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Investigation of chemical preservatives in commercially available fish from Wayanad and Kannur Districts, Kerala, India

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Abstract

This study aimed to assess the safety, quality, and consumer awareness regarding fish sold in local markets in the Kannur and Wayanad districts of Kerala, India, with a particular focus on the detection of harmful chemical preservatives such as formaldehyde and ammonia. A total of 216 fish samples were collected for analysis of 99 from 11 locations in Kannur and 117 from 13 locations in Wayanad. The primary fish species examined included sardines, Indian mackerel, and tuna. Standard chemical tests were used to detect the presence of ammonia and formaldehyde. The Quality Index Method was employed to evaluate fish freshness and overall quality. A one-way ANOVA was conducted to assess differences in quality among fish species, and a Google-based consumer survey (n = 75) was conducted to evaluate awareness, purchasing behavior, and reported health effects from chemically preserved fish.

The results revealed significant contamination levels, particularly in tuna samples. In Kannur, ammonia was detected in 3 out of 33 Indian mackerel, 5 out of 33 sardines, and 18 out of 33 tuna samples. In Wayanad, 8 out of 39 mackerel and 27 out of 39 tuna samples tested positive for ammonia, while no sardine samples showed contamination. Formaldehyde, a known carcinogen (IARC, 2006), was also prevalent detected in 7 out of 33 mackerel and 11 out of 33 tuna samples in Kannur, and in 16 out of 39 mackerel and 15 out of 39 tuna samples in Wayanad. Quality analysis revealed statistically significant differences in fish freshness across species in both Kannur ($F(2, 30) = 7.63$, $p = 0.002$) and Wayanad ($F(2, 36) = 6.06$, $p = 0.005$), with mackerel showing higher quality than sardines, while no significant difference was observed between mackerel and tuna. Sardines were found to be of the lowest overall quality.

The consumer survey indicated a range of adverse symptoms potentially linked to chemically preserved fish, including stomach aches, vomiting, nausea, allergies, loose motion, itching, and throat pain most frequently reported by female respondents. The survey also found that local markets were the most common sources of fish, and 87.7% of respondents expressed concern about the use of chemicals in fish farming. Trust in labeling was mixed, with 45.2% confident in product labels and 42.5% expressing doubt about the effectiveness of government regulations. Additionally, 48.6% of consumers were willing to pay more for safer, chemical-free fish.

This research highlights the urgent need for comprehensive policy reform, stronger regulatory oversight, and widespread consumer education to ensure the safety and sustainability of fish sold in local markets. It advocates for mandatory inspections, transparent labeling practices, and the promotion of sustainable fishing and preservation methods. By enhancing market surveillance and food safety enforcement, this study aims to reduce health risks and improve the overall quality of fish as a critical dietary resource.

1. Introduction

1.1 Fish Nutrients and Importance

Fish is considered a staple food in many cultures and has long been known to be rich in essential nutrients such as protein, omega-3- 3 fatty acids (Hosomi et al., 2012), and sources of minerals (Iodine, Selenium), vitamin D, and amino acids (taurine, carnitine, melatonin, tryptophan, and polyamines) (Mendivil, 2021). All these make the fish an important and delicious part of a healthy diet. Due to such reasons, the production and consumption of fish have been increasing across the globe. China constituted about 15 % of the global captures, surpassing the combined totals of the second- and third-placed nations. Nearly 49 % of the world's total capture production, was produced by the top seven producers (China, Indonesia, Peru, India, the Russian Federation, United States of America, and Vietnam). In the last 20 years, from 1998 to 2018, the average annual global intake of fish increased from 15.6 to 20.4 kg/year on a live weight Basis and from 11.5 to 15.1 kg/year in edible weight, and by 2050, it is expected to increase from 93.6 to 152 million tons (Naylor et al., 2021). The Primary determinant of fish consumption across nations is their income. Asians are the biggest users, followed by Africans and Oceanians as the lowest (FAO, 2022). Omega-3 fatty acids also have been linked to reduced inflammation, improved blood lipid levels, and better vascular function (Djuricic and Calder, 2021). Additionally, fish is rich in protein, vitamins, and minerals that are essential for maintaining good health. For example, Salmon is a good source of vitamin D and selenium, while tuna is high in vitamin B12 and potassium (Hustad et al., 2022). Therefore, it is important to include a variety of fish in a diet to promote optimal nutrition and overall well-being. However, the recommended fish consumption may depend on the income of the countries. Mostly, poor nations, especially Africa and Asia, may not consume the above recommended amounts of fish since they may not be able to afford it. Consumption of long-chain omega-3 fatty acids, in particular docosahexaenoic acid (DHA), is crucial for brain and eye development as well as for mental health in early childhood and adulthood (J.J. Dinicolantonio and O'keefe, 2020). Consumption of omega-3 fatty acids also improves learning, memory, cognitive well-being, and blood flow in the brain (Dighriri et al., 2022). Moreover, some research suggests that regular fish intake may reduce the risk of age-related cognitive decline and dementia (Takeuchi and Kawashima, 2021; Ylilauri et al., 2022).

1.2 About India and Kerala

The contribution of the fisheries sector to the lives and livelihood of coastal people has well been acknowledged worldwide. Indeed, studies point towards increasing fish production in the world despite increasing challenges being posed to the sector from problems like climate change. India comes second in the production and consumption of fish in the world, next to China. Kerala, A state at the southern tip of the Indian sub- continent, has also been famous in its glory in the field of production and consumption of fish products. By accommodating 2.78 per cent of the state's total population, the Kerala Fisheries sector has been playing a significant role in terms of providing avenues of income and employment in the State. Marine fishing still dominates the fisheries sector in the state (Louis et al., 2019). Estimates show that per capita monthly consumption of fish products in the rural areas of Kerala hovers around 2.26kg and in urban areas 2.10Kg (Louis et al., 2019). The deficit in fish production in the state has caused the State to be much reliant on neighbouring and fish surplus states like Karnataka, Andhra Pradesh and Tamil Nadu. It is recorded that almost 60 per cent of the Domestic demand for fish products in the state has been met by imports from the neighbouring states.

Sources

Fish marketing and distribution is an integral aspect of fish production because, it is only when the fish gets to the final destination (consumers) that production can be complete. Marketing has been defined as all processes involved from the production of a commodity until it gets to the final consumer (Crammer et al., 2001). Unlike conventional marketing systems of agricultural products, fish marketing is characterized by heterogeneous nature of the products with respectto species, size, weight, nutritional quality, storage quality and price. Fish being highly perishable commodity and requires proper preservation and storage to increase the shelf life (Clucas and Ward, 1996). Fish marketing and distribution is an integral aspect of fish production because, it is only when the fish gets to the final destination (consumers) that production can be complete. Marketing has been defined as all Processes involved from the production of a commodity until it gets to the final consumer (Crammer et al., 2001). Unlike conventional marketing systems of agricultural products, fish marketing is characterized by heterogeneous nature of the products with respect to species, size, weight, nutritional quality, storage quality and price. Fish being

highly perishable commodity and requires proper preservation and storage to increase the shelf life (Clucas and Ward, 1996).

Major fish

Indian mackerel (*Rastrelligerkanagurta* (Cuvier, 1816) is one of the Major small pelagic fishery resources in India accounting for approximately 2.13 million tonnes in 2020 (CMFRI, 2021) and second only to the Indian oil sardine (*Sardinella longiceps* Valenciennes, 1847) (Yohannan and Sivadas, 2003; Ganga, 2010). Among the maritime states of India, Kerala holds the topmost position in the landings of large pelagics which comprises tunas the average group-wise contribution of large Pelagics landed during 2013-2019 was tunas (54%) (U, Ganga et al., 2020).

Fish freshness

As for other foods, the achievement of high-quality standards is the main objective of the production chain of fish products and this purpose is inextricably linked to the Freshness of the raw material. According to Oehlenschläger and Sörensen (Oehlenschläger and Sörensen,1997), freshness of Fish means that a fish, in its entire characteristics, is not far away from those characteristics It had in the living state, or that only a short time has passed since the fish has been caught or harvested. Physical, chemical, microbiological and biochemical transformations happen immediately after death, resulting in a progressive loss of food properties in terms of taste and quality. The high perishability of fish products is mainly due to their peculiar composition and structure, even if storage time and temperature are crucial factors for the final quality of the product. The major cause of fish perishability is attributable to the high content of non-protein nitrogen compounds and to the low acidity (pH 6) of the flesh, which are conditions favourable to the growth of microorganism-producing metabolites that affect the organoleptic properties of the products. Nevertheless, the rate of spoilage is also due to the kind of fish species, the sanitary conditions on board, and the amount of food in the Guts (Ghalyetal., 2010). In general, the rapid spoilage of fish after harvest is mainly due to different mechanisms, including (i) post mortem enzymic autolysis, (ii) microbial spoilage, and (iii) oxidation of lipids. Immediately after slaughter, the endogenous autolytic enzymes present in fish muscle Become highly active and begin a proteolytic process which leads to protein decomposition and

solubilization; peptides and free amino acids formed via autolysis, as well as biogenic Amines formed through the action of decarboxylases, lead to fish spoilage (Fraserand Sumar,1998).

1.3 Fish Quality index

Consumers demand for high-quality, safe, and healthy foods is increasing on a global basis (Sen 2005). Consumer studies appear to indicate that Quality is still the key buying cue for fish Purchases (Alasalvar et al. 2011). Besides, in order to secure the food safety, it is important to keep the quality of fish at a high level in each link of the whole complex chain from catch to consumer (Nielsen and Hyldig, 2004). Fresh fish is a highly Perishable product. The supplies of fish are unstable, and fresh fish can be stored only for a short time. For commercialization, it is essential to estimate accurately its freshness, one of the most Important aspects of fish and fish products (Olafsdóttir 1997; Huidobro et al. 2001). Thus, the Need for rapid analytical techniques to measure the Food quality and freshness is greater than ever. Many methods have been tested, but sensory evaluation is still considered as the most effective technique to assess fish freshness and quality deterioration (Martinsdóttir 2002; Alasalvar et al. 2011). Often fish is sold and priced on freshness Criteria.

Fish are brought on shore at designated landing sites where it is graded by fish inspector into different price groups based on the Freshness using sensory analysis (Chebet 2010). Therefore, researchers have been working to Improve the sensory methods (Huidobro et al. 2001). ICAR – CIFT has developed a demerit score-based fish quality index (FQI) system for assessing/ evaluating quality/ freshness of fresh fish. The developed FQI system considered five general quality characteristics viz. Appearance of fish outer surface, fisheyes and gills, condition of fish belly and vents. This web-based system would help the consumer to check/ evaluate the quality of fresh fish instantly. This system provides the instructions for evaluating the quality/ freshness of fish. After evaluating the fish in terms of quality characteristics description, the consumer or user must select appropriate score given in the element score sheet. After complete selection of demerit score, a final fish quality index (FQI) would be computed automatically along with the quality description of fish.

1.4 Formaldehyde and ammonia

Between farm and folk, there are quite several ways for contaminants, i.e., harmful parasites, bacteria, viruses, prions, and chemical or radioactive substances to contaminate food. Yet safe and secure food is a fundamental requirement for human health. Unsafe food can cause more than 200 acute and chronic diseases varying from infectious diseases to cancers (Buckley & Reid, 2010; Fukuda, 2015).

Due to increasing consumer demand, limited resources, and a complex supply chain, fish and Seafood have become highly prone to fraud in a large number of ways such as species substitution, adulteration, catch method fraud, uncleared product extension, etc (Fox *et al*., 2018). In 1859 Formaldehyde was discovered and it was the simplest Aldehyde in terms of chemical structure (Abdollahi & Hosseini, 2014). FA (CH_2O) is a type of colourless gas at ambient temperature and with having an irritating smell. In liquid form, FA commonly known as "formalin", is a low-cost chemical, and is used in some parts of the Agriculture sector for preservative and disinfectant purposes (Kundu et al., 2019). FA is used in the sugar industry to inhibit bacterial growth during juice production. Moreover, FA is permitted to use in some varieties of Italian cheese as a bacteriostatic agent (Liteplo et al., 2002). FA Is a useful and important chemical to the global economy and uses in Many industries i.e., construction (wood processing, furniture, textile, Carpeting), consumable household product industries (antiseptics, Medicines, cosmetics, dish-washing liquids, glues, lacquer), etc. (Kim et al., 2011). The illegal addition of FA is one of the major Adulterations occurs in different types of food i.e., fish and seafood (Mohanty et al., 2018), fruits and vegetables (Wahed et al., 2016), fruit Juice (Kundu et al., 2019), mushrooms (Mason et al., 2004), and milk (Veríssimo et al., 2020) to extend the shelf life. However, in the trimethylamine oxide (TMAO) degradation endogenous pathway of fish Muscle quantities of FA can be produced depending on several intrinsic and extrinsic factors including post-harvest practices (Mohanty et al., 2018). Bhowmik et al. (2020) observed FA variability could be attributed to differences in fish dimension, feeding quality, fishing zone, fish Preservation methods, fish handling methods, and fish storage conditions; in fact, all these parameters can significantly impact the TMAO Levels of fish. There was a short review regarding the FA in seafood (Laly et al., 2018).

Ammonia residues were found on ice which were used in freshly marketed fish, in inter- state fish consignments, and even in the ice used during its transportation. Ammonia is used to slow

the melting of ice during the transportation of fish. The main toxic effects of ammonia, which is a corrosive substance, are on the areas of direct contact, the skin, eyes, respiratory tract, mouth, and digestive system (ATSDR 2004). Ammonia could permanently damage human intestinal tissue at high Concentrations.

Illegal usage of formaldehyde and ammonia by fishermen and fish sellers for longer preservation of fish during sales and transportation has recently become a Problem. Formaldehyde and ammonia residues were found on ice used in freshly marketed fish and interstate fish consignments (FSSAI 2018).

No studies have been conducted on contamination of Formaldehyde and ammonia in fish and seafoods sold in Fish markets in Malabar region Therefore, this study was Aimed at detecting formaldehyde and ammonia in fish and quality index commercially important for India obtained from fish markets in Kerala district Kannur and Wayanad (Kannur 11 location and Wayanad 13 location) using rapid Detection kits.

2. Review of literature

Fish are a crucial source of nutrients for human diets, particularly in low- and middle-income countries. The nutrient composition of fish varies widely among species, and understanding this variation is essential for addressing global nutritional needs. Fish are rich in essential nutrients, including macronutrients (proteins and fats) and micronutrients (vitamins and minerals). Key nutrients found in fish include iron, zinc, calcium, vitamin A, and docosahexaenoic acid (DHA) (Fiorella et al., 2019; Byrd et al., 2020). These nutrients are particularly important for vulnerable populations such as pregnant and lactating women and young children, as they can help meet critical nutritional needs (Fiorella et al., 2019; Byrd et al., 2020).In addition to beneficial nutrients, fish can also contain heavy metals such as lead and mercury. The presence of these metals varies among species and can pose health risks if consumed in large quantities (Fiorella et al., 2019; Byrd et al., 2020).

Fish consumption has been associated with improved maternal and child health outcomes. Adding fish to maternal and child diets can reduce the risk of anemia and improve vitamin D status (Byrd et al., 2022; Byrd et al., 2022). However, evidence on the impact of fish consumption on child growth is mixed, with some studies suggesting benefits while others do not find significant effects (Byrd et al., 2022; Byrd et al., 2022). Dietary supplementation of fish with specific nutrients, such as nucleotides, vitamins, and amino acids, can enhance immune responses and disease resistance in fish. This has implications for aquaculture, where improving fish health can lead to better growth and survival rates (Li & Gatlin, 2006; Pohlenz & Gatlin, 2014).

Fisheries play a critical role in addressing micronutrient deficiencies in developing regions. Local fish supplies can provide essential nutrients to low-income populations, helping to combat malnutrition (Vianna et al., 2020). However, overfishing, climate change, and international trade can reduce the availability of nutritious fish in these regions, highlighting the need for policy reforms to prioritize fisheries as a public health asset (Vianna et al., 2020). There is potential to enhance the nutritional value of farmed fish through modified feeding practices. For example, supplementing fish diets with omega-3 fatty acids can improve their fatty acid profile, making them more nutritious for human consumption (Kwasek et al., 2020). Research on fortifying fish

diets with vitamins and minerals is still in its early stages, but it holds promise for improving human health outcomes (Kwasek et al., 2020).

Fish are a vital source of essential nutrients, particularly for vulnerable populations in low- and middle-income countries. Understanding the nutrient composition of different fish species and the health benefits of fish consumption can inform nutrition policies and interventions. Sustainable aquaculture practices and policy reforms are needed to ensure the availability of nutritious fish and address global nutritional needs.

Sardine fish, particularly the Indian oil sardine (Sardinella longiceps), play a significant role in India' s marine fishery, contributing substantially to the economy and livelihoods of coastal communities. The abundance of oil sardine on the Malabar Coast is highly variable, with periods of high abundance and major population crashes observed over the decades. Recruitment success is influenced by environmental factors such as sea level and upwelling, which are linked to the monsoon season (Longhurst & Wooster, 1990). Indian mackerel contributed 8.6% to total marine fish production in India during 1985-2000, with an average annual catch of 0.19 million tonnes. (Yohannan, T., & amp; Sivadas, M. (2000)

The use of formaldehyde and ammonia in fish preservation and aquaculture has raised significant health and environmental concerns. This Studies have shown widespread contamination of fish and seafood with formaldehyde and ammonia in various markets. For instance, in Chennai, India, formaldehyde was detected in 100% of samples from the N4 Beach fish market and in varying percentages in other markets, while ammonia was found in 100% of samples from several markets (Devaraj et al., 2021). Similarly, in Southern Bangladesh, formaldehyde was detected in freshwater fish, with higher concentrations correlating with increased exposure times and concentrations in laboratory simulations (Hoque et al., 2018).

Formaldehyde is a known carcinogen, and its presence in fish poses significant health risks. Continuous consumption of formaldehyde-contaminated fish has been linked to adverse health effects, including damage to the stomach lining and increased blood formaldehyde levels in animal studies (Kundu et al., 2020). The public health risk is particularly concerning in regions where formaldehyde is used as a preservative in fish (Hoque et al., 2018; Kundu et al., 2020). Ammonia toxicity in fish can lead to severe health issues, including convulsions, coma, and death. It disrupts neuronal function by displacing potassium ions and causing excessive calcium

influx, leading to cell death in the central nervous system (Randall & Tsui, 2002). Ammonia exposure also increases physiological stress and oxidative damage in fish, particularly in those pre-exposed to polluted environments (Soler et al., 2020).

Formalin, an aqueous solution of formaldehyde, is commonly used in aquaculture to control parasitic infections. However, it can negatively impact water quality by reducing dissolved oxygen levels and altering pH, which can stress or even kill fish if not managed properly (Rowland et al., 2006; Leal et al., 2018). Formalin treatments can also affect nitrifying bacteria in bio filters, potentially leading to increased nitrite levels in recirculating systems (Keck & Blanc, 2002). Ammonia can accumulate in intensive aquaculture systems due to the decomposition of uneaten food and animal waste. It causes oxidative stress, immune suppression, and apoptosis in fish, leading to poor health and increased mortality. Mitigation strategies, such as the use of exogenous taurine, have shown promise in reducing the adverse effects of ammonia toxicity (Zhang et al., 2018).

The illegal use of formaldehyde and ammonia in fish preservation highlights the need for stricter regulations and enforcement to protect public health. Developing alternative preservation technologies and improving monitoring and control measures are essential steps to mitigate these risks (Devaraj et al., 2021). Effective risk management strategies include regular monitoring of formaldehyde and ammonia levels in fish markets and aquaculture systems, as well as the implementation of safer preservation methods. Public awareness campaigns and education on the dangers of these chemicals can also help reduce their use and protect consumer health (Hoque et al., 2018; Kundu et al., 2020). The presence of formaldehyde and ammonia in fish and seafood poses significant health risks and environmental challenges. Addressing these issues requires a combination of regulatory action, improved preservation technologies, and effective risk management strategies to ensure the safety and sustainability of fish and seafood products.

Consuming fish preserved with chemical preservatives can pose several health risks due to the resence of environmental contaminants and toxic metals. Here are the key health issues associated with eating chemically preserved fish .Fish can accumulate toxic metals such as lead, cadmium, arsenic, and mercury, which can be harmful if consumed in large quantities. These metals can cause various health issues, including neurological and developmental problems, especially in vulnerable populations like children and pregnant women (Bosch et al., 2016; Lehel

et al., 2020).The use of chemical preservatives in fish can lead to the ingestion of substances that may have adverse health effects. While these preservatives help in prolonging shelf life and preventing spoilage, they can also introduce harmful chemicals into the body (Ali et al., 2022).

Mercury, a common contaminant in fish, is particularly harmful to the nervous system. Long-term exposure can lead to cognitive deficits and developmental delays in children (Bosch et al., 2016).While fish is generally beneficial for heart health due to its omega-3 fatty acids, the presence of toxic metals can negate these benefits and potentially contribute to cardiovascular diseases (Domingo, 2016; Thomsen et al., 2021).Certain chemical contaminants found in fish have been linked to an increased risk of cancer. These include persistent organic pollutants (POPs) and other industrial chemicals that can accumulate in fish tissue (Domingo, 2016; Thomsenn et al., 2021).

Consuming a variety of fish species and moderating the frequency and portion size can help balance the health benefits and risks. It is particularly important for women of childbearing age and children to limit the consumption of fish types that are more likely to be contaminated (Thomsen et al., 2021). Ensuring that fish products comply with food safety regulations regarding permissible levels of contaminants can help mitigate health risks. Regular monitoring and stricter regulations are essential for consumer protection (Bosch et al., 2016; Lehel et al., 2020).

While fish is a nutritious food source rich in essential nutrients and omega-3 fatty acids, the presence of chemical contaminants and toxic metals in chemically preserved fish can pose significant health risks. It is crucial to consume a variety of fish in moderation and ensure that fish products meet safety standards to minimize these risks. The quality of fish in commercial markets is a critical factor influencing consumer health, market prices, and overall satisfaction. Various studies have examined different aspects of fish quality, including sensory, microbiological, and physico-chemical properties, as well as the impact of storage and handling practices. Freshness and Storage: Freshness is a key indicator of fish quality.

Studies have shown that fish quality degrades over time, with sensory methods like the Quality Index Method and physical measurements such as Torrymeter values being effective in monitoring this degradation. Seasonal variations also affect freshness, with some species showing better quality in certain seasons (Cardoso et al., 2021; Poli et al., 2003). The nutritional

quality of fish, including moisture, lipid, and fatty acid composition, varies with species and storage conditions. For example, meagre (Argyrosomus regius) showed promising nutritional traits and a shelf-life of up to nine days under proper storage conditions (Poli et al., 2003).Fresh fish can be contaminated with various pathogenic bacteria, including Pseudomonas spp., Aeromonas spp., Escherichia coli, Vibrio spp., and Salmonella spp. Effective control measures are necessary to prevent contamination during postharvest processing (Gao et al., 2022; Menezes et al., 2022).

In different regions, the microbiological quality of fish varies. For instance, fish in the wet markets of Kota Kinabalu, Malaysia, showed high levels of bacterial contamination, while fish in Cuiabá, Brazil, also exhibited significant microbial counts, indicating potential health risks (Gao et al., 2022; Menezes et al., 2022).The method of fish capture significantly impacts stress levels and, consequently, the quality of the fish. For example, saithe (Pollachius virens L.) caught by gillnetting exhibited higher stress indicators compared to those caught by jigging, although the final fillet quality did not show significant differences (Toledo-Guedes et al., 2016). Proper storage conditions, including temperature control, are crucial for maintaining fish quality.

Inadequate storage temperatures can lead to rapid quality degradation, as observed in various studies (Menezes et al., 2022; Mol, 2011).Advances in technology, such as the development of smart sensors, can enhance the prediction and monitoring of fish quality. These sensors can measure biochemical and microbial spoilage indexes, providing accurate estimations of fish quality over time and helping to reduce wastage (García et al., 2017). The performance of fish markets can vary significantly. For example, the ex-vessel market for Atlantic cod in Norway showed that fishing methods had a more substantial impact on prices than the quality index, indicating a need for better market mechanisms to incentivize high-quality fish delivery (Sogn-Grundvåg et al., 2021).In regions like Istanbul, Turkey, the quality of fish varies by location and season, with better quality observed in areas closer to wholesale markets due to faster and more efficient transportation (Mol, 2011). The quality of fish in commercial markets is influenced by a variety of factors, including capture methods, storage conditions, and regional market practices.

Technological advancements and better market mechanisms can help improve fish quality, reduce wastage, and ensure consumer safety. Effective control measures and proper handling practices are essential to maintaining high standards of fish quality across different markets.

Several studies have investigated the quality and safety of fish sold in local markets. For example, a study by Hussain et al. (2019) found that fish samples collected from local markets in Bangladesh contained high levels of formaldehyde, a commonly used preservative. Similarly, a study by Kumar et al. (2018) detected high levels of ammonia in fish samples collected from local markets in India. In terms of fish quality, a study by Oliveira et al. (2017) evaluated the quality of three fish species (tilapia, catfish, and salmon) sold in local markets in Brazil and found significant differences in quality parameters such as pH, texture, and color. However, there is limited research on the quality and safety of fish sold in local markets in India, kerala, particularly in Kannur and Wayanad. This study aims to fill this knowledge gap by evaluating the quality and safety of three fish species sold in local markets in District-1 wayand and District-2 Kannur, with a focus on formaldehyde and ammonia levels.

3. Aim of study

This study aims to evaluate the safety and quality of fish sold in local markets across the Kannur and Wayanad districts of Kerala, India, focusing on detecting harmful preservatives like formaldehyde and ammonia in commonly consumed fish species, including sardine, Indian mackerel, and tuna. This research seeks to understand the extent of contamination in these fish species and assess the factors contributing to the degradation of their quality, such as improper handling, storage, and transportation. In addition to evaluating chemical contamination, the study aims to assess the overall quality and freshness of fish samples using a Quality Index Method and laboratory analyses. By comparing the quality of sardine, mackerel, and tuna across both regions, the study will identify any significant differences in quality and determine what factors affect the fish's freshness and sensory attributes. Furthermore, the present study aims to assess the adverse health effects associated with consuming chemically preserved fish among a sample of individuals, categorized by age and gender, to identify patterns and potential risks linked to such consumption.This research aims to explore consumer awareness, purchasing habits, and concerns regarding fish quality, including their trust in product labels and willingness to pay more for higher-quality fish. The study also examines the role of government regulations in ensuring fish safety and proposes recommendations for improving food safety standards, transparency in fish labelling, and more stringent market regulations. Ultimately, this research seeks to provide actionable insights for improving fish quality and safety in local markets, enhancing consumer education, and ensuring that the fish supply chain operates more effectively to minimize contamination risks.

4. Materials and methods

4.1 Research Design

This study utilized a cross-sectional survey design to evaluate the adverse health effects associated with consuming chemically preserved fish among residents of two districts in Kerala: Wayanad and Kannur (Figure 1-3). The objective was to identify patterns and potential risks related to such consumption across different demographics within these regions.

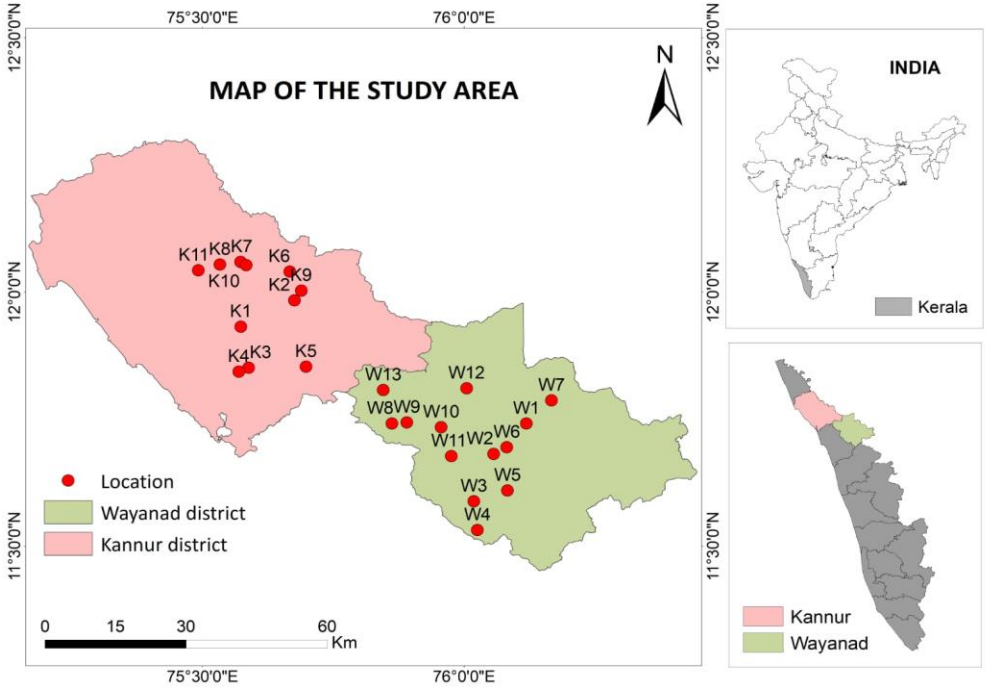

Figure 1: Sampling location in Kannur and Wayanad District.

4.1.2 Sampling method

Participants were selected through convenience sampling, with the survey distributed via Google Forms to individuals accessible through social networks and community groups in Wayanad and Kannur districts.

4.1.3 Sample size

A total of 75 respondents participated in the survey, with 35 from Wayanad and 40 from Kannur. This sample size was chosen to provide preliminary insights while considering resource constraints.

4.1.4 Demographics

The participants were categorized based on age and gender as follows:

- **Ages 20-29:** Wayanad (M-3, F-26), Kannur (M-0, F-0)
- **Ages 30-39:** Wayanad (M-0, F-0), Kannur (M-8, F-15)
- **Ages 40-49:** Wayanad (M-0, F-0), Kannur (M-9, F-9)
- **Ages 50-59:** Wayanad (M-1, F-4), Kannur (M-0, F-0)

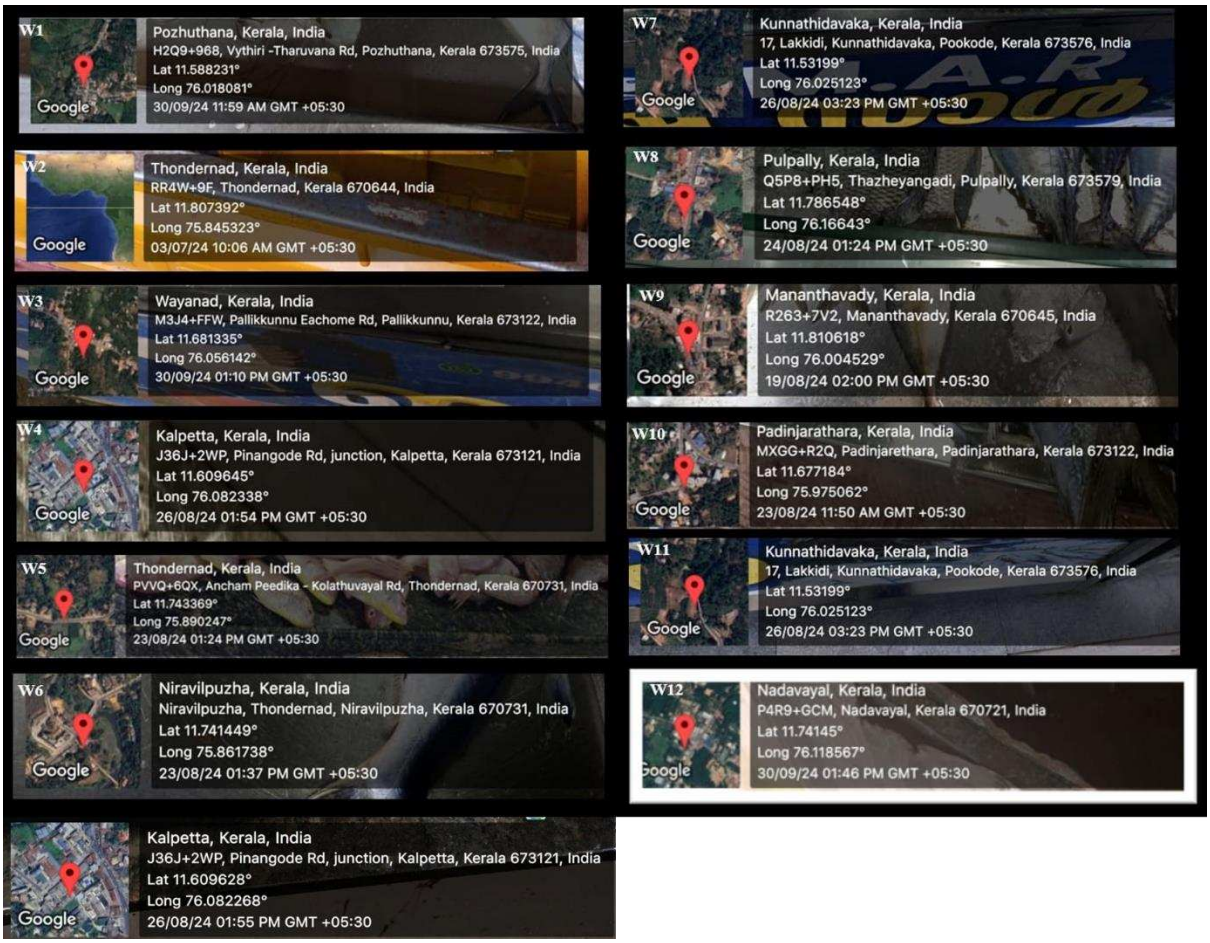

Figure 2: Study location in Wayanad

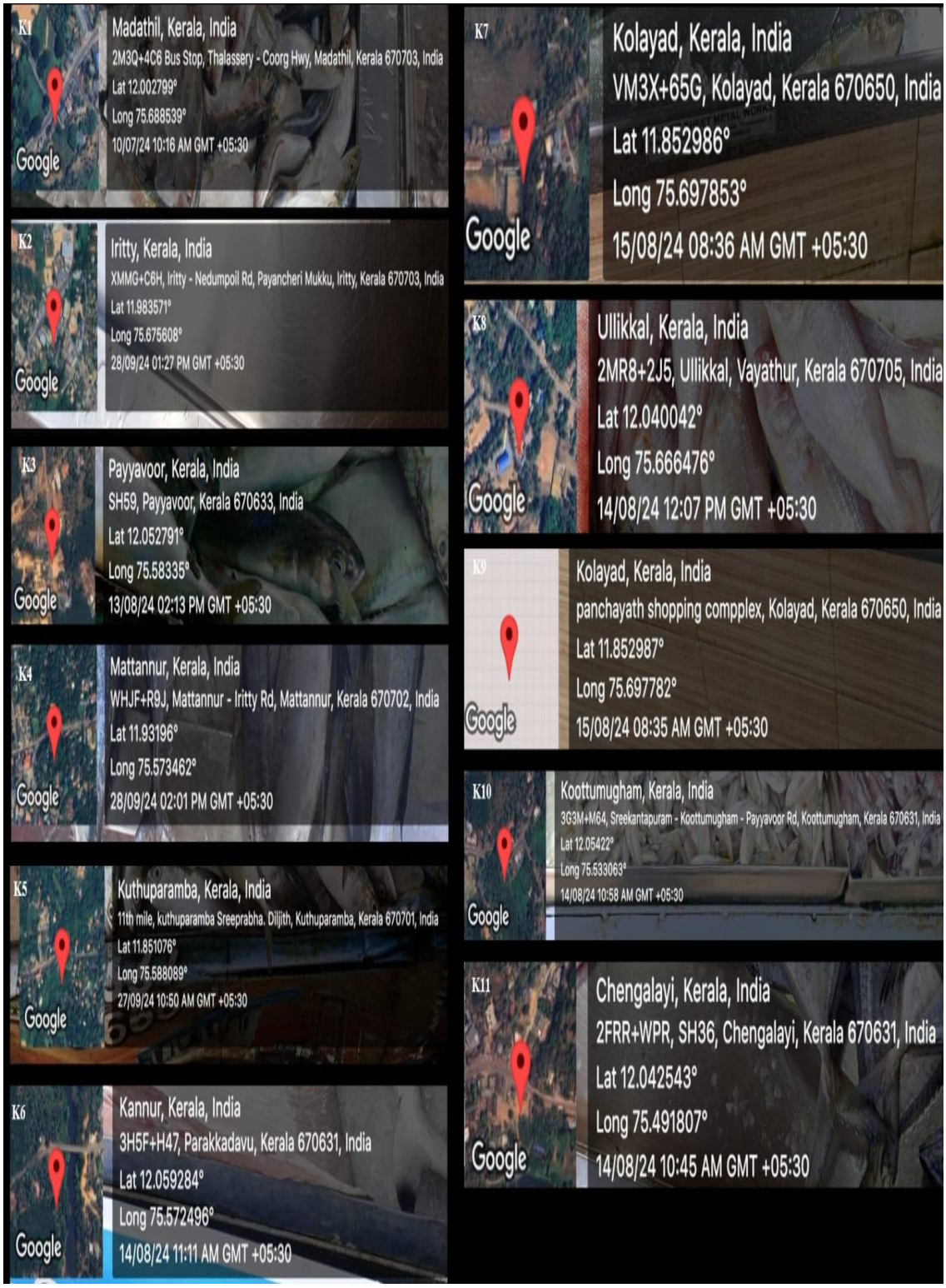

Figure 3: Study location in Kannur

4.1.5 Data Collection

A structured questionnaire was developed specifically for this study, incorporating both closed and open-ended questions to capture a range of responses. A Google survey consisting of 15 questions was employed to gather information on consumer opinions of fish quality in Kannur and Wayanad districtsThe questionnaire included sections on demographic information and a detailed assessment of adverse effects experienced after consuming preserved fish, such as stomach ache, vomiting, nausea, allergies, loose motion, itching, and throat pain.

The online survey was distributed via Google Forms over two weeks. Participants were invited through social media platforms and community forums specific to Wayanad and Kannur districts. A consent form outlining the study's purpose, voluntary participation, and confidentiality was provided at the beginning of the survey. Informed consent was obtained electronically from all participants. Participants were assured of the confidentiality of their responses and their right to withdraw at any time without consequence. Data were anonymized to protect participant identities.

4.2 Detection of formaldehyde, Ammonia and quality index

4.2.1 Research design

Indian mackerel, sardine, and tuna specimens were collected for analyzing fish quality. A total of 11 fish markets in Kannur and 13 in Wayanad were sampled. Each market was visited three times on different dates, and specimens were collected on each occasion.

4.2.2 Formalinand Ammonia detection

Adulterants such as formalin and ammonia were detected using HiMedia'sHiRapid test kits, specifically the Formalin Test Kit (K137) and Ammonia Test Kit (K136). These kits, approved by ICAR CIFT, enable the rapid and user-friendly detection of formalin and ammonia adulteration in fish and seafood.

4.2.3 Ammonia detection using Ammonia Test Kit (K136)

A paper strip taken from Reagent bottle A-1 is first swabbed on the fish, 3 - 4 times in different portions. Then one drop of Reagent A-2 solution is added on to the strip. After a couple of

minutes colour change will occur in the strip (Figure 4). The developed colour is then compared with the standard colour chart provided on the box.

Table 1: Colour changes in Ammonia test strip paper representation.

Colour Development	Results	Interpretation
Yellow / Green colour	Fish free from Ammonia	Fish safe for consumption
Blue colour (Ocean Blue / Sky blue colour)	Ammonia present	Fish unsafe for consumption

Figure 4: Ammonia test strip paper.

4.2.4 Formalin detection using Formalin Test Kit (K137)

For formalin detection, reagent F-2 is prepared first by flipping open the dropper lid from bottle F-2 and emptying the contents of vial F-W into it. Replace the dropper lid and shake well. A strip taken from the Reagent Bottle F-1 is then swabbed on the fish surface/cut surface of the fish. Swabbing is repeated 3 to 4 times at different portions in order to wet the paper strip (Figure 5). One drop of Reagent F-2 is then added onto the swabbed paper strip and waits for 1.5 to 2.0 minutes for maximum colour development. The developed colour is then compared with the standard colour chart provided on the box.

Table 2: Colour changes in Formaldehyde test strip paper representation.

Colour Development	Results	Interpretation
Yellowish colour	Fish free from Formaldehyde/ Formalin	Fish safe for consumption
Green / Dark Bluish colour	Formaldehyde/ Formalin present	Fish unsafe for consumption

Figure 5: Formaldehyde test strip paper

4.3 Quality Index Method

Indian Council of Agricultural Research - Central Instituteof Fisheries Technology (ICAR CIFT) has developed a demerit score-based fish quality index system for assessing/evaluating the quality/ freshness of fresh fish. The developed FQI system considered five general quality characteristics viz. Appearance of fish outer surface, fish eyes and gills, condition of the fish belly and vents. This web based system would help the consumer to check/ evaluate the quality of fresh fish instantly. This system provides the instructions for evaluating the quality/ freshness of fish. After evaluating the fish in terms of quality characteristics description, an appropriate score is selected, given in the element score sheet. After complete selection of demerit score, a final fish quality index would be computed automatically along with the quality description of fish.

4.4 Data analysis

All statistical analyses were performed using IBM SPSS Statistics Version 20. A significance level of $p < 0.05$ was used to determine statistical significance throughout the study. A one-way analysis of variance (ANOVA) was conducted to examine the differences in fish quality among three species (Mackerel, Sardine, and Tuna) collected from multiple sampling locations. In this model, the fish species was treated as the fixed effect, as it represents the categorical independent variable of primary interest. The dependent variable was the fish quality score, measured across all samples. To further explore significant differences identified by the ANOVA, Tukey's Honestly Significant Difference (HSD) post hoc test was employed for pairwise comparisons between the species. Additionally, one-way ANOVA was performed to evaluate the effect of sampling location on fish quality, location was considered the fixed effect to assess spatial variation in quality scores across sites.

5. Results

5.1Google survey

The distribution of respondents by age group and gender among a total sample of 75 individuals, comprising 21 males and 54 females (Table 3). More responses were received from participants residing in Wayanad District (Figure6). Overall, the highest proportion of respondents falls within the 20–29 age group, accounting for 38.7% of the total sample. This age group is predominantly female, with 48.1% of female respondents belonging to it, compared to only 14.2% of male respondents. The second most represented age group is 30–39, making up 30.7% of the total, with a balanced distribution between genders 38.1% among males and 27.8% among females. The 40–49 age group comprises 24% of the total sample, and it is the most common age group among males, representing 42.86% of them, while only 16.7% of females fall into this category. The least represented group is 50–59, which accounts for just 6.7% of the total, with minimal participation from both genders. From the data, it is evident that younger respondents, particularly those aged 20–29, are predominantly female, while middle-aged males, especially in the 40–49 age group, form the majority among the male participants. Female respondents are more numerous across all age groups, and the overall sample shows a skewed gender distribution, with females making up nearly three-quarters of the participants.

Table 3: Distribution of the sample by age group and gender, values are percentages of respondents (%).

Variable	Total		Male		Female	
Age	Frequency n =75	Percentage %	Frequency n =21	Percentage %	Frequency n =54	Percentage %
20-29	29	38.7%	3	14.2%	26	48.1%
30-39	23	30.7%	8	38.1%	15	27.8%
40-49	18	24%	9	42.86%	9	16.7%
50-59	5	6.7%	1	4.8%	4	7.5%

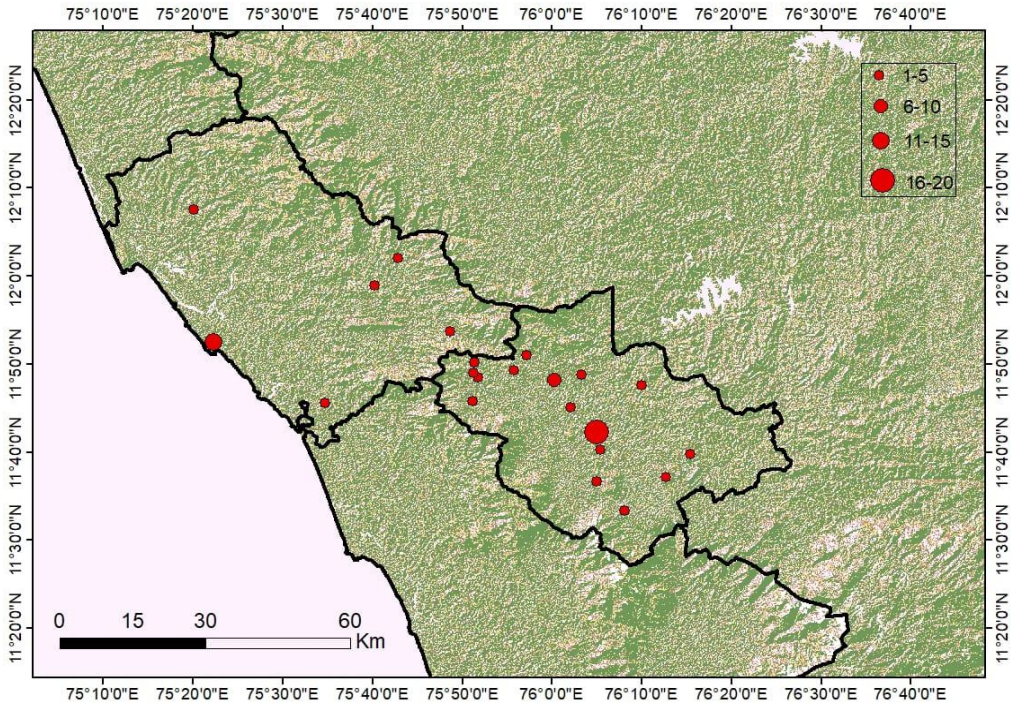

Figure 6: Demographic information: Geographical distribution of participants.

In analysing the adverse reactions reported by survey participants after consuming fish, the following symptoms were documented (Table 4). Among all symptoms, stomach ache was the most commonly reported problem, affecting 12% of the total respondents. Interestingly, all cases of stomach ache (9 out of 9) were reported only by females, accounting for 16.7% of the female group, while none of the males reported this issue. Vomiting was the next most frequent symptom, experienced by 6.67% of the total participants, with one male (1.34%) and four females (7.4%) affected. Nausea was reported by only two individuals (2.67%) one male and one female indicating an equal but minimal presence in both genders. Other symptoms such as allergy, loose motion, itching, and throat pain were exclusively reported by females. Each of these symptoms had a low overall frequency (2.67% or less), but collectively, they highlight that females experienced a wider variety of post-fish consumption issues than males. No male respondents reported symptoms like allergy, loose motion, itching, or throat pain. Overall, the data suggests that female participants reported more health-related complaints after consuming fish compared to males, both in terms of frequency and variety of symptoms.

Table 4: Gender-wise distribution of health problems after eating fish

Variable	**Total**		**Male**		**Female**	
Symptoms	Frequency n = 75	Percentage %	Frequency n=21	Percentage %	Frequency n =54	Percentage %
Stomach ache	9	12%	0	0	9	16.7%
Vomiting	5	6.67%	1	1.34%	4	7.4%
Nausea	2	2.67%	1	1.34%	1	1.85%
Allergy	2	2.67%	0	0	2	3.7%
Loose motion	2	2.67%	0	0	2	3.7%
Itching	3	4%	0	0	3	5.56%
Throat pain	2	2.67%	0	0	2	3.7%

Where do you usually buy fish from?

The results of the survey conducted on fish sales across two districts indicate where consumers typically purchase their fish. The majority of respondents, 68%, reported buying fish from local vendors. In comparison, 28% of participants stated they buy fish from fish markets. A smaller percentage, 1.3%, purchase their fish from supermarkets, while an equal 1.3% opt for online sources. Lastly, 1.3% of respondents indicated they buy fish from other sources. These findings highlight the preference for local vendors and fish markets over more commercialized or online options for purchasing fish.

Which measure do you take to ensure the quality of fish.

The responses to the question about measures taken to ensure the quality of fish reveal a variety of practices. One respondent highlighted the importance of maintaining proper temperature, ensuring sanitization, and only purchasing fresh, new fish. Another respondent emphasized buying locally available fish, engaging with the vendor to inquire about the fish's quality, and

exclusively purchasing from trusted personal vendors. Additionally, they stressed the importance of avoiding cross-contamination and carefully selecting fish to ensure its freshness and safety. These responses reflect a strong focus on both hygienic practices and sourcing fish from reliable suppliers.

Suggestions to improve the quality of fish available in the market.

The responses to the question on improving fish quality in the market suggest several key measures. First, respondents emphasized the need to avoid the use of harmful chemical components in fish processing and to implement stricter checks to prevent the sale of old fish. There is also a call for government regulations to prohibit the use of chemicals and for more thorough government evaluations of fish quality. Furthermore, locally available fish should be prioritized and supplied in local markets, with a request for standardized testing across all sales points. Regular inspections and immediate delivery of fish from harvesters to proper storage after being caught are also recommended. To enhance quality assurance, respondents proposed compulsory checks at all stages of the sales process, along with the use of self-testing kits. Additionally, it was suggested that fish be supplied directly from harbours to homes through cooperative or self-help groups. Providing local vendors with a daily sales capacity, ensuring government-backed quality confirmations, and raising awareness through media campaigns were also mentioned as key strategies. Finally, proper packaging with labels directly from fishing boats was proposed to ensure transparency and traceability.

Encountered issues with the quality of fish you purchased

The survey responses reveal several concerns regarding the quality of the fish purchased. A common issue reported by five individuals was experiencing allergic reactions, particularly on their hands, after handling the fish. Other respondents highlighted unpleasant smells, such as formalin and ammonia, which raised doubts about the freshness and safety of the fish. One person noted that old and new fish were mixed, potentially compromising the overall quality. Another respondent described the fish as having a bad odour, with washing water mixed with dried plants, suggesting improper handling. Lastly, a severe complaint was food poisoning experienced after consuming the fish, raising serious concerns about its safety for consumption. These issues reflect a need for improved quality control and hygiene in the fish supply chain.

Do you trust the labelling of fish products in terms of quality and origin?

The results from the survey reveal mixed opinions on the trustworthiness of fish product labelling in terms of quality and origin. A significant portion, 45.2%, expressed confidence in the labelling, indicating that they trust the information provided about the quality and origin of the products. However, 20.5% of respondents voiced scepticism, suggesting a lack of trust in the accuracy or transparency of such labels. The remaining 34.2% indicated a more cautious stance, trusting labels only sometimes, which points to a level of uncertainty about the consistency and reliability of the labelling system. Overall, while a majority seem to place some level of trust in fish product labels, a considerable number of people remain doubtful or uncertain about their authenticity.

Would you be willing to pay more for fish that is guaranteed to be higher?

The survey results indicate a strong interest in paying more for fish that is guaranteed to be of higher quality. 48.6% of respondents expressed a willingness to pay a premium for such products, suggesting that many consumers value quality assurance when it comes to fish. On the other hand, 13.9% of participants were not inclined to pay extra, indicating that price might be a more important factor for them than quality guarantees. The largest group, 37.5%, stated that their decision would depend on the price, showing that while they may appreciate higher quality, the cost plays a significant role in their purchasing choices. Overall, the responses reveal that many consumers are open to paying more for guaranteed quality, but price remains a key consideration.

Do you think government regulation are sufficient to ensure fish quality?

The survey results highlight a divided opinion on whether government regulations are sufficient to ensure fish quality. A small minority, 37%, believe that current regulations are adequate, suggesting some level of confidence in the system. However, a larger portion, 42.5%, disagrees, expressing concern that government oversight may not be enough to guarantee high-quality fish products. Additionally, 20.5% of respondents were uncertain, indicating a lack of clarity or confidence regarding the effectiveness of regulations. Overall, the majority of participants feel

that government regulations may fall short, emphasizing a need for stronger oversight or improvements in the regulatory framework to ensure fish quality.

Are you concerned about the use of chemical in fish farming?

The survey results reveal a significant concern among respondents about the use of chemicals in fish farming, with 87.7% expressing worry. This overwhelming majority suggests that most people are apprehensive about the potential health and environmental impacts of chemical use in aquaculture. On the other hand, 12.3% of participants were uncertain, indicating a lack of clear knowledge or understanding of the issue. Overall, the data highlights a strong public concern regarding the use of chemicals in fish farming, pointing to a desire for more transparency and regulation in the industry to address these concerns.

Do you check the freshness of fish before purchasing?

The survey results reveal that consumers' attention to fish freshness before purchasing varies. Half of the respondents, 42.5%, always check the freshness, showing a strong preference for ensuring the quality of the product they buy. Another 42.5% check sometimes, indicating that while freshness is a consideration, it may not be a consistent priority for them. A smaller group, 11%, rarely checks the freshness, suggesting that they might place less emphasis on this factor when buying fish. Overall, the findings reflect that while many consumers are mindful of freshness, it is not always a uniform practice across all buyers.

What kinds of fish do you usually buy?

The survey results indicate a clear preference for certain types of fish among respondents. Sardines lead with 42.5% of participants typically purchasing them, suggesting they are a popular choice. Mackerel follows closely behind at 35.6%, showing that many people also favour this fish. Choora, with 17.8%, is the third most commonly bought type, while 4.1% of respondents selected "other" as their preferred fish, indicating a variety of less common choices. Overall, the findings highlight sardines and mackerel as the most popular options among consumers, with a smaller proportion opting for choora or other varieties.

5.2 Assessment of Ammonia and Formaldehyde in fish

The presence of ammonia and formaldehyde in three fish samples: sardine, Indian mackerel, and tuna, across 24 locations in Kannur and Wayanad was identified (Tables 5 and 6) using test stripe paper (Figure 7). In Kannur, a total of 99 samples were collected from 11 locations, while in Wayanad, 117 samples were collected from 13 locations. The results revealed varying levels of ammonia and formaldehyde contamination across the samples. In Kannur, Indian mackerel samples showed ammonia presence in 3 out of 33 samples and formaldehyde presence in 7 samples. Sardine samples had ammonia presence in 5 out of 33 samples, while tuna samples showed ammonia presence in 18 out of 33 samples and formaldehyde presence in 11 samples. Similarly, in Wayanad, Indian mackerel samples had ammonia presence in 8 out of 39 samples and formaldehyde presence in 16 samples. Tuna samples showed ammonia presence in 27 out of 39 samples and formaldehyde presence in 15 samples, while sardine samples did not show any presence of ammonia or formaldehyde.

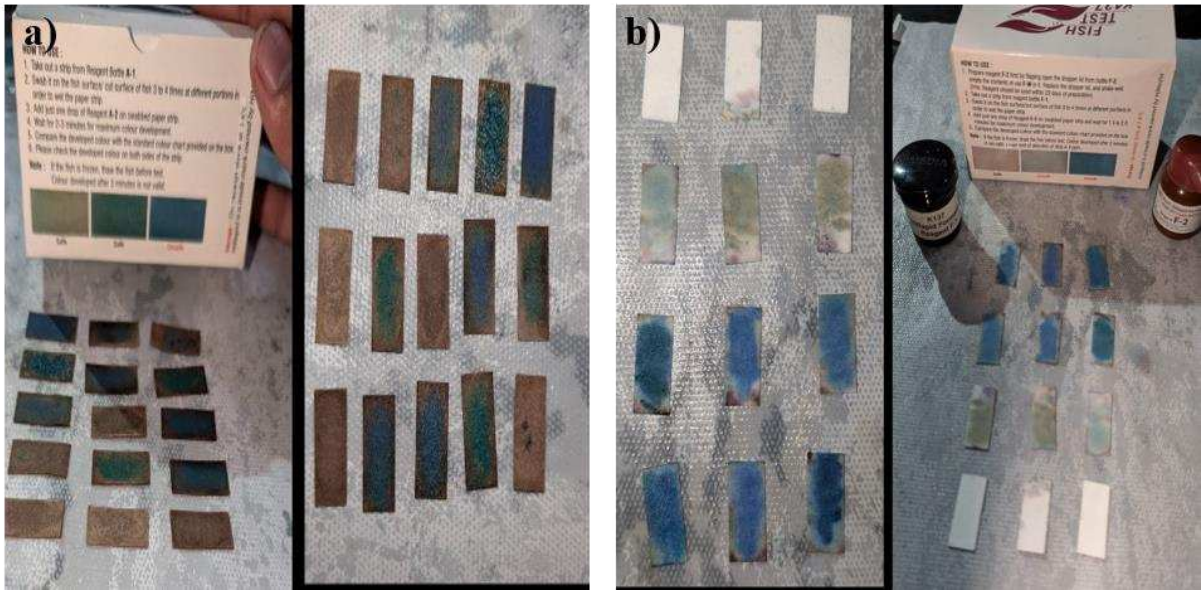

Figure 7: Strip paper results of the test for ammonia and formaldehyde

The results of the study indicate that ammonia and formaldehyde contamination are prevalent in fish samples from both Kannur and Wayanad. The highest levels of ammonia contamination were observed in tuna samples from both regions, with 18 out of 33 samples testing positive in Kannur and 27 out of 39 samples testing positive in Wayanad. Formaldehyde contamination was also observed in fish samples from both regions, with Indian mackerel samples showing the

highest levels of contamination. The presence of formaldehyde in fish samples is a concern, as it is a known carcinogen and can have adverse health effects.

The results of the study suggest that there may be differences in the levels of ammonia and formaldehyde contamination in fish samples from different regions. Further studies are needed to determine the sources of contamination and to develop strategies for reducing the levels of ammonia and formaldehyde in fish samples. The study highlights the need for regular monitoring of fish samples for ammonia and formaldehyde contamination, particularly in regions where fish is a staple food. The results of the study can be used to inform policymakers and regulatory agencies about the need for stricter controls on the use of formaldehyde in fish processing and handling.

Ammonia and formaldehyde contamination in fish samples from Kannur and Wayanad.

Table 5: Ammonia and formaldehyde contamination in fish samples from Kannur

Date	Location	Fish Sample	Ammonia Detection	Formaldehyde Detection
02/07/2024	K1	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	-
02/07/2024	K2	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	-
04/07/2024	K3	Indian mackerel	-	-
		Sardine	+	-
		Tuna	+	-
04/07/2024	K4	Indian mackerel	-	-
		Sardine	+	-
		Tuna	+	-
05/07/2024	K5	Indian mackerel	-	-
		Sardine	-	-

		Tuna	-	-
05/07/2024	K6	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	-
05/07/2024	K7	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	+
05/07/2024	K8	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	+
07/07/2024	K9	Indian mackerel	-	-
		Sardine	+	-
		Tuna	-	-
07/07/2024	K10	Indian mackerel	-	-
		Sardine	+	-
		Tuna	-	-
07/07/2024	K11	Indian mackerel	-	-
		Sardine	+	-
		Tuna	-	-
20/08/2024	K1	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+
20/08/2024	K2	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+
20/08/2024	K3	Indian mackerel	+	+
		Sardine	-	-

		Tuna	+	-
22/08/2024	K4	Indian mackerel	+	+
		Sardine	-	-
		Tuna	-	+
22/08/2024	K5	Indian mackerel	+	+
		Sardine	-	-
		Tuna	-	-
22/08/2024	K6	Indian mackerel	-	+
		Sardine	-	-
		Tuna	-	-
22/08/2024	K7	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+
26/08/2024	K8	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	+
26/08/2024	K9	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	+
26/08/2024	K10	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	+
26/08/2024	K11	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
10/10/2024	K1	Indian mackerel	+	-
		Sardine	-	-

		Tuna	-	-
10/10/2024	K2	Indian mackerel	+	-
		Sardine	-	-
		Tuna	-	-
10/10/2024	K3	Indian mackerel	+	-
		Sardine	-	-
		Tuna	-	-
12/10/2024	K4	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
12/10/2024	K5	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
13/10/2024	K6	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
13/10/2024	K7	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
14/10/2024	K8	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
14/10/2024	K9	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
14/10/2024	K10	Indian mackerel	-	-
		Sardine	-	-

		Tuna	+	+
14/10/2024	K11	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	+

Table 6: Ammonia and formaldehyde contamination in fish samples from Wayanad

Date	Location	Fish Sample	Ammonia Detection	Formaldehyde Detection
10/07/2024	W1	Indian mackerel	-	+
		Sardine	-	-
		Tuna	-	+
10/07/2024	W2	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+
10/07/2024	W3	Indian mackerel	-	+
		Sardine	-	-
		Tuna	-	+
13/07/2024	W4	Indian mackerel	-	+
		Sardine	-	-
		Tuna	-	+
13/07/2024	W5	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+
14/07/2024	W6	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+
14/07/2024	W7	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+

17/07/2024	W8	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	-
17/07/2024	W9	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	-
17/07/2024	W10	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
19/07/2024	W11	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
19/07/2024	W12	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
19/07/2024	W13	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
11/08/2024	W1	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	-
11/08/2024	W2	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	-
11/08/2024	W3	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	-
16/08/2024	W4	Indian mackerel	+	+
		Sardine	-	-

		Tuna	+	-
16/08/2024	W5	Indian mackerel	+	-
		Sardine	-	-
		Tuna	-	-
16/08/2024	W6	Indian mackerel	+	-
		Sardine	-	-
		Tuna	+	-
16/08/2024	W7	Indian mackerel	+	-
		Sardine	-	-
		Tuna	-	+
07/09/2024	W8	Indian mackerel	+	-
		Sardine	-	+
		Tuna	-	-
08/09/2024	W9	Indian mackerel	+	+
		Sardine	-	-
		Tuna	+	-
08/09/2024	W10	Indian mackerel	-	+
		Sardine	-	-
		Tuna	+	+
08/09/2024	W11	Indian mackerel	-	+
		Sardine	-	-
		Tuna	-	+
09/09/2024	W12	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	+
10/09/2024	W13	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	+
26/09/2024	W1	Indian mackerel	-	-

		Sardine	-	-
		Tuna	+	-
26/09/2024	W2	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
28/09/2024	W3	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
28/09/2024	W4	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	-
28/09/2024	W5	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	-
01/10/2024	W6	Indian mackerel	-	-
		Sardine	-	-
		Tuna	-	-
01/10/2024	W7	Indian mackerel	-	-
		Sardine	-	-
		Tuna	+	-
01/10/2024	W8	Indian mackerel	+	-
		Sardine	-	-
		Tuna	+	+
01/10/2024	W9	Indian mackerel	+	-
		Sardine	-	-

5.3 Fish quality

The results of this study provide valuable insights into the quality differences between three fish species mackerel (T1), sardine (T2), and tuna (T3)with a significant impact on the overall fish quality observed.

5.3.1 Fish Quality of Samples Collected from Wayanad

Firstly, the significant difference found between T1 and T2 suggests that the two species vary notably in terms of their quality, with T1 showing a higher mean quality score (M = 0.38) compared to T2 (M = 0.28). This result could be attributed to the biological and environmental factors affecting these species. T1, being a larger, fatty fish, might have a different composition and texture that contributes to its perceived higher quality compared to sardines, which are smaller and may have a different lipid profile. Additionally, differences in diet, habitat, or handling during fishing and storage could also explain these observed quality discrepancies. The significant p-value (p = 0.036) indicates that the difference is not due to random chance, highlighting the relevance of species-specific factors in determining fish quality.

Conversely, no significant difference was observed between T1 and T3 (p = 0.755). Both species had similar mean quality scores (M = 0.38 for mackerel and M = 0.41 for tuna), suggesting that, in terms of quality, these two species might be considered comparable. The most striking finding, however, was the significant difference between T2 and T3, where tuna exhibited a considerably higher quality score (M = 0.41) than sardines (M = 0.28), with a statistically significant p-value (p = 0.006).

A one-way ANOVA was employed to assess the quality of fish samples (T1, T2, and T3) taken at Wayanad (Table 7and8). The results revealed a statistically significant difference in fish quality among the fish taken for the study, $F(2,36) = 6.06$, $p = 0.005$, $n^2 = 0.25$

.The results showed:

- A significant difference between T1 (M=0.38, S.D=0.14) and T2 (M=0.28, S.D=0.08) with (p=0.036), indicating that the quality of fish differs significantly between Mackeral (T1) and Sardine (T2).

- No significant difference between T1 (M=0.38, S.D=0.14) and T3 (M=0.41, S.D=0.09) (p=0.755), suggesting similar quality levels between Mackerel (T1) and Tuna (T3).
- A significant difference between T2 (M=0.28, S.D=0.08) and T3 (M=0.41, S.D=0.09) (p=0.006), indicating a notable disparity in fish quality between T2 and T3.

These findings suggest that there is a significant impact on the quality of fish, particularly between T1 and T2, and between T2 and T3.

Table 7: Fish qualities represent using one way ANOVA (Wayanad)

Location	T1	T2	T3
W1	0.50 ± 0.14	0.28±0.19	0.42±0.23
W2	0.51±0.18	0.28±0.18	0.30±0.18
W3	0.52±0.18	0.27±0.21	0.40± 0.12
W4	0.46± 0.12	0.18± 0.12	0.31± 0.17
W5	0.38±0.19	0.20±0.12	0.28± 0.06
W6	0.49±0.17	0.20± 0.20	0.33± 0.06
W7	0.11±0.14	0.18± 0.39	0.59± 0.16
W8	0.17± 0.06	0.40±0.07	0.47±0.08
W9	0.20±0.04	0.41±0.43	0.47± 0.28
W10	0.39± 0.19	0.34± 0.31	0.51± 0.32
W11	0.54± 0.13	0.29± 25	0.43± 0.28
W12	0.36±0.20	0.28± 0.25	0.45± 0.30
W13	0.37± 0.17	0.28± 0.24	0.43± 0.27
ANOVA	*P value*= 005389 $F_{df(2,36)}$=6.06015		

Note: Values are expressed as mean ± S.D; W1-W13 denotes the study sites taken at Wayanad.

Table 8: Post Hoc Tukey HSD (beta)

Pairwise Comparisons		$HSD_{.05}$ = 0.1023 $HSD_{.01}$ = 0.1301	$Q_{.05}$ = 3.4568 $Q_{.01}$ = 4.3961
T_1:T_2	M_1 = 0.38 M_2 = 0.28	0.11	Q = 3.66 (p = .03581)

T_1:T_3	M_1 = 0.38 M_3 = 0.41	0.03	Q = 1.01 (*p* = .75515)
T_2:T_3	M_2 = 0.28 M_3 = 0.41	0.14	Q = 4.68 (*p* = .00593)

A one-way ANOVA was conducted to evaluate whether fish quality varied significantly across 13 sampling locations in Wayanad. The analysis showed no significant difference in mean fish quality between locations ($F(12,26) = 0.292$, $p = 0.985$, $p > 0.05$). This suggests that location had no substantial effect on the overall fish quality across the three species assessed.

5.3.2 Fish Quality of Samples Collected from Kannur

The results of this study provide insightful information about the quality differences between three fish speciesT1, T2, and T3caught in Kannur. The one-way ANOVA results revealed a statistically significant difference in the quality of these fish species, with an F-value of 7.63 ($p = 0.002$), indicating that the quality varies significantly across species. The effect size ($\eta^2 = 0.34$) suggests that approximately 34% of the variability in fish quality can be attributed to the species factor, which highlights the importance of species differences in determining quality. Post hoc analyses using Tukey's HSD test allowed for more precise pairwise comparisons to identify where these differences lie. The following points emerged from the comparison of the fish species:

T1 vs. T2

The first notable finding is the significant difference in quality between T1 and T2. T1 had a mean quality score of 0.44 (SD = 0.13), while T2 had a mean quality score of 0.30 (SD = 0.10). The p-value of 0.00391 indicates that the difference is statistically significant.

T1 vs. T3

There was no significant difference in quality between T1) and T3, as evidenced by a p-value of 0.95505, which indicates that both species have similar perceived quality. Mackerel had a mean score of 0.44 (SD = 0.13), and tuna had a mean score of 0.43 (SD = 0.04).

T2 vs. T3

A significant difference in quality was observed between T2 and T3, with sardines having a mean score of 0.30 (SD = 0.10) and tuna having a mean score of 0.43 (SD = 0.04). The p-value of 0.00821 confirms that the disparity in quality between these two species is statistically significant.

A one-way ANOVA was employed to assess the quality of fish samples (T1, T2, and) taken at Kannur (Table 9 and 10). The analysis was performed with a significance level set at $p<0.05$. The results revealed a statistically significant difference in fish quality among the fish taken for the study, $F(2, 30) = 7.63$, $p = 0.002$, $n^2 = 0.34$

The results showed:

- A significant difference between T1 (M=0.44, S.D=0.13) and T2 (M=0.30, S.D=0.10) with (p=0.00391), indicating that the quality of fish differs significantly between T1 and T2.
- No significant difference between T1 (M=0.44, S.D=0.13) and T3 (M=0.43, S.D=0.04) with (p=0.95505), suggesting similar quality levels between T1 and T3.
- A significant difference between T2 (M=0.30, S.D=0.10) and T3 (M=0.43, S.D=0.04) with (p=0.00821), indicating a notable disparity in fish quality between T2 and T2.

These findings suggest that there is a significant impact on the quality of fish, particularly between T1 and T2 , and between T2 and T3.

Table 9: Fish qualities represent using one way ANOVA

Location	T1	T2	T3
K1	0.29 ± 0.26	0.25 ± 0.20	0.39 ± 0.18
K2	0.43 ± 0.27	0.36 ± 0.08	0.37 ± 0.18
K3	0.46 ± 0.31	0.34 ± 0.10	0.38 ± 0.16
K4	0.39 ± 0.25	0.27 ± 0.09	0.46 ± 0.27
K5	0.63 ± 0.30	0.30 ± 0.14	0.51 ± 0.26
K6	0.53 ± 0.13	0.25 ± 0.14	0.48 ±0.26
K7	0.52 ± 0.20	0.19 ± 0.05	0.44 ± 0.17
K8	0.26 ± 0.13	0.18 ± 0.08	0.42 ±0.17
K9	0.27 ± 0.18	0.43 ± 0.41	0.47 ±0.10
K10	0.54 ± 0.33	0.49 ± 0.36	0.40 ± 0.09
K11	0.54 ± 0.14	0.22 ± 0.10	0.41 ± 0.17
ANOVA	p-value = 0 .002093 $F_{df\ (2,30)}$=7.63144		

Note: Values are expressed as mean ± S.D; K1-K11 denotes the study sites taken at Kannur

Table 10: Post Hoc Tukey HSD (beta)

Pairwise Comparisons		$HSD_{.05}$ = 0.1006 $HSD_{.01}$ = 0.1286	$Q_{.05}$ = 3.4864 $Q_{.01}$ = 4.4549
T_1:T_2	M_1 = 0.44 M_2 = 0.30	0.14	Q = 4.98 (p = .00391)
T_1:T_3	M_1 = 0.44 M_3 = 0.43	0.01	Q = 0.41 (p = .95505)
T_2:T_3	M_2 = 0.30 M_3 = 0.43	0.13	Q = 4.57 (p = .00821)

A one-way ANOVA was conducted to examine differences in fish quality among species (T1, T2, T3) across sampling sites in Kannur (K1–K11). The result showed a statistically significant difference ($F(2,30) = 7.63144$, $p = 0.002093$), indicating that at least one species differs significantly from the others in quality. The significance level was set at $p < 0.05$. However, this analysis does not account for variation between locations.

6. Discussion

The fish industry in Kerala, particularly in the districts of Wayanad and Kannur, is a vital part of the local economy and a primary source of nutrition for the population. The presence of chemical preservatives such as ammonia and formaldehyde in fish samples collected from local markets raises serious public health concerns. In the present study, qualitative and quantitative analysis confirmed the adulteration of fish with these hazardous chemicals. The intentional use of formaldehyde, a known carcinogen, to extend the shelf life of fish is particularly alarming. According to previous reports, formaldehyde is sometimes added to prevent spoilage and maintain the appearance of freshness, especially in warm climates where fish spoil rapidly during transportation and storage (Jinadasa et al., 2022; Bhowmik et al., 2017). Similarly, ammonia, which may either result from microbial degradation or be added externally as a preservative, poses risks including respiratory and gastrointestinal irritation upon consumption (Devaraj et al., 2021). The Google survey conducted among fish consumers revealed that participants experienced symptoms such as headaches, nausea, throat irritation, and gastrointestinal disturbances after consuming fish. These health issues may be linked to the ingestion of chemically preserved fish. The predominance of female respondents experiencing symptoms such as stomach aches, vomiting, and itching is consistent with studies indicating that fish allergies are more prevalent among women. A systematic review by Sicherer et al. (2016) found that the prevalence of fish allergy varies globally, with some regions reporting higher rates among females.Stomach ache, vomiting, nausea, and diarrhea are gastrointestinal symptoms that may be indicative of scombroid poisoning, also known as histamine fish poisoning. This occurs when certain fish, such as tuna and mackerel, are improperly stored, leading to histamine accumulation.Symptoms typically manifest within minutes to hours of consumption.Hungerford (2010) emphasized that inadequate cooling following harvest promotes bacterial histamine production, leading to scombroid poisoning.Itching**-**This symptom could be associated with allergic reactions to fish proteins, particularly parvalbumin, a major fish allergen.Fish allergies often lead to skin-related symptoms, including itching and hives.Pali-Schöll and Jensen-Jarolim (2021) discussed how sex hormones may influence the development of food allergies, potentially contributing to the observed gender differences in allergic reactions.Throat Pain**:**Both allergic reactions and irritants from certain fish toxins can cause throat discomfort.The occurrence of

throat pain in both male and female respondents suggests a possible irritant effect or an allergic response.The survey's higher prevalence rates of adverse reactions may be influenced by sampling and reporting biases.Wennberg et al. (2012) highlighted that fish consumption is often linked to healthier behaviors, yet gender differences exist in perceptions of food healthiness and avoidance.These perceptions can lead to biased reporting, as individuals may underreport adverse reactions due to their positive associations with fish consumption.Scombroid poisoning, resulting from consuming fish with elevated histamine levels due to improper storage, is frequently misdiagnosed as a food allergy or bacterial food poisoning.Hungerford (2010) noted that without awareness, physicians might attribute symptoms to allergies or infections, leading to inappropriate treatments.Fish quality is influenced by multiple factors, including the species itself, the method of capture, storage conditions, and the surrounding environment. In this study, mackerel generally showed higher quality compared to sardine, both in Wayanad and Kannur. This could be due to the inherent characteristics of mackerel, which may retain its freshness for longer periods under similar storage conditions. On the other hand, sardine, being a smaller, oily fish, is more prone to rapid degradation and may exhibit quicker spoilage, leading to a lower quality score (Wu et al., 2022). The use of formaldehyde and ammonia is often not disclosed on the fish labels, and consumers may not always have the means to verify whether the fish they are purchasing is free from harmful chemicals. This lack of transparency and insufficient information on labels leads to consumer distrust and highlights the urgent need for more robust enforcement of food safety regulations.

The widespread use of formaldehyde and ammonia in fish preservation is a major public health concern, as both substances pose significant risks to human health. Formaldehyde, in particular, has been linked to carcinogenesis and other serious health issues, while ammonia can cause neurological damage and death in aquatic organisms. Both chemicals are often used illegally to extend the shelf life of fish and prevent spoilage, but this practice not only poses a direct threat to public health but also raises environmental concerns. The illegal use of formaldehyde and ammonia in fish markets and aquaculture systems reflects a lack of regulation and oversight in the sector, highlighting the need for stricter enforcement of food safety standards. In the case of fish markets in Chennai and Southern Bangladesh, widespread contamination with formaldehyde and ammonia has been reported (Devaraj et al., 2021; Hoque et al., 2018). These chemicals are

used illegally, often in high concentrations, to maintain the appearance and freshness of the fish, especially when the fish is not fresh or has been stored improperly.Formaldehydeposes significant risks to human health. Long-term consumption of fish contaminated with formaldehyde can lead to gastrointestinal issues, skin irritations, and even more severe conditions like cancer, as indicated by Kundu et al. (2020). Similarly, ammonia toxicity in fish can cause neurological disorders, convulsions, and death in severe cases, which makes it a serious concern for both the fish and its consumers (Randall & Tsui, 2002; Soler et al., 2020).In local markets in Kerala, especially in Kannur and Wayanad, there is growing concern regarding the use of these chemicals. If these chemicals are being used to preserve fish in these markets, it reflects a lack of stringent regulatory oversight and control measures. Despite government regulations on the use of chemicals in food products, the illegal use of harmful chemicals in fish preservation continues to be prevalent in many markets. This poses significant risks to public health, as consumers are often unaware of the potential contamination present in the fish they purchase. The results of this study align with previous research conducted in other regions, which has reported widespread contamination of fish with ammonia and formaldehyde. For instance, a study conducted in Chennai, India, found that formaldehyde was detected in 100% of samples from the N4 Beach fish market, and ammonia was found in 100% of samples in several other markets (Devaraj et al., 2021). Similarly, in Southern Bangladesh, formaldehyde contamination was observed in freshwater fish, with higher concentrations found in fish that were exposed to longer storage times (Hoque et al., 2018). These findings underscore the global nature of the problem and the urgent need for intervention. Ammonia, while not carcinogenic, is highly toxic to both fish and humans (IARC, 2006). In fish, ammonia toxicity can cause severe neurological damage, leading to convulsions, coma, and even death. Ammonia disrupts neuronal function by displacing potassium ions and increasing calcium influx, which in turn leads to cell death in the central nervous system (Randall and Tsui, 2002). Furthermore, exposure to ammonia increases oxidative stress in fish, impairing their immune systems and making them more susceptible to infections and disease (Soler et al., 2020). Given the levels of ammonia contamination observed in the present study, particularly in tuna, the potential for negative health effects on both fish and consumers is a significant concern. Unfortunately, as the survey results suggest, there is a general lack of confidence in the regulatory framework for ensuring fish quality. Only 37% of respondents believed that current government regulations were sufficient to

ensure the quality of fish, while a significant portion (42.5%) felt that government oversight was inadequate. This reflects a broader perception that regulatory frameworks are either underdeveloped or poorly enforced, which contributes to the continued use of harmful chemicals in fish preservation. Health risks posed by the consumption of chemically preserved fish are well-documented in the literature. Toxic metals such as mercury, lead, and cadmium, which can accumulate in fish tissue, pose significant health risks to consumers, especially pregnant women and children (Bosch et al., 2016). These metals are known to cause developmental and neurological issues, with long-term exposure leading to cognitive and motor deficits. The presence of these toxic metals can offset the nutritional benefits of consuming fish, especially in regions where fish is a primary protein source.

The findings from both laboratory analyses and survey data suggest a potential public health threat from the continued sale of chemically adulterated fish in local markets. Lack of regulatory oversight, poor awareness among consumers, and inadequate cold chain infrastructure might be contributing to the prevalent use of such hazardous chemicals (Kaur et al., 2024). These findings underscore the urgent need for stricter enforcement of food safety standards and routine monitoring of fish products. The results of the survey conducted in the region reflect a growing awareness among consumers about the quality and safety of fish. For example, nearly half of the respondents (42.5%) reported that they always check the freshness of the fish before purchasing, which shows that consumers are taking steps to ensure the quality of their food. However, concerns over the use of chemicals in fish preservation were also evident, as 87.7% of respondents expressed worry about the use of chemicals in fish farming. This overwhelming concern suggests that consumers in Kerala are aware of the potential health risks associated with chemically preserved fish.Additionally, the survey indicated a significant distrust in the labelling of fish products regarding their quality and origin. This lack of trust, highlighted by 20.5% of respondents expressing scepticism about the labels, points to the challenges of ensuring transparency in the fish supply chain. The fact that 34.2% of respondents only trust fish labels "sometimes" further underscores the need for stronger regulations and more reliable quality control mechanisms.

The similarity in the quality of mackerel and tuna in both regions (Kannur and Wayanad) could also be a reflection of their similar handling processes. Both species may benefit from similar

post-capture preservation methods, such as refrigeration or ice storage, which slows down the degradation process. This suggests that the quality of fish may be more influenced by post-capture handling practices rather than inherent species characteristics alone. The significant disparity in the quality of sardine and tuna observed in both regions is also noteworthy. Tuna, being a larger, more robust fish with thicker muscle tissue, likely maintains a higher quality compared to sardine, which is more delicate. Furthermore, tuna is often subjected to more rigorous post-capture handling and storage processes, including faster refrigeration or freezing, which can help preserve its quality better than sardine.The findings of this study are consistent with previous research on fish quality, particularly regarding the differences in quality among species. Several studies have shown that fish quality degrades over time, with different species exhibiting varying levels of freshness and spoilage depending on their inherent characteristics. For instance, studies on meagre (*Argyrosomus regius*) and other fish species have shown that proper storage conditions significantly enhance the shelf life and nutritional quality of fish, with some species able to remain fresh for up to nine days under ideal conditions (Poli et al., 2003). Similarly, the freshness and quality of fish are known to vary according to species-specific traits such as muscle composition and fat content (Cardoso et al., 2021).The influence of seasonal variations on fish quality is also well-documented. Fresh fish, particularly oily fish like sardine, are more prone to quality degradation during certain seasons, which may explain the observed differences in the quality of fish across regions and seasons (Poli et al., 2003). Seasonal temperature variations could lead to differences in the metabolic rates of the fish and, consequently, the rate of spoilage, which is particularly evident in smaller, oily fish like sardine.Furthermore, studies have shown that fish quality is also influenced by the handling and storage methods post-capture. Improper storage temperatures, for instance, can accelerate the degradation of fish quality, especially in species with delicate flesh like sardines (Menezes et al., 2022). On the other hand, advances in fish preservation technologies, such as the use of smart sensors to monitor biochemical and microbial spoilage, have helped in improving the estimation of fish quality over time, reducing wastage and ensuring higher-quality products (García et al., 2017).

The quality and safety of fish in local markets in Kerala, particularly in the districts of Wayanad and Kannur, is a pressing concern, especially with regards to the use of harmful chemicals such

as formaldehyde and ammonia. While consumers are becoming more aware of the risks associated with chemically preserved fish, the lack of trust in labelling and the insufficient regulation of the fish supply chain continue to be significant challenges. Strengthening regulatory frameworks, improving market transparency, and educating consumers are essential steps to ensure the safety and quality of fish sold in local markets. Only through a concerted effort by all stakeholders can we protect public health and ensure that fish remains a nutritious and safe food source for the population.In this study, ammonia contamination was most pronounced in tuna samples, with 18 out of 33 samples testing positive in Kannur and 27 out of 39 samples in Wayanad. Sardine samples, on the other hand, showed minimal contamination, with only 5 out of 33 samples in Kannur exhibiting ammonia presence and none in Wayanad. The presence of ammonia in tuna and Indian mackerel samples is particularly concerning, as it is an indicator of poor handling or improper preservation practices, such as inadequate refrigeration or improper storage conditions. The ammonia levels observed in the tuna samples may also reflect the use of ammonia-based compounds in the preservation process, which is a known practice in some fish markets and aquaculture systems, despite its associated risks.Formaldehydedetected in the fish samples, particularly in Indian mackerel and tuna. In Kannur, formaldehyde was found in 7 out of 33 Indian mackerel samples and 11 out of 33 tuna samples, while in Wayanad, 16 Indian mackerel samples and 15 tuna samples tested positive for formaldehyde contamination. These findings corroborate earlier research, which has shown that formaldehyde is commonly used in fish preservation, despite its toxic nature (Hoque et al., 2018; Kundu et al., 2020). Formaldehyde is often added to fish as a preservative to extend shelf life and prevent spoilage, but its use raises significant health concerns, as it can lead to long-term carcinogenic effects in humans (IARC, 2006).

The findings of this study have important implications for public health and policy. The detection of ammonia and formaldehyde in fish samples from Kannur and Wayanad underscores the need for regular monitoring of fish products to ensure that they are safe for human consumption. Regular quality assessments using techniques like the Quality Index Method, which has been widely used in fish spoilage studies (Cardoso et al., 2021; Poli et al., 2003), could help improve the overall quality of fish sold in these markets. Further, increasing awareness among fish traders about the impact of handling practices and storage conditions on

fish quality could lead to improved market performance and reduced spoilage rates. Given the potential health risks associated with these chemicals, particularly the carcinogenic effects of formaldehyde, it is critical that authorities implement stricter regulations and enforcement mechanisms to prevent the illegal use of harmful preservatives in the fish supply chain (IARC, 2006). Furthermore, there is a need to explore and promote alternative preservation methods that are safer for both fish and consumers. Current preservation techniques, such as the use of formaldehyde and ammonia, pose significant risks to both human health and the environment. The development and implementation of safer alternatives, such as refrigeration, freezing, and the use of natural preservatives, could help reduce the reliance on harmful chemicals in fish processing and handling. Natural and safer preservation alternatives such as ice storage, chitosan coatings, and herbal extracts like turmeric or neem are being studied and promoted for their antimicrobial properties and ability to extend shelf life (Goulas and Kontominas, 2005; Ojagh et al., 2010). Education and public awareness campaigns are also essential in addressing the risks associated with ammonia and formaldehyde contamination in fish. Consumers must be informed about the potential dangers of consuming contaminated fish, and fish traders and processors need to be educated on safer and more sustainable preservation methods. Additionally, strengthening regulatory frameworks and ensuring that fish markets and aquaculture systems adhere to food safety standards will be key to mitigating the risks posed by these harmful chemicals. Several key measures can be implemented to improve fish quality and ensure safety in local markets. First, stricter government regulations and more frequent inspections of fish markets are needed to prevent the use of harmful chemicals in fish preservation. Regular monitoring of formaldehyde and ammonia levels in fish products, as well as the introduction of more advanced testing methods, would help identify contaminated products before they reach consumers. Second, there is a need to raise consumer awareness about the risks associated with consuming chemically preserved fish. Educational campaigns that inform the public about the dangers of formaldehyde and ammonia, as well as the importance of purchasing fish from trusted sources, could help reduce the demand for chemically treated fish. Additionally, the introduction of technological innovations such as smart sensors and real-time quality monitoring systems could help reduce wastage and improve the overall quality of fish available in the market, ensuring that consumers have access to safer, fresher products. Moreover, establishing clearer market mechanisms to

incentivize the delivery of high-quality fish could help create a sustainable supply chain that benefits both consumers and producers.

7. Conclusion

This study provides a comprehensive examination of the safety, quality, and consumer perceptions of fish sold in local markets across the Kannur and Wayanad Districts of Kerala, India. The primary objective was to assess the presence of harmful preservatives, such as ammonia and formaldehyde, in commonly consumed fish species (sardine, Indian mackerel, and tuna) and to explore the broader implications of these findings on public health, consumer awareness, and regulatory measures.

This survey of 75 participants reveals a significant association between consuming chemically preserved fish and adverse health effects, particularly among female respondents.The higher incidence of symptoms such as stomach aches, vomiting, and itching among females aligns with existing research indicating that females are more susceptible to food-related adverse reactions.Additionally, the gastrointestinal symptoms reported may be indicative of histamine poisoning, commonly associated with improperly stored fish.These findings underscore the need for enhanced awareness regarding the health risks of consuming chemically preserved fish, particularly among females, and highlight the importance of proper food safety practices to mitigate such adverse effects.The presence of both ammonia and formaldehyde in the fish samples collected from local markets, with varying levels of contamination across species and regions. Notably, tuna exhibited the highest levels of ammonia contamination, followed by Indian mackerel, while sardines generally showed the least contamination. Formaldehyde, a known carcinogen, was also present in considerable amounts in both mackerel and tuna samples, raising serious concerns about the safety of consuming fish contaminated with this substance. These findings are alarming, as they point to widespread use of harmful preservatives in local markets, often for the purpose of prolonging shelf life, which could have long-term health implications for consumers.

The findings from the Quality Index Method show that mackerel generally had the highest quality compared to sardines, but no significant difference was found between mackerel and tuna in both regions. Sardines, on the other hand, consistently exhibited lower quality, which may be attributed to improper preservation methods or transportation issues. These quality differences emphasize the need for better handling and storage practices throughout the fish supply chain to

ensure the freshness and nutritional value of fish sold in markets.In addition to the laboratory analysis, the survey conducted among 75 respondents revealed a strong consumer interest in the quality and safety of the fish they purchase. A majority of respondents expressed concerns about the use of harmful chemicals in fish preservation, with 87.7% indicating worry over chemical usage in fish farming. Despite the widespread concern, there is also a significant lack of trust in fish labelling, with many respondents sceptical about the authenticity of the information provided regarding the quality and origin of the fish they buy. These concerns further underscore the need for greater transparency and regulation within the fish industry.While consumers seem to demand higher quality fish, there is an evident lack of faith in government regulations to ensure this quality. With 42.5% of respondents believing that current regulations are inadequate, there is a clear call for stronger enforcement of food safety laws and more rigorous quality control checks at all stages of the supply chain. Furthermore, a large portion of respondents (48.6%) expressed a willingness to pay a premium for fish that is guaranteed to be free from harmful chemicals and of higher quality, indicating a clear market demand for safer and fresher fish. This consumer willingness presents an opportunity for stakeholders in the fish supply chain, from local vendors to regulatory authorities, to enhance their offerings and provide higher-quality, safer fish to the public.

In conclusion, this research underscores the widespread issue of chemical contamination in fish and calls for immediate reforms in quality control and regulatory practices governing the fish industry. Key measures include enhanced market surveillance, routine inspections, and mandatory quality checks throughout the fish supply chain to prevent the use of harmful chemicals and ensure consumer access to safe, high-quality fish. Furthermore, improved consumer education and awareness campaigns can empower individuals to make informed choices and advocate for higher standards. Through robust policies, effective enforcement, and heightened consumer awareness, it is possible to reduce health risks, enhance food safety, and support the long-term sustainability of Kerala's fishery sector—ensuring fish remains a nutritious and trusted food source.

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