government budgets. The research reveals that, on average, the total input subsidy in India over a span of seven years amounted to approximately Rs 9,000 crore, equivalent to around 17 percent of net value added in Indian agriculture. Notably, more than 70 percent of the total input subsidy was allocated to irrigation through major and medium schemes. The study highlights the regional disparities in input subsidy distribution, with states like Uttar Pradesh, Andhra Pradesh, and Punjab receiving a significant share compared to their gross cropped area.

Furthermore, Lohra and Salomonsson (2000) examine conversion subsidies for organic production in Sweden and explore their potential implications for the United States. Their findings indicate that farmers who require subsidies manage larger, less-diversified farms and prioritize organic inspection, quality, and technical advice. The study suggests that access to a greater number of market outlets and information sources serves as a substitute for the payment level in farmers' utility function. This implies that services, rather than subsidies, could be utilized to encourage organic agriculture. The authors argue that similar conditions may exist in the U.S. organic sector, indicating that market-based programs such as cost-sharing for conversion and improving market access could foster the growth of this industry.

Gerarden (2018) points out two significant aspects: the potential understatement of the true effects of government policy when using short- run economic methods and the inefficiency of decentralized government intervention in a global market. The paper specifically addresses the underinvestment in new technologies like solar panels due to innovation spillovers across borders.

Moving on to the agricultural sector in India, Fan et al. (n.d.) provide a comprehensive review of government subsidies and investments, offering a conceptual framework and model to assess their impact on agricultural growth and poverty reduction. The research reveals that while initial subsidies in credit, fertilizer, and irrigation played a crucial role in technology adoption by small farmers, continued subsidies led to inefficiencies in the overall economy. The study identifies agricultural research, education, and rural roads as the most effective public spending items in promoting agricultural growth and poverty reduction consistently over time. The authors conclude that the sustainability of long-term agricultural production growth lies in cutting subsidies and increasing investments in research, development, infrastructure, education, and nonfarm opportunities. Furthermore, they emphasize the importance of institutional reforms in driving future agricultural and rural growth and poverty reduction.

Another study by Narayanamoorthy (n.d.) focuses on the economic viability of drip irrigation systems in banana and grape cultivation. The field-level results demonstrate that drip irrigation not only contributes to water conservation and additional irrigation benefits but also reduces cultivation costs and increases crop productivity compared to conventional methods. The paper reveals that the investment in drip irrigation systems is economically viable even without government subsidies, with farmers recovering the fixed investment cost in the first year itself. However, subsidies are still necessary to encourage widespread adoption, particularly among smaller farmers. The findings suggest that subsidies can be gradually phased out once the technology gains enough traction through the demonstration effect.

In the realm of aquaculture, several research papers shed light on the allocation of funds, the effectiveness of extension services, institutional support, and the overall development of the sector. Guillen et al. (2019) provide a comprehensive overview of the allocation of structural funds in the aquaculture sector across EU Member States from 2000 to 2020. Despite significant investments from the European Union, the study finds that EU aquaculture production has not experienced significant growth. In fact, EU production volume in 2016 was lower than that in 2000, while global production increased substantially. The paper highlights the challenge of reaching national goals if mussel production does not recover in the next five-year period.

Examining the Indian context, Kumaran et al. (2012) presents a study on the extension service in the fisheries and aquaculture sector in India. The research aims to streamline the extension service by understanding the research-extension-farmer linkage and assessing the organizational, manpower, and extension capabilities of the Fisheries Departments in sample states. The findings reveal a heavy reliance on private extension sources by aqua farmers, limited information-seeking behavior among extension personnel, and low consultation rates between researchers and extension agencies. The study suggests the need for a National Fisheries and Aquaculture Extension Service (NFAES) to enhance the capabilities of fisheries departments through structural and functional realignments and partnerships with farm leaders and fisheries professionals.

Furthermore, Pandey et al. (2008) discuss the role of institutional support in the development of freshwater aquaculture in the Mirzapur district of Uttar Pradesh, India. The study highlights the important contributions of the Fish Farmers Development Agency (FFDA) in providing institutional support to fish farmers, including training, arranging pond leases, technical assistance, loan facilitation, and subsidies. However, while the FFDA excelled in training and creating awareness, its effectiveness in seed supply was relatively weaker. The paper emphasizes the significance of adequate and effective institutional support to facilitate technology transfer, enhance productivity, generate employment, and increase income.

Kumaran et al. (2020) investigate the economic viability and sustainability of aquaculture-based livelihood development interventions. The study reveals that these interventions provide employment, income, and livelihood assets to families, reducing the need for migratory labor. The findings suggest the implementation of a government scheme with built-in subsidies to upscale these interventions across the region, enhancing the livelihood security of farm families in coastal areas of the country.

Ngoc et al. (2021) investigate the willingness of shrimp farmers to invest in improved production methods and assess the alignment of government policies with farmers' preferences using a discrete choice experiment. The study finds that farmers prioritize increased yields and more successful crops as their main drivers for investment, showing less concern for environmental impacts. Additionally, there is a mismatch between the current subsidized interest rate and the interest rate desired by farmers. To promote better investment in improved production methods, the authors suggest focusing on the regulatory framework, monitoring and control of environmental impacts, and reevaluating the size of the credit subsidy.

2.05 Literature Gap

While biofloc and Recirculating Aquaculture Systems (RAS) are relatively new techniques introduced in Kerala, there is a research gap in understanding the economic viability and sustainability of fish farming using these methods in the region. Although the researcher has examined the economic viability of biofloc and RAS fish farming among farmers who received subsidies through the Kerala government's Pradhan Mantri Matsya Sampada Yojana (PMMSY) scheme, further investigation is needed to provide a comprehensive analysis of these innovative techniques. Specifically, there is a need to compare the performance, profitability, and environmental impact of biofloc and RAS methods. This comparison would enable a better understanding of the relative advantages and disadvantages of these different approaches, and their suitability for the local context. Such a study would contribute to filling the gap in knowledge regarding the optimal choice of fish farming techniques in Kerala, taking into account factors such as resource availability, local conditions, and market demands. Additionally, the research could explore consumer preferences towards farm-produced freshwater fish, specifically focusing on biofloc and RAS products. Investigating consumer perceptions, including factors influencing their choice, willingness to pay, and perceived quality attributes of fish produced through these techniques, would provide valuable insights for market development strategies and further promote the adoption of sustainable aquaculture methods. Lastly, the thesis could provide policy recommendations for improving the implementation and impact of the PMMSY subsidy scheme, specifically targeting farmers engaged in biofloc and RAS fish farming. By addressing these research gaps, the study would contribute to the existing knowledge and provide valuable insights for the sustainable development of the aquaculture sector in Kerala.

2.06 Conclusion

In conclusion, the literature review has provided a comprehensive understanding of the key themes and research findings related to the economic viability and sustainability of fish farming using biofloc and Recirculating Aquaculture Systems (RAS) methods in Kerala. The review highlighted the relative novelty of these techniques in the region and their potential to transform the aquaculture sector.

The findings indicated that while biofloc and RAS methods have gained attention for their potential benefits, there is still a need for further research to fully understand their economic viability and sustainability in the local context. The studies reviewed focused on the economic aspects of fish farming using these methods, specifically examining the farmers who received subsidies through the Pradhan Mantri Matsya Sampada Yojana (PMMSY) scheme. However, there is a research gap in terms of comparative analysis between these two techniques. Such a comparison would provide valuable insights into the advantages and disadvantages of different approaches and inform decision-making for farmers and policymakers.

Furthermore, the literature review highlighted the importance of understanding consumer preferences towards farm-produced freshwater fish, particularly those produced through biofloc and RAS methods. Exploring consumer perceptions, including factors influencing their choices and willingness to pay, would contribute to market development strategies and promote the adoption of sustainable aquaculture techniques.

Overall, the literature review has provided a foundation for the subsequent research in this thesis, highlighting the gaps in knowledge and the need for further investigation. By addressing these gaps, the study aims to contribute to the understanding of the economic viability and sustainability of biofloc and RAS fish farming in Kerala and provide insights for the development of policies and strategies to promote the adoption of these innovative techniques in the aquaculture sector.

Chapter 3. METHODOLOGY

3.01 Introduction

The research methodology chapter serves as a critical component of any study, providing a framework for how the research was conducted and the methods employed to gather and analyze data. This chapter aims to outline the approach used to investigate the economic feasibility of Biofloc and RAS (Recirculating Aquaculture System) fish farming techniques in the specific study area of Kerala, along with an exploration of consumer preferences in the context of fish consumption.

The chapter begins with a description of the study area (Section 3.2), providing an overview of Kerala, including its geographical location, size, and key characteristics. This section aims to familiarize readers with the context in which the research was conducted, highlighting the significance of the study area in relation to the research objectives. Section 3.3 describes the workflow of the study, offering a step-by-step explanation of the research process, including data collection, economic viability analysis, and validation of findings.

Section 3.4 focuses on the calculation of Return on Investment (ROI), which serves as the basis for assessing the economic feasibility of fish farming systems. The section includes detailed computations of cost, profit, and ROI, with parameter optimization to ensure accurate and reliable results. Section 3.5 addresses consumer preferences by analyzing the choices and perceptions of consumers, thereby integrating critical insights that complement the economic analysis.

Finally, Section 3.6 concludes the chapter by summarizing the methodological framework. Together, these sections provide a clear and logical flow of the research process, ensuring a comprehensive understanding of the tools, techniques, and steps involved in the study. This chapter serves as the foundation for presenting and analyzing the results in the subsequent sections.

3.02 Study Area

Kerala (Figure 3.1) is a state located on the southwestern coast of India. It is known for its scenic beauty, lush green landscapes, backwaters, and rich cultural heritage. Kerala is often referred to as "God's Own Country" due to its natural splendour and diverse attractions.

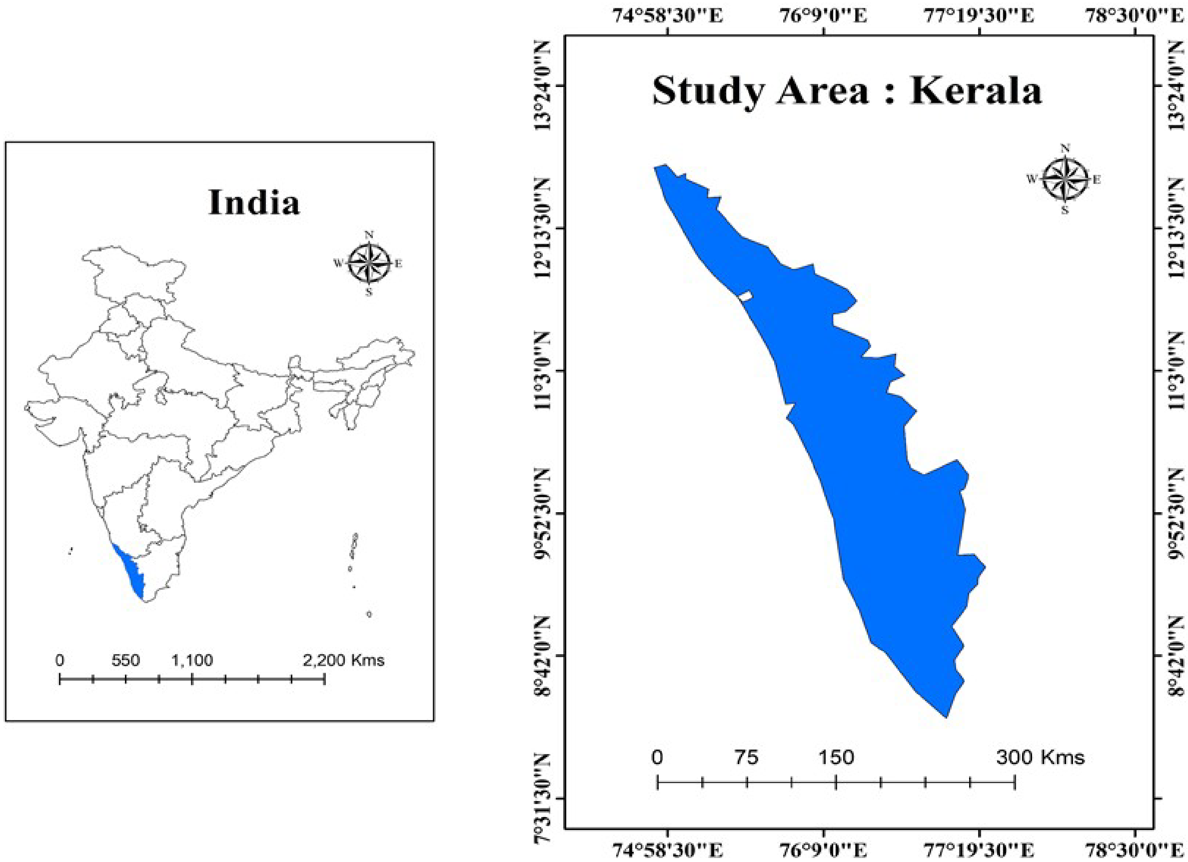

Figure 3-1. Study Area: Kerala (Source: Author's own compilation)

Geographically, Kerala is situated between the Arabian Sea on the west and the Western Ghats Mountain range on the east. It shares its borders with Tamil Nadu to the east and Karnataka to the north. The state covers an area of approximately 38,863 square kilometers, making it one of the smaller states in India.

Kerala has a population of over 33 million people, according to the latest available data. It is known for its high literacy rate, which is one of the highest in India. The state boasts a strong education system and has made significant advancements in healthcare and social welfare.

The economy of Kerala is characterized by a mix of agriculture, industry, and services sectors. Agriculture plays a crucial role in the state's economy, with crops such as rubber, coconut, tea, coffee, spices, and cashew being major contributors. Kerala is also famous for its fishery resources, with fishing and aquaculture being significant economic activities.

In recent years, Kerala has seen substantial growth in the tourism industry. The state attracts both domestic and international tourists with its beautiful beaches, tranquil backwaters, hill stations, wildlife sanctuaries, and Ayurvedic treatments. Tourism has become a vital source of revenue and employment generation in Kerala.

Kerala has a diverse cultural heritage, influenced by a mix of Hindu, Muslim, and Christian traditions. The state is known for its vibrant festivals, such as Onam, Vishu, Thrissur Pooram, and the boat race festival of Vallam Kali. Kathakali, a traditional dance-drama form, and Mohiniyattam, a graceful classical dance form, are prominent art forms that showcase Kerala's cultural richness.

The state of Kerala also boasts high social indicators, including healthcare facilities, life expectancy, and low infant mortality rates. It has achieved significant progress in achieving social welfare, gender equality, and human development.

Kerala is a unique and culturally rich state with abundant natural resources, a strong education system, a growing economy, and a focus on social welfare. Its diverse attractions and progressive policies make it a popular destination for tourists and a place of pride for its residents.

3.03 Work flow of the study

The workflow of the study (figure 3.2) is structured to ensure a systematic and comprehensive approach to achieving the research objectives. The process begins with an extensive literature review, which serves as the foundation for the study. The literature review helps identify existing research gaps, theoretical frameworks, and key areas of focus, which inform the development of a structured questionnaire. The questionnaire is designed to collect primary data from key stakeholders, including Biofloc fish farmers, RAS (Recirculating Aquaculture System) fish farmers, consumers, and PMMSY (Pradhan Mantri Matsya Sampada Yojana) coordinators.

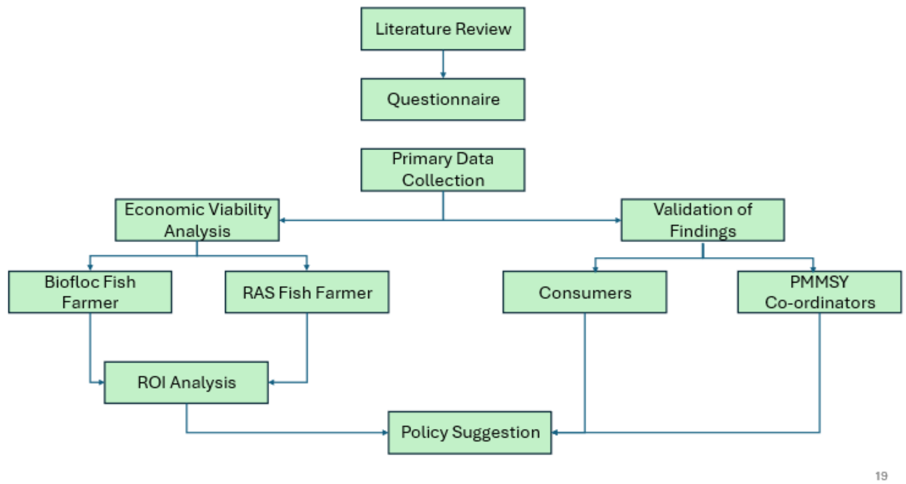

Figure 3-2. Workflow of the thesis (Source: author's own compilation)

The primary data collected is subsequently analyzed to assess the economic viability of both Biofloc and RAS systems. This analysis involves evaluating the financial performance, costs, and benefits associated with each system to determine their comparative feasibility. Further, a return-on-investment (ROI) analysis is conducted for both systems to quantify the financial returns, offering insights into their profitability and efficiency.

To ensure the robustness and validity of the findings, the results are subjected to a validation process. This involves engaging with consumers and PMMSY coordinators to incorporate their perspectives and feedback into the analysis. Such validation strengthens the credibility of the findings and ensures they are grounded in practical realities.

3.04 Calculation of ROI

The methodology employed for calculating the return on investment (ROI) for a single crop in the context of fish farming integrates data simulation, iterative analysis, and established principles of ROI analysis, which have been extensively applied in the assessment of profitability for fish farming ventures (Adewuyi et al., 2010; Awoyemi, 2011; Kuton MP, 2015). ROI analysis serves as a standardized and quantitative measure for evaluating financial performance, capturing the relationship between the net income generated and the total investment made. This methodology enables comparisons across different projects and techniques, offering critical insights into the economic viability and sustainability of fish farming operations.

The process begins with the initialization phase, where base values for key parameters, including N (number of crops), FC (fixed costs), VCC (variable cost coefficient), TS (total subsidies), and TRC (total revenue collected), are obtained from primary data sources. These base values form the foundation for simulating data to generate various combinations of input values across a defined range. Investment costs considered in the analysis include infrastructure development, equipment acquisition, stocking of fish, and operational expenses, which together constitute the total cost. On the revenue side, the income generated from the sale of fish products is a critical component of financial returns.

The ROI calculation process proceeds systematically. First, the total variable cost (TVC) is calculated by multiplying the variable cost coefficient (VCC) with the number of units (N). The total cost (TC) is then determined by adding the fixed costs (FC) to the total variable cost. To account for external financial factors, an adjusted total cost (ATC) is derived by subtracting total subsidies (TS) from the total cost. The average adjusted total cost (Avg_ATC) is computed by dividing the adjusted total cost by the number of units, ensuring the costs are normalized across production scales.

The profit is calculated as the difference between the total revenue collected (TRC) and the average adjusted total cost (Avg_ATC), which reflects the net income from fish farming operations. The ROI is then determined using the formula ROI = (Profit × 100) ÷ Avg_ATC, which expresses profitability as a percentage relative to the average adjusted cost. This approach ensures that the ROI calculation accurately reflects the financial performance of the fish farming enterprise.

To identify the best possible ROI, parameter optimization is conducted by generating multiple parameter combinations within predefined ranges. For this analysis, the ranges for the parameters include: N between 10 and 30, FC between 800,000 and 1,000,000, VCC between 150,000 and 250,000, TS between 200,000 and 400,000, and TRC between 100,000 and

300,000. For each valid combination of parameters, the ROI is calculated, and the results are systematically stored for further evaluation .

The results are analyzed by conducting statistical assessments for each parameter, including minimum, maximum, and average ROI values. This analysis allows for the identification of parameter ranges that yield positive ROI and provides insights into the financial feasibility of the fish farming operations. The ability to compare ROI across different investment scenarios offers a robust framework for decision-making, as noted in prior studies that employed ROI analysis to evaluate profitability and sustainability (Adewuyi et al., 2010; Awoyemi, 2011; Kuton MP, 2015). Figure 3.3 illustrates the methodology in graphical format. By systematically incorporating investment costs, revenue, and simulated data, the methodology ensures a comprehensive evaluation of the financial performance of fish farming ventures. The results not only facilitate comparisons across varying conditions but also provide critical recommendations for optimizing resource allocation and fostering profitable and sustainable fish farming practices.

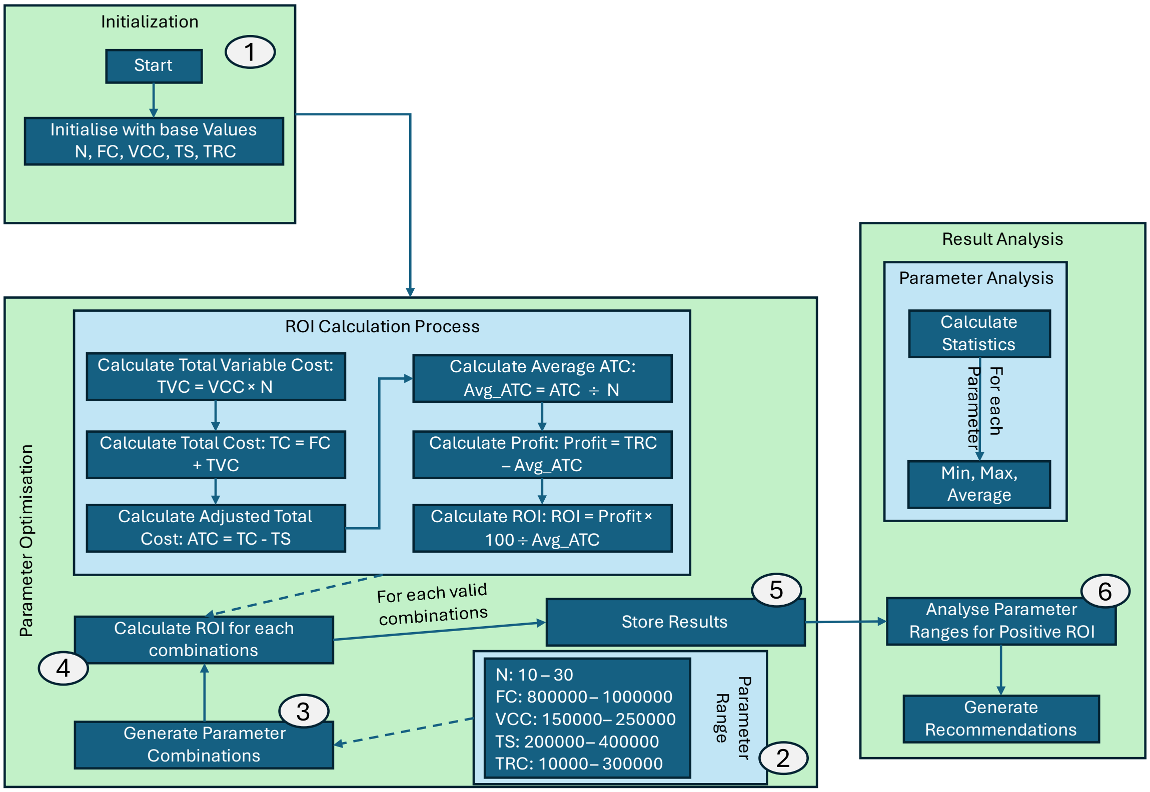

Figure 3-3. Methodology of ROI calculation (Source: Author's own compilation).

3.05 Consumer Preference

For collecting data on consumer preferences towards fish consumption, an online survey was conducted using Google Forms. The choice of an online survey platform was motivated by its convenience, wide reach, and ease of data management. The survey was designed to capture various aspects of consumer behavior and preferences related to fish consumption.

To ensure the reliability and validity of the collected data, the survey questions were carefully constructed, taking into account prior research on consumer behavior and fish consumption. The questionnaire underwent a pre-testing phase among a small group of individuals from the target population. This pre-test helped identify any ambiguities or issues in the questions, allowing for necessary adjustments and refinements.

The survey was distributed through multiple channels, including social media platforms, emails, and online communities specific to Kerala. Participants were assured of the confidentiality and anonymity of their responses, emphasizing the ethical considerations of the study. The data collected were used solely for research purposes.

A total of 221 respondents voluntarily participated in the online survey. From this sample, 217 respondents were selected for the analysis, while four respondents were excluded due to the presence of false or unreliable data. This exclusion aimed to ensure the integrity and accuracy of the collected data. The remaining 217 respondents formed the basis for the subsequent analysis and findings presented in this research report.

By employing an online survey methodology, ensuring the validity of the questionnaire, and obtaining a sizable sample of respondents, the study aimed to gather comprehensive and representative data on consumer preferences towards fish consumption. The findings from this data analysis will provide valuable insights into consumer behaviors, factors influencing fish consumption, opinions on organic fish, and the willingness to pay for farm-produced freshwater fish in the study area.

3.06 Conclusion

In conclusion, the research methodology chapter provides a comprehensive overview of the methods and approaches employed in investigating the economic feasibility of Biofloc and RAS fish farming techniques, as well as exploring consumer preferences in the context of fish farming in Kerala.

The study area description (Section 3.2) provided insights into the geographical location, size, and key characteristics of Kerala, establishing the context for the research. This understanding of the study area is crucial in comprehending the relevance and applicability of the research findings.

Section 3.3 focused on the economic viability of Biofloc and RAS fish farming techniques. The selection of beneficiaries of the PMMSY subsidy for Biofloc and RAS fish farming schemes as the study sample ensured that the research was conducted among relevant stakeholders in the field. The structured questionnaire designed to collect primary data on investment costs, operational expenses, production output, revenue, and profitability of the fish farms played a vital role in obtaining comprehensive and reliable information. The pre-testing process further enhanced the validity and reliability of the collected data, ensuring the accuracy of the findings.

Section 3.4 addressed the exploration of consumer preferences in fish consumption. By employing appropriate data collection techniques such as surveys, interviews, or focus groups, the study aimed to understand the factors influencing consumer choices and preferences related to fish farming techniques. The analysis of these preferences using statistical or qualitative analysis techniques contributed to a deeper understanding of consumer behavior and its implications for the fish farming industry.

Overall, the research methodology chapter establishes a solid foundation for the subsequent chapters of the study. It ensures that the research was conducted in a systematic and rigorous manner, thereby enhancing the credibility and validity of the findings. By employing appropriate data collection techniques, pre-testing processes, and analysis methods, the study aimed to provide valuable insights into the economic viability of Biofloc and RAS fish farming techniques and the factors influencing consumer preferences in Kerala. The forthcoming chapters will build upon the research methodology outlined in this chapter and present the findings, analysis, and conclusions of the study, providing a comprehensive understanding of the economic feasibility of Biofloc and RAS fish farming techniques in Kerala, as well as consumer preferences in the context of fish consumption

Chapter 4. DATA ANALYSIS

4.01 Introduction

Chapter 4 of this thesis focuses on the data analysis, presenting key findings and insights related to the economic viability of biofloc and recirculating aquaculture systems (RAS), as well as consumer preferences towards farmed fish. This chapter aims to provide a comprehensive understanding of the economic feasibility of these innovative aquaculture technologies and the market demand for farmed fish.

Section 4.2 describes the district wise distribution of the fish farmers and their socio-economic profile. Understanding the socio-economic profile of the fish farmers is important while analysing the economic feasibility of the farming. Section 4.3 delves into the economic viability of the biofloc system, examining its financial aspects and assessing its profitability under two scenarios: with subsidy and without subsidy. This dual analysis aims to highlight the impact of government subsidies on the economic performance of biofloc fish farming, providing a clearer understanding of the cost-effectiveness and financial sustainability of implementing biofloc technology. By analyzing the data collected from the study, this section identifies the potential benefits and challenges associated with adopting biofloc systems, while emphasizing the role of subsidies in enhancing profitability.

Following that, Section 4.3 focuses on the economic viability of the RAS system, similarly evaluating its financial feasibility under subsidy and non-subsidy conditions. By comparing these scenarios, this section aims to assess the extent to which subsidies influence the profitability and cost-effectiveness of RAS technology relative to traditional fish farming methods. A thorough analysis of the data provides valuable insights into the economic implications, potential advantages, and challenges associated with adopting RAS systems. The findings contribute to informed decision-making for aquaculture entrepreneurs and investors by illustrating the importance of policy incentives in fostering economically sustainable aquaculture practices.

Furthermore, Section 4.4 explores consumer preferences towards farmed fish. Consumer behavior plays a crucial role in shaping market demand for fish products. By analyzing survey data and conducting statistical analyses, this section aims to identify and understand the factors that influence consumers' choices and preferences when it comes to purchasing farmed fish. These insights will assist aquaculture producers and marketers in developing targeted strategies to meet consumer expectations, enhance product acceptance, and improve market competitiveness.

The data analysis presented in this chapter is based on a comprehensive dataset collected through rigorous surveys, interviews, and financial evaluations. The inclusion of subsidy and non-subsidy scenarios in the economic analysis of biofloc and RAS technologies offers a nuanced understanding of their financial feasibility under varying policy conditions. The findings will contribute to the existing body of knowledge on the economic viability of these aquaculture technologies while also providing valuable insights into consumer preferences within the aquaculture sector

4.02 Socio-economic Profile of the Fish Farmers

Table 4-1. District wise distribution of fish farmers (Source: Primary Survey).

District	Biofloc	RAS
Thiruvananthapuram	25	21
Kollam	10	10
Pathanamthitta	11	9
Alappuzha	50	29
Kottayam	33	13
Idukki	15	27
Ernakulam	33	17
Thrissur	47	22
Palakkad	12	7
Malappuram	17	7
Kozhikode	11	7
Wayanad	11	9
Kannur	8	6
Kasargod	10	4
TOTAL	293	188

The distribution of fish farmers utilizing Biofloc and Recirculating Aquaculture Systems (RAS) across various districts shows significant variation, as illustrated in the provided table. In total, there are 293 Biofloc and 188 RAS fish farmers, indicating a higher adoption of Biofloc technology compared to RAS.

Among the districts, Alappuzha stands out with the highest number of Biofloc farmers (50) and a comparatively large share of RAS farmers (29), suggesting a strong inclination towards aquaculture practices in the region. Similarly, Thrissur and Kottayam also report notable numbers of Biofloc farmers, with 47 and 33 respectively, while RAS adoption in these districts remains relatively lower at 22 and 13.

In contrast, districts such as Kollam and Pathanamthitta exhibit relatively balanced numbers between Biofloc and RAS farmers, indicating comparable preference for both technologies. Conversely, districts like Palakkad, Malappuram, and Kozhikode have limited RAS adoption (ranging between 6 to 7 farmers), while Biofloc farmers in these regions also remain comparatively lower, signaling a lower aquaculture uptake.Notably, Idukki emerges as an exception where RAS farmers (27) outnumber Biofloc farmers (15), highlighting a district-specific preference for RAS systems. On the other hand, Kannur and Kasargod report the lowest numbers of both Biofloc and RAS farmers, with 8 and 6 Biofloc farmers respectively, alongside a minimal RAS presence.

Overall, the data reveals a clear preference for Biofloc systems across most districts, while RAS adoption, though lower, remains significant in select regions. These variations reflect regional differences in the adoption of aquaculture technologies, possibly influenced by factors such as infrastructure, financial support, and local awareness of advanced fish farming practices.

In terms of age distribution (Fig 4.1), the data highlights that fish farming is predominantly practiced by individuals in the older age groups. The 30-40 age group constitutes the smallest segment, with only 38 individuals, indicating limited involvement from younger cohorts. The participation increases in the 40-50 age group, which accounts for 126 individuals, and further rises to 134 individuals in the 50-60 age group. The above 60 age group demonstrates the highest frequency, with 183 individuals, showing that older individuals make up the majority. This trend suggests that fish farming may rely heavily on experienced individuals or generational knowledge transfer, while younger individuals may be less engaged in the profession.

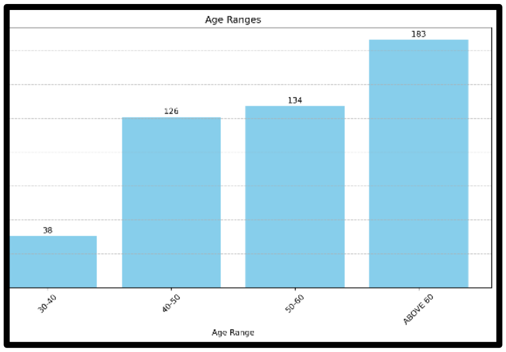

Figure 4-1. Age of the farmers.

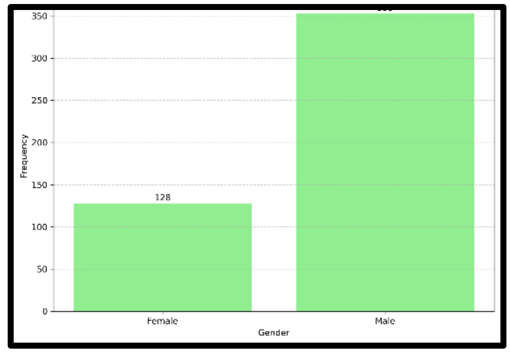

Figure 4-2. Gender of the farmers.

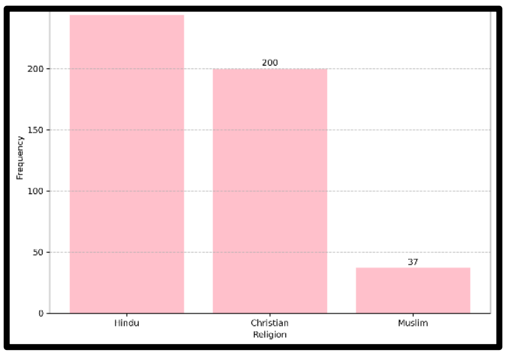

Figure 4-3. Religion of the farmers.

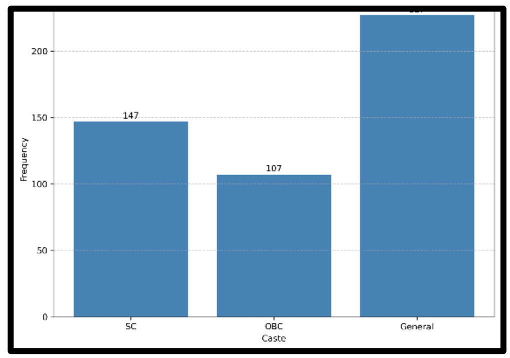

Figure 4-4. Caste of the farmers.

The gender distribution (Fig 4.2) reveals a clear disparity, as male participation significantly outweighs female participation. Males account for over 350 individuals, while females constitute only 128 individuals. This gender imbalance highlights the predominance of men in fish farming activities, which could be attributed to socio-cultural norms, gender roles, or physical labor requirements associated with the occupation.

The analysis of religious distribution (Fig 4.3) shows that fish farming is largely concentrated within the Hindu and Christian communities. The Hindu religion has the largest share, with over 200 individuals, followed closely by Christians, who account for 200 individuals. In contrast, the Muslim community has a smaller representation, with only 37 individuals. This religious composition may reflect regional demographics, occupational traditions, or cultural preferences related to fish farming.The caste distribution(Fig 4.4) further highlights disparities across social groups. The General category has the highest representation, with over 200 individuals, followed by the Scheduled Caste (SC) group, which comprises 147 individuals. The Other Backward Class (OBC) group shows the lowest participation, with 107 individuals. These variations may be influenced by historical access to resources, land ownership patterns, or socio-economic conditions that shape occupational choices.

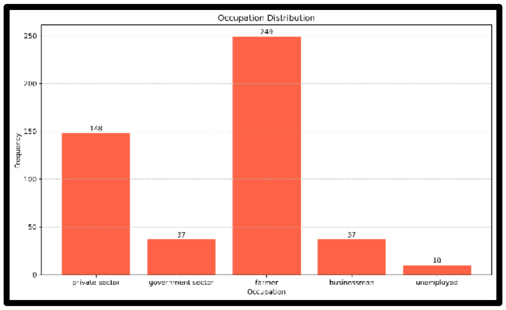

Figure 4-5. Occupation of the farmers

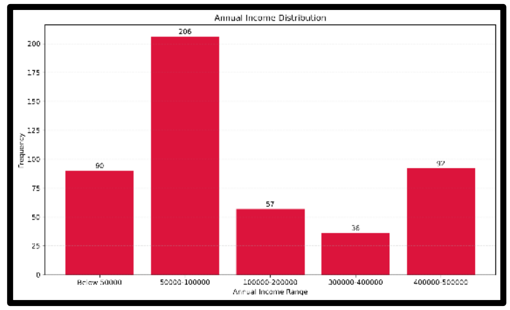

Figure 4-6. Annual Income of the farmers.

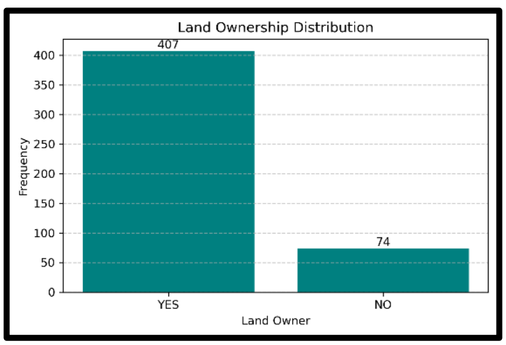

Figure 4-7. Land ownership

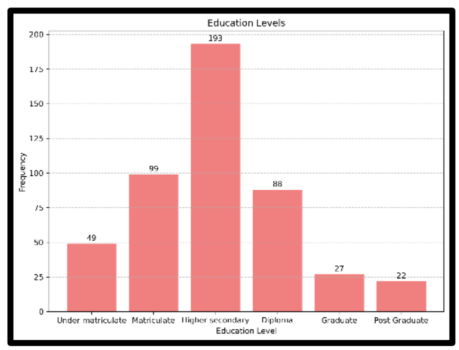

Figure 4-8. Education level of farmers.

The Occupation Distribution (Fig 4.5) reveals that a significant proportion of respondents (249) are engaged in farming, indicating that agriculture is the predominant occupation. Comparatively, other occupational categories such as the private sector (148), government sector (37), businessmen (37), and unemployed individuals (10) show a much smaller representation.

The Annual Income Distribution (Fig 4.6) highlights that a large portion of the respondents falls within the income range of ₹50,000 to ₹100,000 annually (206), followed by the lower income bracket of below ₹50,000 (90). Fewer respondents report incomes in higher ranges, with 57 in the ₹100,000–₹200,000 category, 36 in the ₹300,000–₹400,000 category, and

92 in the ₹400,000–₹500,000 bracket. This pattern indicates that the surveyed population predominantly belongs to the low-to-moderate income group.

The Land Ownership Distribution (Fig 4.7) indicates that a substantial majority of respondents (407) own land, while only 74 do not. This finding suggests a strong prevalence of land ownership, which could be a critical factor influencing their engagement in farming and other livelihood activities.

The Education Levels analysis (Fig 4.8) reveals that the largest group of respondents (193) have completed higher secondary education, suggesting a moderate level of educational attainment in the population. This is followed by matriculate individuals (99) and those with diplomas (88). A smaller proportion have only attained education below the matriculate level (49), while even fewer respondents have graduated (27) or completed post-graduate studies (22). The distribution suggests a concentration of respondents with mid-level education while highlighting a limited presence of higher education qualifications.

4.03 Economic Viability: Biofloc

The analysis of the economic viability of biofloc fish farming under both subsidy and non-subsidy conditions highlights significant financial challenges associated with this farming method. Under the Biofloc with subsidy scenario (Table 4.2), the total number of crops remains constant at 16, with a fixed cost of ₹971,843 and a variable cost per crop of ₹257,956. The inclusion of a subsidy amounting to ₹222,973 helps reduce the adjusted total cost (ATC) to ₹4,876,166. Consequently, the adjusted total cost per crop (average ATC) is ₹304,760.4. However, the total revenue generated per crop is ₹13,323.21, resulting in a negative profit per crop of ₹-291,437.2. This leads to a return on investment (ROI) of -95.6283%, indicating that even with the subsidy, biofloc farming is economically non-viable, as costs significantly exceed the revenue.

Table 4-2. Biofloc with subsidy (Source: Author's calculation based on Primary data).

Calculation	Formula	Values
Input		
Total number of crops (N)*		16
Fixed cost (FC)		971843

Variable cost per crop (VCC)		257956
Total Subsidy (TS)		222973
Total revenue per crop (TRC)		13323.21
Total Variable cost (TVC)	TVC = VCC*N	4127296
Total Cost (TC)	TC = FC + TVC	5099139
Adjusted Total cost (ATC)	ATC = TC - TS	4876166
Adjusted Total cost per crop (Avg ATC)	Avg ATC = ATC/N	304760.4
Profit per crop (Profit)	Profit = TRC - Avg ATC	-291437.2
Output		
ROI	ROI = Profit*100/(Avg ATC)	-95.6283

In the Biofloc without subsidy condition (Table 4.3), the economic challenges become even more pronounced. While the fixed and variable costs remain identical to the subsidized condition, the absence of subsidy leads to an adjusted total cost (ATC) of ₹5,099,139. The average ATC per crop increases to ₹318,696.2. Given that the total revenue per crop remains ₹13,323.21, the profit per crop worsens to ₹-305,373, further exacerbating the financial losses. The ROI under this scenario is -95.81946%, reflecting a marginally lower return compared to the subsidized condition.

Table 4-3. Biofloc without subsidy (Source: Author's calculation based on Primary data).

Calculation	**Formula**	**Values**
Input		
Total number of crops (N)*		16
Fixed cost (FC)		971843
Variable cost per crop (VCC)		257956
Total Subsidy (TS)		0
Total Variable cost (TVC)	TVC = VCC*N	4127296
Total Cost (TC)	TC = FC + TVC	5099139
Adjusted Total cost (ATC)	ATC = TC - TS	5099139
Adjusted Total cost per crop (Avg ATC)	Avg ATC = ATC/N	318696.2
Total revenue per crop (TRC)		13323.21
Profit per crop (Profit)	Profit = TRC - Avg ATC	-305373

Output		
ROI	ROI = Profit*100/(Avg ATC)	-95.81946

In a nutshell, the study suggests that biofloc fish farming incurs substantial financial losses under both subsidy and non-subsidy conditions. While the subsidy reduces the adjusted total cost and mitigates losses to a limited extent, it is insufficient to offset the significant gap between revenue and costs. The negative ROI in both cases underscores the lack of economic feasibility, highlighting the need for further evaluation of cost structures, revenue potential, and subsidy levels to improve the financial sustainability of biofloc fish farming

The correlation matrix (Fig 4.9) illustrates the relationships between various factors influencing the Return on Investment (ROI) of biofloc fish farming. Notably, ROI demonstrates a strong positive correlation with Total Revenue per Crop (TRC) at 0.754, indicating that higher revenues significantly contribute to improving ROI. Conversely, the Variable Cost per Crop (VCC) shows a strong negative correlation with ROI, with a value of -0.657. This suggests that an increase in variable costs substantially reduces ROI, highlighting the sensitivity of profitability to operational expenses.Fixed Costs (FC) exhibit a weak negative correlation with ROI (-0.210), signifying a marginal impact on profitability. Interestingly, Total Subsidy (TS) shows an almost negligible correlation with ROI (-0.004), implying that subsidies, while reducing total costs, do not directly translate into notable improvements in ROI. The total number of crops (N) has a very weak positive correlation (0.092), indicating minimal influence on profitability.

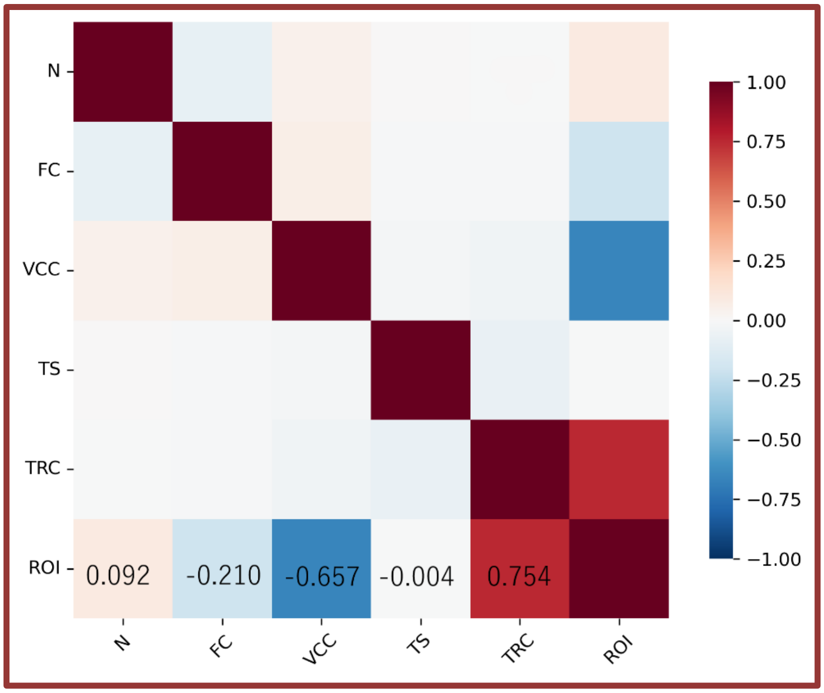

Figure 4-9. Correlation matrix: Biofloc.

Overall, the matrix underscores that revenue generation (TRC) and variable costs (VCC) are the most critical determinants of ROI in biofloc fish farming. Effective cost management, particularly for variable expenses, and enhancing revenue streams are key strategies for improving the financial viability of biofloc systems.

The analysis of parameters for the Biofloc Return on Investment (ROI) highlights significant findings and offers key recommendations for achieving positive ROI in fish farming operations. A total of 51,678 parameter combinations were analyzed, resulting in the identification of the best ROI combination with a value of 76.31%. The optimal input parameters that yielded this ROI include a number of crops (N) of 29.00, fixed cost (FC) of 800,000.00, variable cost (VCC) of 150,000.00, total subsidy (TS) of 380,000.00, and total revenue per crop (TRC) of 290,000.00.

The recommendations derived from the simulation emphasize targeted adjustments to achieve a positive ROI. Specifically, there is a need to increase the total revenue component (TRC) from 13,323.21 to approximately 290,000.00, which represents a substantial increase of 2076.7%. Simultaneously, the variable cost (VCC) must be reduced from 257,956.00 to around

150,000.00, reflecting a decrease of 42%. Additionally, the total subsidy (TS) should be increased from 222,973.00 to approximately 380,000.00, representing a growth of 70.42%. These changes, based on the analysis of the simulated data, are critical for achieving a sustainable and positive return on investment in Biofloc fish farming systems.

4.04 Economic Viability: RAS

Similar to biofloc fish farming, the economic viability of Recirculating Aquaculture Systems (RAS) in fish farming is assessed under two conditions: with subsidy and without subsidy. In the subsidized scenario (Table 4.4), the total number of crops (N) remains constant at 16, with a fixed cost (FC) of 778,629 and a variable cost per crop (VCC) of 254,212.37. A total subsidy (TS) of 221,645.2 is applied, which significantly adjusts the overall costs. The total variable cost (TVC), calculated as VCC multiplied by N, amounts to 4,067,397.92. By summing the fixed cost and the total variable cost, the total cost (TC) is determined as 4,846,026.92. After applying the subsidy, the adjusted total cost (ATC) is reduced to 4,624,381.72. The average total cost per crop, calculated as ATC divided by N, is 289,023.8575. The total revenue per crop (TRC) stands at 13,016.4, which results in a negative profit per crop of -276,007.4575. Consequently, the return on investment (ROI), calculated as the ratio of profit to average total cost multiplied by 100, is -95.49642714, indicating a significant economic loss even under subsidized conditions.

Table 4-4. RAS with subsidy (Source: Author's calculation based on Primary data).

Calculation	Formula	Values
total number of crops (N)		16
Fixed cost (FC)		778629
Variable cost per crop (VCC)		254212.37
Total Subsidy (TS)		221645.2
Total Variable cost (TVC)	TVC = VCC*N	4067397.92
Total Cost (TC)	TC = FC + TVC	4846026.92
Adjusted Total cost (ATC)	ATC = TC - TS	4624381.72

Adjusted Total cost per crop (Avg ATC)	Avg ATC = ATC/N	289023.8575
Total revenue per crop (TRC)		13016.4
Profit per crop (Profit)	Profit = TRC - Avg ATC	-276007.4575
ROI	ROI = Profit*100/(Avg ATC)	-95.49642714

In the scenario without subsidy (Table 4.5), the total costs are relatively higher due to the absence of financial support. Here, the fixed cost (FC) and variable cost per crop (VCC) remain unchanged at 778,629 and 254,212.37, respectively. The total variable cost (TVC) remains the same at 4,067,397.92, and the total cost (TC), being the sum of FC and TVC, is also 4,846,026.92. Since no subsidy is applied, the adjusted total cost (ATC) remains equal to the total cost, amounting to 4,846,026.92. Consequently, the adjusted total cost per crop rises to 302,876.6825. The total revenue per crop (TRC) remains constant at 13,016.4, which results in a higher negative profit per crop of -289,860.2825. The return on investment (ROI) under these conditions is -95.70240935, which reflects a marginally greater economic loss compared to the subsidized scenario.

Table 4-5. RAS without subsidy (Source: Author’s calculation based on Primary data.

Calculation	**Formula**	**Values**
total number of crops (N)		16
Fixed cost (FC)		778629
Variable cost per crop (VCC)		254212.37
Total Subsidy (TS)		0
Total Variable cost (TVC)	TVC = VCC*N	4067397.92
Total Cost (TC)	TC = FC + TVC	4846026.92
Adjusted Total cost (ATC)	ATC = TC - TS	4846026.92
Adjusted Total cost per crop (Avg ATC)	Avg ATC = ATC/N	302876.6825

Total revenue per crop (TRC)		13016.4
Profit per crop (Profit)	Profit = TRC - Avg ATC	-289860.2825
ROI	ROI = Profit*100/(Avg ATC)	-95.70240935

The correlation matrix (Fig 4.10) further illustrates the factors affecting the ROI of RAS fish farming. It provides insight into the relationships between ROI and other key parameters, such as the total number of crops (N), fixed cost (FC), variable cost per crop (VCC), total subsidy (TS), and total revenue per crop (TRC). The most significant positive correlation is observed between ROI and the total revenue per crop (TRC), with a correlation coefficient of 0.726. This indicates that an increase in TRC has the most substantial positive impact on ROI, underlining the importance of revenue generation for improving economic viability. Conversely, the variable cost per crop (VCC) exhibits a strong negative correlation with ROI, with a coefficient of -0.613. This suggests that higher variable costs significantly reduce ROI, emphasizing the need to minimize production costs to achieve profitability.

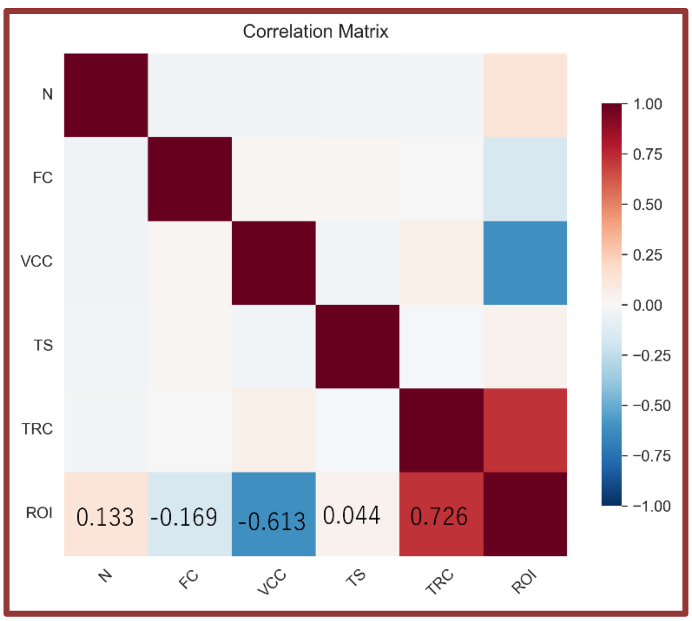

Figure 4-10. Correlation matrix: RAS.

The fixed cost (FC) also shows a negative correlation with ROI, with a coefficient of -0.169. Although this relationship is relatively weaker compared to VCC, it still highlights that elevated fixed costs can adversely affect the financial performance of RAS fish farming. The correlation between ROI and the total number of crops (N) is weakly positive at 0.133, suggesting that while increasing the number of crops may contribute to ROI improvement, its impact is relatively minimal. The total subsidy (TS) displays a near-neutral correlation with ROI at 0.044, indicating that while subsidies reduce overall costs, they do not directly contribute to profitability in a substantial manner.

The study identifies the optimal ROI combination at 76.31%, achieved under specific input conditions. These parameters include the following values: N (29.00), FC (800,000.00), VCC (150,000.00), TS (380,000.00), and TRC (290,000.00). To achieve a positive ROI, recommendations derived from the simulated data indicate significant adjustments in key parameters. Specifically, TRC (Total Resource Cost) must be increased from 13,016.40 to approximately 290,000.00, reflecting a substantial rise of 2127.96%. Simultaneously, VCC (Variable Cost Component) should be reduced from its current value of 254,212.37 to around 150,000.00, representing a decrease of 40.99%. Furthermore, TS (Total subsidy) must be increased from 221,645.50 to approximately 380,000.00, a 71.44% increase. These changes are necessary to optimize the economic feasibility and profitability of RAS fish farming systems. The recommendations are data-driven and highlight the critical role of cost management and revenue enhancement in improving ROI outcomes.

4.05 Consumer Preferences towards Farmed Fishes

Table 4-6. socio economic characteristics of Consumers (Source: Primary Survey).

	No of respondents	%		No of respondents	%
Gender			**Job**		
Male	111	51.1	Agricultural Labour	8	3.7
Female	106	48.9	Business / Entrepreneurship	7	3.2
Category			Contract (Private / Public)	14	6.5
General	159	73.3	Government	53	24.4
OBC	53	24.4	Retired	29	13.4
SC	4	1.9	Professional	48	22.1
ST	1	0.5	Others	58	26.7

Religion			**Monthly Family Income**		
Hindu	124	57.1	10000-15000	10	4.6
Christian	65	29.9	15000-20000	17	7.8
Muslim	15	6.9	20000-25000	41	18.8
Don't Want To Disclose	13	5.9	5000-10000	12	5.52
Education			Below 5000	9	4.1
Degree And Above	159	73.3	More Than 25000	128	58.9
Higher Secondary	28	12.9	**Average Family Size**	4.64	
Diploma	17	7.9			
SSLC	9	4.1			
Upper Primary	4	1.9			
Age					
18-25	27	12.4			
26-35	92	42.4			
36-45	36	16.6			
46-55	19	8.8			
56-65	31	14.3			
Above 65	6	2.7			
Below 18	6	2.8			

The data in table 4.6 presents the socio-economic characteristics of the consumers. Out of the total respondents, 111 individuals identified as male, representing 51.1% of the total. Similarly, 106 individuals identified as female, accounting for 48.9% of the total respondents. Regarding the category, the respondents were classified into General, OBC, SC, and ST categories. The majority of the respondents, 159 individuals (73.3%), belonged to the General category. The OBC category had 53 individuals, representing 24.4% of the total respondents. A small percentage of respondents, 4 individuals (1.9%), belonged to the SC category. Lastly, there was one individual (0.5%) who identified themselves as belonging to the ST category. In terms of religion, the respondents were categorized into different religious groups. The majority, with 124 individuals (57.1%), identified themselves as Hindus. Christians accounted for 65 respondents (29.9%), followed by 15 respondents (6.9%) who identified as Muslims. Additionally, 13 respondents (5.9%) chose not to disclose their religion. Regarding education, the respondents were classified based on their educational attainment. The largest group, consisting of 159 individuals (73.3%), reported having a degree or above. This was followed by

28 respondents (12.9%) who had completed their higher secondary education, and 17 respondents (7.9%) with a diploma. A smaller percentage of respondents had completed SSLC (9 respondents, 4.1%) or upper primary education (4 respondents, 1.9%). In terms of age, the respondents were segmented into different age brackets. The age group of 26-35 had the highest number of respondents, with 92 individuals (42.4%), followed by the age groups of 36-45 (36 respondents, 16.6%)

and 56-65 (31 respondents, 14.3%). The 18-25 age group accounted for 27 respondents (12.4%), while the age groups of 46-55, above 65, and below 18 each had fewer respondents, with 19 (8.8%), 6 (2.7%), and 6 (2.8%) individuals, respectively. In terms of occupation, the respondents were classified into various job categories. Agricultural laborers accounted for 8 respondents (3.7%), while 7 respondents (3.2%) identified themselves as involved in business or entrepreneurship. The category of contract workers, both in the private and public sectors, comprised 14 respondents (6.5%), and 53 respondents (24.4%) were employed in government jobs. The retired population accounted for 29 respondents (13.4%), and 48 respondents (22.1%) were professionals in their respective fields. Additionally, 58 respondents (26.7%) identified themselves as belonging to the "Others" category, which could include individuals in different job roles or unemployed individuals. Regarding monthly family income, the respondents were segmented based on their reported income ranges. The largest group of respondents, comprising 128 individuals (58.9%), reported a monthly family income higher than 25000. The income range of 20000-25000 was reported by 41 respondents (18.8%), followed by 17 respondents (7.8%) in the 15000-20000 income range. A smaller percentage of respondents reported monthly family incomes between 5000-10000 (12 respondents, 5.5%), 10000-15000 (10 respondents, 4.6%), and below 5000 (9 respondents, 4.1%). Additionally, the data indicates that the average family size among the respondents is 4.64 individuals.

Table 4-7. Fish consumption pattern of Consumers (Source: Primary Survey).

Do you or your family eat fish	
Yes	201
No	16
Grand Total	**217**
How often do you or your family eat fish	
3 - 6 times a week	75

2 times a week	37
Everyday	37
Once in a week	31
Once in every 2 weeks	12
Once in a month	9
Grand Total	**201**
What processed fish products do you consume?	
Not used	84
Dry Fish	76
Dry Fish, Fish Pickle	26
Fish Pickle	15
Grand Total	**201**
How often do you consume such processed fish products	
Not used	84
Once in a month	48
Once in a week	27
3 - 6 times a week	14
2 times a week	13
Once in every 2 weeks	10
Everyday	5
Grand Total	**201**

Table 4.7 shows that most respondents, 201 out of 217, reported eating fish. This suggests that fish is a common part of their diet or that they prefer consuming fish-based dishes. On the other hand, 16 respondents stated that they do not eat fish. They cited various reasons such as dietary restrictions and personal preferences as the reasons for avoiding fish consumption. Out of 201 respondents, 75 eat fish 3 to 6 times a week, 37 eat it twice a week, and 37 eat it every day. Additionally, 31 respondents eat fish once a week, 12 eat it once every two weeks, and 9 eat it once a month. These findings highlight a strong preference for regular fish consumption among the surveyed individuals and their families.

Further the table 4.7 reveals that out of 201 respondents, 84 do not consume processed fish products. Among the respondents who do, 76 consume dry fish, 26 consume both dry fish and fish pickle, and 15 consume fish pickle alone. Regarding frequency, 48 respondents consume processed fish products once a month, 27 consume them once a week, and smaller groups consume them more frequently, ranging from 3 to 6 times a week to daily. These findings indicate varied preferences and frequencies in the consumption of processed fish products among the surveyed individuals.

Table 4-8. Preference towards various fish items (Source: Primary Survey).

Fish Item	No. of Consumers
Sardine	120
Mackerel	105
Pink Perch	50
Anchovy	90
Shrimp	75
Shark	25
Squid	40
Tilapia	30
Pearl Spot	20
Pomfret	15
Cutla	10
Rohu	35
Assam Vala	5
Nutter Readybelly	8

From the table 4.8, it is evident that the majority of the respondents in this study prefer sea fish over freshwater fish. Sea fish such as Sardine and Mackerel were the most popular choices, with 120 and 105 consumers respectively purchasing these species. Anchovy and Shrimp also garnered a significant number of consumers, with 90 and 75 respectively. On the other hand, the preference for freshwater fish was relatively lower. Freshwater fish like Tilapia, Pearl Spot, Pomfret, Cutla, and Rohu received moderate to low levels of consumer interest.

The data suggests that sea fish, with their distinct flavours and availability, hold greater appeal for the consumers in this study. The higher number of consumers purchasing sea fish highlights the preference for their taste, texture, and perhaps the perceived health benefits associated with these species. Freshwater fish, while still being chosen by a portion of the respondents, appears to be less popular overall.

Table 4-9. Factors affecting fish purchasing (Source: Primary Survey).

Factor	Frequency
Price of the fish	120
Availability of favorite fish	180
Health benefits	65
Safety	40
Quality of the fish	190
Production method	30
Knowledge of fish cooking	55
Origin of the fish	20

Table 4.9 provides insights into the factors influencing consumers' fish purchasing behavior. Among the factors considered, the price of the fish was mentioned by 120 respondents, indicating that cost plays a significant role in their decision-making process. This suggests that consumers are mindful of their budget and may opt for fish varieties that are more affordable. Another prominent factor is the availability of favorite fish, as mentioned by 180 respondents. This highlights the importance of having access to the specific fish species that consumers prefer. When their preferred fish is easily obtainable, it greatly influences their purchasing decisions. Additionally, the data also suggests that consumers consider the quality of the fish. Consumers prioritize the freshness, taste, and overall quality of the fish they purchase. The frequencies of these factors indicate a strong preference for sea fish among consumers. Factors like price and availability are likely influencing this preference. Sea fish may offer a wider variety, accessibility, and competitive pricing compared to freshwater fish, leading to the higher consumer preference observed in the data.

Table 4.10 presents consumer opinions and preferences regarding farm- produced freshwater fish and sea fish. In response to the statement about the safety of farm-produced fish compared to sea fish, respondents hold a range of opinions. The highest number of respondents, 63, expressed a neutral stance, indicating an equal perception of safety for both types of fish. However, a significant portion of respondents, 60 in total, agree that farm-produced fish is safer. On the other hand, 36 respondents disagree and believe sea fish is safer, while 24 strongly agree with the statement. Furthermore, 18 respondents strongly disagree with the notion that farm- produced fish is safer.

Table 4-10. Consumer's perception about farm raised freshwater fish (Source: Primary Survey).

Statement	Opinion	Frequency
In your opinion, farm produced freshwater Fish is safer than sea fish"	Neutral	63
	Agree	60
	Disagree	36
	Strongly Agree	24
	Strongly Disagree	18
According to you, it is Better for the environment to produce fish on the farms than harvesting from sea	Strongly Agree	40
	Agree	67
	Neutral	50
	Disagree	29
	Strongly Disagree	15
Are you willing to pay high price for farm produced freshwater fish	I Am Not Sure	82
	Yes	63
	No	56

Regarding the environmental impact of fish production, a majority of respondents demonstrate a preference for farm-produced fish. A total of 67 respondents agree that it is better for the environment to produce fish on farms, while 40 respondents strongly agree with this statement. However, 29 respondents disagree, expressing a preference for harvesting fish from the sea. Additionally, 15 respondents strongly disagree with the notion of farm-produced fish being better for the environment.

When it comes to willingness to pay a high price for farm-produced freshwater fish, respondents' opinions vary. The largest group, 82 respondents, are uncertain about paying a higher price. However, 63 respondents are willing to pay a high price, indicating a perceived value in farm-produced fish. Conversely, 56 respondents state that they are not willing to pay a high price for farm-produced fish.

Overall, the table highlights that consumer preferences regarding sea fish are influenced by perceptions of safety, environmental concerns, and price considerations. While a significant number of respondents perceive farm- produced fish as safer and better for the environment, individual opinions vary, emphasizing the complexity of consumer decision-making in relation to seafood preferences.

4.06 Conclusion

In conclusion, Chapter 4 presents a detailed analysis of the economic viability of biofloc and recirculating aquaculture systems (RAS), as well as consumer preferences towards farmed fish. Through this analysis, several important insights have been obtained, offering a better understanding of the financial prospects and market demand within the aquaculture industry.

The investigation conducted in section 4.2 examined the economic viability of biofloc systems. The results suggest that biofloc technology holds promise in terms of its potential to improve water quality, enhance feed conversion efficiency, and reduce the reliance on external inputs. However, it is crucial to consider factors such as initial capital investment, operational costs, and prevailing market conditions to ensure the practicality and financial feasibility of implementing biofloc systems in aquaculture operations.

Similarly, the analysis carried out in section 4.3 focused on the economic viability of RAS. The findings indicate that RAS has the potential to revolutionize fish farming by offering efficient water recirculation and optimized waste management, which can lead to significant cost savings in the long term. However, careful evaluation of the high initial investment costs and energy requirements associated with RAS is necessary to determine its overall financial sustainability.

Additionally, section 4.4 provided valuable insights into consumer preferences towards farmed fish. The analysis shed light on various factors that influence consumer choices, including taste, quality, price, and environmental sustainability. Understanding these preferences is crucial for producers to develop effective marketing strategies and meet market demands, ultimately enhancing the competitiveness and sustainable growth of the industry.

To sum up, the data analysis conducted in this chapter contributes to the existing knowledge on the economic viability of biofloc and RAS systems, as well as consumer preferences in the aquaculture sector. These insights serve as valuable guidance for industry stakeholders, policymakers, and researchers in making informed decisions to promote sustainable and economically viable aquaculture practices.

Going forward, continued monitoring and evaluation of the economic performance of biofloc and RAS systems in different contexts and market conditions will be essential. Additionally, ongoing research on consumer preferences and emerging market trends will provide valuable information to support the growth and development of the aquaculture industry. By embracing innovative technologies and aligning production practices with consumer demands, the aquaculture sector can thrive while contributing to sustainable food production and environmental stewardship.

Chapter 5. FINDINGS AND POLICY SUGGESTIONS

5.01 Introduction

Chapter 5 of this thesis focuses on presenting the findings and policy suggestions related to the comparison of two innovative fish farming techniques: Biofloc and Recirculating Aquaculture Systems (RAS). These techniques have gained significant attention in recent years due to their potential to enhance fish production efficiency, environmental sustainability, and profitability. This chapter aims to provide a comprehensive analysis of the data collected from the coordinators of the Pradhan Mantri Matsya Sampada Yojana (PMMSY) project, as well as insights into consumer preferences towards farmed fish. Based on these findings, policy suggestions will be proposed to further support the development and adoption of these fish farming techniques.

Section 5.2 offers a detailed comparison of Biofloc and RAS systems. It explores their respective principles, operation methods, and advantages, as well as their limitations and challenges. By examining key performance indicators such as water quality management, feed utilization, disease control, and economic viability, this section aims to provide a comprehensive understanding of the strengths and weaknesses of each technique. The comparison serves as a basis for the subsequent analysis of the data collected from the coordinators of the PMMSY project.

In Section 5.3, a summary of the data collected from the coordinators of the PMMSY project is provided. This data includes valuable insights into the implementation and outcomes of Biofloc and RAS systems across different regions. The summary highlights key findings, challenges faced, and successes achieved in adopting these techniques. It offers a comprehensive view of the practical aspects and real-world implications of Biofloc and RAS systems in the context of the PMMSY project. This analysis sets the stage for the subsequent section on consumer preferences towards farmed fish.

Section 5.4 focuses on understanding consumer preferences towards farmed fish. By analyzing consumer behavior, attitudes, and purchasing patterns, this section provides insights into the factors that influence consumer choices. It explores the reasons behind the low demand for organically produced fish and the consumer preference for sea fish over freshwater varieties. Understanding consumer preferences is essential for developing effective marketing strategies and promoting the acceptance and consumption of farmed fish. The findings from this analysis inform the subsequent section on policy suggestions.

Finally, in Section 5.5, policy suggestions are proposed based on the findings and analysis presented in the previous sections. These suggestions aim to address the challenges faced by fish farmers, enhance the marketability of farmed fish, and promote the adoption of sustainable and profitable fish farming techniques. The policy recommendations encompass various aspects, such as government support, subsidy programs, awareness campaigns, and improvements in marketing infrastructure. These suggestions provide actionable insights for policymakers, stakeholders, and industry participants to create an enabling environment for the growth and success of Biofloc and RAS systems within the fisheries sector.

By analyzing the comparison between Biofloc and RAS systems, summarizing the data collected from the PMMSY project coordinators, understanding consumer preferences towards farmed fish, and proposing policy suggestions, this chapter contributes to the broader understanding of the opportunities and challenges associated with these innovative fish farming techniques. It offers valuable insights that can guide policymakers, researchers, and industry stakeholders in promoting sustainable and profitable fish farming practices

5.02 Bio floc and RAS: Comparison

The analysis of the economic viability of biofloc and recirculating aquaculture systems (RAS) in fish farming reveals substantial financial challenges under both subsidy and non-subsidy conditions. In the case of biofloc fish farming, the study highlights that even with financial support, the system remains economically non-viable. Under subsidized conditions, the adjusted total cost per crop is ₹304,760.4, while the total revenue generated per crop is only ₹13,323.21. This results in a significant negative profit per crop of ₹-291,437.2 and a return on investment (ROI) of -95.6283%. In the absence of subsidies, the economic situation worsens, with the average total cost per crop rising to ₹318,696.2 and the profit per crop declining further to ₹-305,373. The ROI in the non-subsidized condition stands at -95.81946%, indicating that the reduction in costs provided by subsidies does little to offset the significant gap between total costs and revenue. The findings emphasize that the current revenue levels are highly insufficient to achieve economic sustainability, while variable costs play a dominant role in eroding profitability.

The correlation analysis for biofloc fish farming further reinforces these findings, indicating that total revenue per crop (TRC) has a strong positive correlation with ROI at 0.754, underscoring the critical role of revenue enhancement in improving financial outcomes. Conversely, variable costs per crop (VCC) show a strong negative correlation with ROI, with a value of -0.657, reflecting the sensitivity of profitability to operational costs. Fixed costs (FC), while negative, exhibit a weaker correlation with ROI at -0.210, suggesting that their impact on financial performance is relatively marginal. Notably, the total subsidy (TS) demonstrates an almost negligible correlation with ROI (-0.004), implying that while subsidies reduce overall costs, they do not meaningfully improve profitability. This analysis highlights that achieving positive ROI in biofloc fish farming would require substantial increases in revenue alongside significant reductions in operational costs. Specifically, simulated data suggests that revenue per crop would need to rise by over 2000%, while variable costs must decrease by approximately 42% to achieve financial sustainability.

A similar assessment of recirculating aquaculture systems (RAS) reveals comparable economic challenges, despite lower fixed costs compared to biofloc systems. Under the subsidized scenario, the adjusted total cost per crop is ₹289,023.8575, while the total revenue per crop remains at ₹13,016.4. This results in a negative profit of ₹-276,007.4575 and an ROI of -95.49642714. Without subsidies, the adjusted total cost per crop rises to ₹302,876.6825, leading to a further decline in profit per crop to ₹-289,860.2825 and an ROI of -95.70240935. These findings suggest that while subsidies marginally mitigate the financial losses in RAS systems, they fail to address the fundamental revenue shortfall and high cost structure that undermine economic viability.

The correlation matrix for RAS fish farming provides additional insights into the factors influencing ROI. Similar to biofloc systems, total revenue per crop (TRC) exhibits the strongest positive correlation with ROI at 0.726, reinforcing the importance of revenue generation as a primary driver of profitability. Variable costs per crop (VCC) show a strong negative correlation with ROI at -0.613, underscoring the need for effective cost management strategies. Fixed costs (FC), while also negatively correlated, display a weaker relationship with ROI at -0.169, suggesting a relatively limited impact on overall financial performance. The correlation between ROI and the total number of crops (N) is weakly positive at 0.133, while the total subsidy (TS) has a near-neutral correlation of 0.044. This indicates that subsidies, while reducing costs, do not significantly improve ROI outcomes.

The study identifies an optimal scenario for achieving positive ROI in both biofloc and RAS systems through targeted adjustments in key economic parameters. For biofloc systems, the simulation suggests that revenue per crop must increase to approximately ₹290,000.00, representing a significant improvement of over 2000%, while variable costs should be reduced by 42%, and subsidies must rise by around 70%. Similarly, in RAS systems, achieving optimal ROI requires a revenue increase of approximately 2130%, a 41% reduction in variable costs, and a 71% increase in subsidies. These findings underscore the necessity of addressing both revenue generation and cost management to improve the financial sustainability of fish farming systems.

In conclusion, the economic viability of both biofloc and RAS fish farming in Kerala remains constrained by substantial gaps between costs and revenues. While subsidies provide limited cost relief, they are insufficient to achieve profitability. The findings highlight the critical need for strategies aimed at significantly enhancing revenue streams and reducing operational costs to ensure the long-term economic sustainability of these systems.

5.03 Summary of Data Collected From Co-Ordinator's of PMMSY Project

During the survey conducted among fish farmers, one of the primary concerns raised by the respondents was the lack of proper guidance and support from the fisheries department, along with a lack of awareness about subsidy details and the provision of low-quality seedlings by the department. To verify and cross-check these findings, interviews were conducted with a few project coordinators of the Pradhan Mantri Matsya Sampada Yojana (PMMSY) scheme. The summary of the interview findings is described below:

Subsidy Discrepancies: The interviews revealed that 40% of the total project cost is provided as a subsidy. However, in order to avail the subsidy, beneficiaries are required to establish the project and submit the bill details to the fisheries department. Some farmers used second-hand products, resulting in the absence of proper bills. As a consequence, there were differences in the amount of subsidy received by farmers.

- **Seedling Quality and Mortality Rate**: The fisheries department provides seedlings in large quantities. However, negligence by the workers during the collection and grouping process can lead to an increase in mortality rates. It is advisable to collect the seedlings within 3-4 hours and transfer them to a larger pond. However, some farmers collect the seedlings from the department only after a long time, such as in the afternoon, which can further increase the mortality rate.
- **Marketing Challenges:** There is a lack of government-level marketing facilities for organic fish in Kerala. Farmers are encouraged to market the products themselves. However, certain behavioral aspects of farmers, such as not giving proper advertisements

or lacking initiative, are influencing the demand. Additionally, some farmers harvest the fish within 3-4 months, well before the maturity period of 6 months, and then complain about low-quality seedlings. Lack of patience among farmers becomes a major barrier in achieving desired outcomes.

- **Fish Farmer's Producer Organization (FFPO):** The government plans to establish FFPOs across Kerala to facilitate the procurement of organically produced fish and support the farmers. These organizations would serve as a single-window facility for handling various tasks, including the distribution of subsidies and procurement of fish.
- **Differential Subsidy Allocation**: Initially, during the start of the project, everyone received an equal percentage of subsidy, which was 40% of the project cost. However, over time, priority was given to individuals in the SC (Scheduled Caste) and ST (Scheduled Tribe) categories, who started receiving 50% of the project cost as subsidy.

In conclusion, the findings from the interviews with project coordinators of the PMMSY scheme highlight various challenges and potential solutions within the fisheries sector. Addressing the lack of guidance and support from the fisheries department, ensuring proper subsidy allocation and documentation, improving seedling quality management, and establishing marketing facilities are crucial for the success and sustainability of fish farming projects. The proposed establishment of FFPOs aims to streamline processes and provide comprehensive support to fish farmers. These findings contribute to a better understanding of the key issues and policy considerations necessary for promoting and enhancing the organic fish farming sector in Kerala

5.04 Consumer’s Preference towards Farmed Fish

The findings regarding consumer preferences towards farmed fish reveal a complex interplay of perceptions, attitudes, and willingness to pay. While farm-produced freshwater fish are acknowledged positively in some areas, they face challenges in consumer acceptance when compared to sea fish.

The safety of farm-produced fish relative to sea fish generated mixed responses. A significant portion of respondents (60 individuals) agreed that farmed fish is safer, while 24 respondents strongly agreed. However, a notable number of respondents (36) disagreed, and 18 strongly disagreed, indicating skepticism about the safety of farm-produced fish. Furthermore, 63 respondents remained neutral, reflecting uncertainty or a lack of definitive opinions on this aspect. This indicates that while farmed fish are increasingly perceived as safe, the acceptance is far from universal, with persistent doubts among a portion of the consumers.

In terms of environmental impact, respondents demonstrated a relatively stronger inclination towards farmed fish production. Majority of the respondents agreed that producing fish on farms is better for the environment compared to harvesting from the sea. This suggests that a considerable segment of respondents recognizes the environmental benefits of aquaculture. However, some resistance remains highlighting varying levels of environmental awareness and concern among consumers.

When it comes to the willingness to pay a higher price for farmed fish, consumer responses were divided. A large segment expressed uncertainty, reflecting hesitation to commit to paying a premium for farm-produced freshwater fish. Meanwhile, 63 respondents indicated a willingness to pay a higher price, suggesting a perceived value in farmed fish among this group. Conversely, 56 respondents outright rejected the idea of paying more, emphasizing the price sensitivity that still prevails among consumers.

Overall, the findings indicate that while there is a growing acknowledgment of the safety and environmental benefits of farm-produced freshwater fish, consumer preferences remain tilted toward sea fish. This preference is likely influenced by factors such as taste, availability, and established habits. Price remains a critical barrier to the broader acceptance of farmed fish, with a significant portion of consumers unwilling or uncertain about paying a premium. Addressing these concerns, particularly by improving perceptions of quality, enhancing affordability, and raising awareness about environmental benefits—will be essential to increasing consumer acceptance of farmed fish.

5.05 Policy Suggestions

- **Subsidy and Loan Support:** The government could increase the subsidy and loan support available to fish farmers. This can be achieved by expanding existing subsidy programs and providing additional financial assistance to fish farmers. The government can also provide technical assistance and training to farmers to help them access these subsidies effectively. Furthermore, creating new loan programs specifically tailored to the needs of fish farmers can provide them with the necessary financial resources to invest in their farms, improve infrastructure, and expand their operations.

- **Marketing and Distribution Channels:** The government can establish marketing and distribution channels for freshwater fish and organic fish. This can involve working closely with retailers to ensure that these products are available in local markets at reasonable prices. The government can collaborate with fish farmers and retailers to develop efficient supply chains that prioritize the timely delivery of fresh fish to consumers. Additionally, the government can explore the establishment of direct-to-consumer sales channels, such as farmers markets or online marketplaces, to help fish farmers reach consumers directly and increase accessibility to these products.
- **Quality Control and Certification Programs:** To build consumer trust and encourage demand for fresh water fish and organic fish, the government could establish quality control and certification programs for these products. This would involve establishing standards for fish farming practices, certification programs for organic fish, and labeling requirements for fresh water fish. By implementing these measures, the government can ensure that consumers have access to safe, high-quality fish products and can make informed choices while purchasing fish.
- **Technical Assistance and Research Support:** The government can provide technical assistance and research support to fish farmers to help them improve the quality of their fish and increase their yields. This can include providing training and technical assistance on best practices for fish farming, including water quality management, feed management, disease prevention, and sustainable farming techniques. Additionally, conducting research on optimal growing conditions for different fish species can provide valuable insights to farmers, enabling them to enhance productivity and profitability.
- **Awareness and Education Programs:** The government of Kerala could launch awareness and education programs to educate the public about the benefits of freshwater fish and organic fish. These programs can include public campaigns, workshops, and

seminars highlighting the health benefits of freshwater fish and the advantages of consuming organic fish. Through these initiatives, the government can educate the public about the nutritional value of freshwater fish and the benefits of consuming fish that is produced using organic farming methods.

- **Promotion of Local Cuisine:** To encourage the consumption of freshwater fish, the government can initiate efforts to promote local cuisine that features these fish varieties. This can include organizing food festivals, culinary competitions, and cooking demonstrations where chefs and local communities showcase traditional recipes and innovative dishes using freshwater fish. By highlighting the unique flavors and culinary diversity associated with freshwater fish, the government can create a demand for these products.

By implementing these policy suggestions, the government of Kerala can promote the consumption of freshwater fish and organic fish, support the livelihoods of fish farmers, ensure the availability of safe and high-quality fish products, and contribute to the overall economic and environmental sustainability of the region's fisheries sector.

5.06 Conclusion

Chapter 5 of this thesis examines various aspects of aquaculture practices, consumer preferences, and policy implications. The chapter began by comparing biofloc technology and Recirculating Aquaculture Systems (RAS) in fish farming, highlighting their effectiveness in improving water quality and promoting sustainable practices. However, it is important to acknowledge that the implementation of these methods as part of the PMMSY project in Kerala faced challenges and resulted in failure.

The data collected from the coordinators of the PMMSY project in Kerala shed light on the difficulties encountered during the project's implementation. These challenges could be attributed to factors such as inadequate infrastructure, limited technical expertise, and insufficient support systems. The outcomes of the project in Kerala provide valuable insights into the complexities involved in executing large-scale aquaculture initiatives and emphasize the need for a tailored approach that considers local conditions and consumer preferences.

Regarding consumer preferences, it is worth noting that in Kerala, consumers tend to prefer sea fish. While consumer preferences remain crucial in aquaculture, it is necessary to align production methods with the specific demands of the local market. This highlights the importance of understanding and catering to the preferences of consumers in Kerala, particularly their inclination towards sea fish.

Considering the failures experienced in Kerala, it is crucial to reflect on the lessons learned and propose appropriate policy suggestions. These suggestions should address the specific challenges encountered in Kerala and aim to overcome them effectively. For instance, they may include improving infrastructure, enhancing technical expertise through training programs, strengthening the sea fish supply chain, and conducting market research to better understand consumer preferences and tailor production accordingly.

In conclusion, the case of Kerala within the PMMSY project serves as a valuable example of the challenges faced in aquaculture initiatives and the need to adapt to local consumer preferences. By incorporating these lessons, future aquaculture projects can strive towards success by aligning production methods with market demands, ensuring sustainable practices, and promoting the growth of the sea fish sector in Kerala.

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