



A Comprehensive Insight on the Quality Assurance of Fish Hamour and Harid Production in Saudi Arabia: A Review

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Abstract

Hamour and Harid fish are popular seafood choices in Gulf countries, known for their delicate flavors and nutritional benefits. However, ensuring the quality and safety of these products is crucial to protect consumer health and maintain industry standards. This review offers an analysis of the processes involved in the production, handling, packaging, quality testing, and control framework of Hamour and Harid fish in Saudi Arabia. It also highlights the significance of these processes in relation to the health of consumers. The review also includes references to the quality assurance measures implemented for these fish species. Furthermore, it provides insights into the measures for ensuring the quality control of these fisheries. The comments provided in this review focus on standard treatment approaches and research efforts aimed at informing policymaking and facilitating its implementation in the Kingdom of Saudi Arabia.

Keywords: Contaminants; Hamour; Harid; Fish Consumption; Health; Saudi Arabia

Introduction

Fish hamour belong to family, (*Epinephelus Summana*) and harid belong to family (*Scarus Frenatus*) are widely consumed fish species in various cuisines worldwide. Fish hamour, also known as orange-spotted grouper, is highly prized for its delicate flavor and

firm texture [1]. It is commonly used in dishes such as fish soups, curries, and grilled preparations [2]. Fish hamour is native to the Indo-Pacific region and is a popular choice among seafood lovers due to its versatility in various cuisines [3]. Its mild taste pairs well with a wide range of ingredients, making it a favorite among chefs for creating flavorful and visually appealing dishes [4]. Fish

is believed to possess a variety of proteins that are essential for maintaining a healthy diet. Additionally, hamour is known to be a good source of omega-3 fatty acids, which are beneficial for heart health and brain function [5]. In Saudi Arabia, it is among the most consumed seafood, often prepared in traditional dishes such as sayadiyah and grilled with a blend of spices [5]. The popularity of grouper in Saudi Arabian cuisine is also attributed to its availability in the Red Sea, making it a local and sustainable choice for seafood enthusiasts [6].

On the other hand, harid, also called Malabar trevally, is sought after for its rich taste and versatility in cooking. Harid is a popular fish among seafood enthusiasts due to its firm texture and delicate flavor. Its versatility in cooking allows it to be prepared in various ways, such as grilling, baking, or pan-frying, making it a favorite choice for many culinary dishes. It is often featured in seafood stir-fries, fish biryanis, and traditional fish curries. In addition to its culinary appeal, harid is also known for its nutritional benefits. It is a good source of lean protein and contains essential omega-3 fatty acids, which are important for heart health. Its low mercury content also makes it a safe choice for regular consumption. It is mostly consumed in the central part of Saudi Arabia, where it is a staple in many traditional dishes [6]. The rich flavors of harid complement a variety of spices and ingredients, making it a popular choice for both home-cooked meals and restaurant menus [7]. Whether grilled, baked, or simmered in a curry, harid's tender flesh and delicate taste are sure to satisfy any seafood lover's palate [8].

Both the hamour and harid fish species contribute to the diversity of their taste, texture, and nutritional content [9]. The hamour fish is known for its firm and flaky texture, while the harid fish has a delicate and tender texture [10]. Additionally, hamour fish is rich in omega-3 fatty acids, which are beneficial for heart health, while harid fish is a good source of protein and essential vitamins and minerals [11].

However, there have been some issues related to the quality of hamour and harid fish products sold and consumed in the Kingdom of Saudi Arabia. These issues mainly revolve around the mislabeling of fish species, where cheaper fish are often sold as hamour or harid [12]. This has raised concerns among consumers about the authenticity and safety of the fish they are purchasing [13]. Additionally, there have been reports of contamination and

improper handling practices in some fish markets, leading to potential health risks for consumers. It's critical to comprehend the elements that influence the safety and health of marine fish as a food source. This review paper aims to provide a comprehensive analysis of the quality assurance measures employed in the production, processing, and distribution of fish hamour and harid in the Kingdom of Saudi Arabia.

Classification

Hamour

Kingdom: Animals; Phylum: Chordata; Class: Actinopterygii; Order: Perciformes; Family: Serranidae; Genus: *Epinephelus*; Species: *Epinephelus Summana* [14].

Harid

Kingdom: Animals; Phylum: Chordata; Class: Actinopterygii; Order: Perciformes; Family: Serranidae; Genus: *Scarus*; Species: *Scarus Frenatus* [15].

Fishing activities

In many parts of the world, especially in coastal communities, fishing and the consumption of fish and shellfish are significant cultural practices that also provide protein [16]. In addition to its cultural significance and protein source, fishing also plays a crucial role in supporting local economies and providing employment opportunities for countless individuals [17]. In many regions of the world, especially in coastal towns, the consumption of seafood is typically rising [12]. Fish and shellfish are frequently the only easily accessible forms of protein that people may self-harvest in many locations, all year round [12].

Regular fish intake is widely recommended as an integral part of a well-balanced diet due to its provision of high-quality protein, essential vitamins, and other vital components that are crucial for maintaining optimal human health [18]. A growing body of evidence suggests that incorporating fish into one's diet can significantly reduce the risk of developing cardiovascular disease and promote healthy fetal development during pregnancy [19]. Consumption of fish has been associated with lower levels of blood cholesterol, increased likelihood of successful pregnancies, and improved cognitive test results in children [20]. This beneficial effect can be attributed to the presence of omega-3 (n-3) fatty acids

in fish and fish oil, which have been found to lower cholesterol levels and mitigate the risk of heart disease, high blood pressure, stroke, and preterm birth [21].

Fishing activities in Saudi Arabia

Saudi Arabia, being a country with a long coastline along the Red Sea and the Arabian Gulf, offers numerous cities and towns where fishing activities are prevalent [22]. Jeddah, Dammam, Yanbu, Jizan, Rabigh, Al Khobar, Thuwal, and Al Lith are the coastal cities in the Kingdom of Saudi Arabia that exhibit the highest levels of fishing activity [23]. These locations provide ample opportunities for both commercial and recreational fishing [22]. Nevertheless, inland towns such as Riyadh experience lower fisheries production and fish consumption due to factors including limited production capacity, high population density, and restricted import capabilities [8]. The coastal cities mentioned above serve as prominent hubs for fishing activities in the Kingdom of Saudi Arabia [24]. These cities are strategically located along the coastline, providing easy access to the abundant marine resources of the Red Sea and the Arabian Gulf [6]. The geographical advantage of these cities allows for a thriving fishing industry, with fishermen actively engaged in capturing various species of fish [6,25].

On the other hand, inland towns like Riyadh face certain challenges that hinder their fisheries sector [8]. Firstly, these areas have limited production capacity compared to coastal cities [26]. The absence of natural water bodies suitable for fish farming or aquaculture restricts the ability to produce a significant amount of fish [26]. Consequently, inland towns heavily rely on imported fish to meet their consumption demands [6]. Moreover, high population density plays a role in limiting fisheries and fish consumption in inland towns [25]. Cities like Riyadh have many residents who require a steady supply of food, including fish [8]. However, with the lack of local production and limited importing capacity, it becomes challenging to meet the fish demand of such densely populated areas [27]. Additionally, constrained importing capacity further exacerbates the issue. Inland towns often face logistical challenges when it comes to importing fresh fish from coastal regions or other countries [27]. The transportation time and costs associated with bringing fish from distant locations can result in delays and increased prices [25]. These factors contribute to lower fish availability and consumption in inland towns like Riyadh [25].

Microorganisms associated with fish products

The deterioration of fish products during cold storage is a multifaceted process involving the growth and reproduction of microorganisms, the oxidation of proteins and lipids, and the formation of unpleasant odors [28]. Among these factors, the complex microbial community plays a crucial role in the formation of flavor substances [28]. Microorganisms that proliferate during the spoilage of aquatic products produce a variety of compounds, including hydrocarbons, acids, esters, sulfur, and nitrogen compounds, using aldehydes in varying degrees [29]. These compounds contribute to the development of unpleasant odors in fish products [28]. Specifically, methyl fatty acids, methyl mercaptan, trimethylamine, and indole are the primary odor compounds produced during this process [28].

The growth and reproduction of microorganisms during cold storage are facilitated by the availability of nutrients, water activity, and temperature [29]. The optimal temperature range for microbial growth in fish products is between 2°C and 10°C, with many microorganisms growing at temperatures between 5°C and 8°C [29]. The oxidation of proteins and lipids during cold storage also plays a significant role in the spoilage of fish products [28]. The oxidation of these compounds leads to the formation of volatile compounds, such as aldehydes and ketones, which contribute to the development of unpleasant odors [7]. In addition, the presence of oxygen and other gases in the storage environment can also influence the spoilage of fish products [7]. For example, the presence of oxygen can promote the growth of microorganisms that produce hydrogen sulfide, which is a potent odor compound [30]. Furthermore, during the storage of fish, the occurrence of certain flavors such as grassy, earthy, and fishy can be attributed to the automatic oxidation of fatty acids [31]. The primary result of lipid oxidation, such as hydroperoxide, is inherently unstable and subsequently undergoes further decomposition into secondary oxidative rancidity [30]. This secondary rancidity manifests in the form of volatile low-molecular substances including aldehydes, ketones, and carboxylic acids, ultimately leading to an unpleasant oxidative rancidity and an irritating taste [7]. Simultaneously, the process of protein decomposition yields various compounds such as amine, ammonia, indole, ketone, aldehyde, peroxide, and low-grade acid [30]. These compounds contribute to the development of an unpleasant smell. It is important to note that the formation of aquatic product odor is a highly intricate process [30].

To prevent the spoilage of fish products during cold storage, it is essential to maintain a consistent temperature range, minimize the availability of nutrients, and control the storage environment to prevent the growth of microorganisms [31]. Additionally, the use of antimicrobial agents and other preservation techniques can help to extend the shelf life of fish products and prevent spoilage [32].

How bacteria spoiled the fish

Bacteria are integral agents contributing to fish deterioration, particularly in rendering them unsuitable for consumption. The decomposition of fish is chiefly a product of microbial reactions, prominently driven by bacteria [65]. Herein lies an elaborate elucidation of bacterial-induced spoilage in fish and the operative mechanisms.

Primary contamination

Initial defilement with bacteria emanates from diverse sources including water bodies, handling interfaces, equipment utilized, and environmental factors [65,66]. This contamination is ubiquitous - even healthy fishes harbor bacteria on their outer surfaces as well as within their gastrointestinal tracts.

Microbial augmentation

Following capture or harvest, given conducive conditions exist; bacteria propound to multiply expeditiously on the fish body. Drivers like temperature dynamics, humidity levels, pH scale range and oxygen availability exert substantial influence over the growth progression of decaying bacteria [67].

Temperature mismanagement

Any degree of misuse concerning optimal storage or transit temperatures that could boost rapid bacterial proliferation indeed hastens the process of decay. Indicatively positioned between 4°C - 60°C (40°F-140°F), this potential hazard zone allows swift bacterial expansion.

Targeted spoilage organisms (TSOs)

Specific variants of bacteria hold singular responsibility towards spoiling fish stocks - aptly termed 'Targeted Spoilage Organisms' (TSOs). Common TSO species associated with instigating spoilage include *Pseudomonas*, *Shewanella*, *Photobacterium*, and *Moraxella* varieties. These entities secrete enzymes and metabolic by-products leading to degradation at molecular levels such as

proteins & lipids alongside other constituents found in flesh layers- emitting undesirable odors/flavors while inducing textural modifications [66].

Enzymatic and chemical transformations

Certain bacteria generate enzymes that facilitate biochemical reactions as shown in Figure 1, thus causing the decomposition of proteins, fats, and carbohydrates within piscine tissues. For instance, proteases are responsible for protein degradation which subsequently leads to the softening of fish flesh along with the emanation of volatile compounds associated with disagreeable scents. Lipases are known to dismantle fats thereby introducing rancidity and unfavorable tastes [56,66]. The amalgamation of these enzymatic activities coupled with the chemical transformations triggered by bacterial metabolism significantly contributes towards diminishing fish quality.

Production of metabolites

As bacteria flourish on marine life surfaces, metabolic by-products surface including but not limited to ammonia, hydrogen sulfide and diverse organic acids. These compounds collectively induce undesired flavors or odors while accelerating the overall degeneration process concerning sensory traits in fish.

Spoilage patterns

Diverse strains of spoilage bacteria unveil unique spoiling sequences within fishes. *Pseudomonas* species exhibit a connection with perpetuating fruity or ammonia-like smells whereas *Shewanella* species tend to produce aquatic-life related or rotten odors.

Optical changes

Furthering odoriferous and empyreumatic changes, bacterial deterioration often leads towards various visual alterations in regard to fishes such as modifications concerning coloration patterns, textures and superficial slime secretion dynamics. In conclusionary terms, microbiological spoilage involving aquatic creatures encompasses growth proliferation specific deteriorating organisms alongside enzymatic cum chemical aberrations in piscine tissues coupled with metabolite production plus optical mutations eventually rendering these offerings inappropriate for human consumption purposes [66]. Implementing suitable handling protocols effectively minimizes contamination stemming

from microbes while extending shelf viability pertaining to maritime consumables.

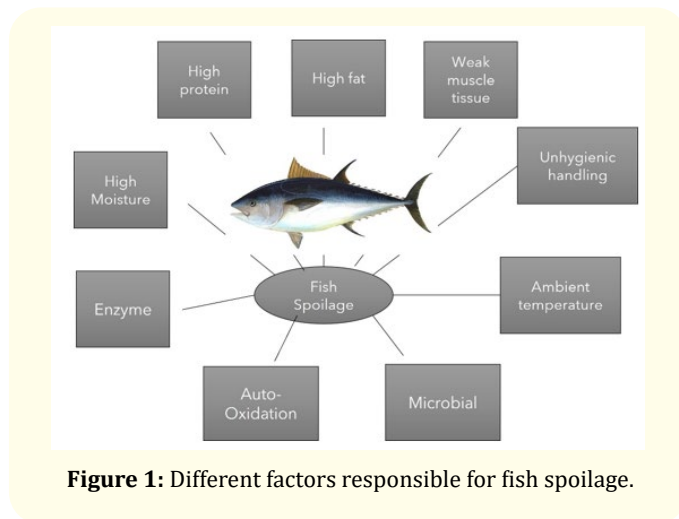


Figure 1: Different factors responsible for fish spoilage.

Biochemical composition of fish

The biochemical composition of fish can vary depending on the species, age, diet, and environmental factors. However, fish are known for their high-quality protein content and are a rich source of essential nutrients. The following are the primary components of the biochemical composition of fish [33-36].

- **Protein:** Fish is a great source of high-quality protein, containing all the essential amino acids required by the human body. Proteins in fish contribute to muscle growth, repair, and various metabolic functions.
- **Fat:** Fish contain varying amounts of fats, including both saturated and unsaturated fats. The type and amount of fat depend on the species and their diet. Fatty fish like salmon, mackerel, and sardines are known for their high content of omega-3 fatty acids, which are beneficial for heart health and brain function. Omega-3 Fatty Acids: Some fish species are particularly rich in omega-3 fatty acids, including eicosatetraenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids are essential for brain development, reducing inflammation, and promoting cardiovascular health.
- **Minerals:** Fish provide several essential minerals, such as iodine, selenium, zinc, and iron. These minerals are important for various bodily functions, including thyroid function, immune system support, and oxygen transport.

- **Vitamins:** Fish are a good source of various vitamins, including vitamin D, vitamin B12, and vitamin A. Vitamin D is important for bone health and calcium absorption, while vitamin B12 is essential for red blood cell production and nerve function. Vitamin A is beneficial for vision and immune function.
- **Carbohydrates:** Fish generally contain minimal amounts of carbohydrates, with the exception of certain species like eels and carp that may have higher carbohydrate content.

Overview of the fish industry in Saudi

The fisheries sector in Saudi Arabia plays a significant role in both the country’s economy and food security [23]. This sector not only provides employment opportunities but also contributes to the country’s Gross Domestic Product (GDP). Moreover, it serves a crucial function in meeting the increasing demand for seafood among the population [37]. The Ministry of Environment, Water, and Agriculture of Saudi Arabia (MEWA) recently stated that the fisheries sector primarily focuses on capturing fish and other seafood, with a smaller portion dedicated to aquaculture [24].

The FAO highlights the importance of the fisheries sector in Saudi Arabia. As an authoritative source, their information is based on extensive research and expertise in the field [44]. Similarly, the MEWA, which is responsible for environmental and agricultural affairs within Saudi Arabia, provides valuable insights into the composition and focus of the fisheries sector [13]. The FAO report underscores the pivotal position of the fisheries sector in Saudi Arabia as a provider of employment opportunities for coastal communities [44]. Moreover, the government has been implementing a range of initiatives and regulations to ensure sustainable fishing practices and the preservation of marine resources [23].

Fisheries in Saudi Arabia

Saudi Arabia’s fisheries sector produced approximately 244,000 metric tons of fish and other seafood in 2018, with a value of around \$1.2 billion [23]. This represents a significant increase from the 174,000 metric tons produced in 2010, with a value of around \$700 million [23]. Most of the production comes from wild catch, with a smaller component of aquaculture [23]. Most of the fish and seafood produced in Saudi Arabia is consumed domestically, with a smaller portion exported to other countries in the region [23].

The most caught species include fish such as hamour (grouper), hamour (threadfin), and harid (kingfish), as well as shrimp and crab [23].

Trend in hamour and harid fish in Saudi

The value of the fisheries sector in Saudi Arabia has also increased significantly over the past decade, from around \$700 million in 2010 to around \$1.2 billion in 2018 [23]. This represents a compound annual growth rate of around 6% [23]. Most of the value of the sector comes from the sale of fish and seafood, with a smaller portion coming from other products such as fishmeal and fish oil [23]. The growth in the value of the fisheries sector in Saudi Arabia is largely driven by increasing domestic demand for seafood as well as exports to other countries in the region [23]. The sector also benefits from investments in infrastructure and technology, such as the development of new fishing ports and the use of more efficient fishing vessels and equipment [23].

Hamour fish

While there is limited information on the production of *E. coioides* in Saudi Arabia, the country has been actively developing its aquaculture industry to enhance food security. The focus has primarily been on species such as shrimp, tilapia, seabream, and seabass. *E. coioides*, being a tropical marine fish species, may have the potential for cultivation in Saudi Arabia due to favorable environmental conditions [13]. But specific production statistics for this species are currently unavailable. However, on the global scale, *E. coioides*, is a tropical marine fish species that is widely distributed across the Indo-Pacific region [37]. It is highly valued in the aquaculture industry due to its fast growth rate, high market demand, and potential for export [38].

Globally, China is currently the largest producer of *E. coioides*, followed by countries like Indonesia, Thailand, Malaysia, and the Philippines [38]. These countries have favorable climatic conditions and established aquaculture practices for rearing this species [13]. During the early 1990s, the annual production of grouper in Hong Kong amounted to approximately 3000 metric tons [39]. However, this production has significantly declined to only 1000 metric tons per year. This decline can be attributed to various issues related to production and the environment as highlighted by [40]. One of the major challenges faced is the high mortality rate experienced

during the initial weeks or months after introducing fry to the cages. Additionally, mortality rates are also observed during water temperature changes, which occur twice a year. These changes involve an increase in temperature during April/May and a decrease in temperature during November [40,41].

Harid fish

Scarus Frenatus, known as harid fish, is not a primary target for commercial fishing in Saudi Arabia. The country's commercial fishing activities mainly concentrate on species that have high economic value, including shrimp, tuna, and various demersal fish species [25]. Consequently, there is a lack of comprehensive statistical data specifically pertaining to the production of *Scarus Frenatus* in Saudi Arabia.

Production control

The production stage is a critical control measure in the aquaculture industry, where fish are either caught directly from natural seawater or cultivated in an aquaculture setting. In the latter case, strict monitoring of water quality parameters is essential to ensure optimal growth and minimize stress on the fish [42]. These parameters include temperature, dissolved oxygen levels, pH, and ammonia concentration, which are carefully maintained within recommended ranges to create a suitable environment for the fish [43]. Regular water testing and analysis must also be conducted to detect any potential issues and promptly take corrective action. This represents a crucial stipulation set forth by the [13]. By adhering to these stipulations, fish farmers can ensure the overall well-being and soundness of their fish populations [45]. Monitoring these parameters allows for early identification of any deviations that could have adverse effects on the fish, thereby enabling swift intervention and the implementation of measures to alleviate the situation [46]. This dedication to upholding water quality aligns with the ministry's objective of promoting sustainable aquaculture practices and bolstering the long-term sustainability of the industry [47].

Finally, regular health checks, vaccination programs, and disease prevention measures must be implemented to maintain the overall well-being of the fish, which is also a prerequisite in the fisheries industry of the Kingdom [48]. By ensuring regular health checks, vaccination programs, and disease prevention measures,

the ministry aims to minimize the risk of disease outbreaks and ensure the overall well-being of the fish population [49]. This proactive approach not only safeguards the fisheries industry but also promotes responsible and ethical practices in aquaculture [46].

To uphold the general welfare of the fish population, it is imperative to implement regular health examinations, vaccination initiatives, and preventive measures against diseases [50]. These actions are considered essential prerequisites within the fisheries industry of the Kingdom. The primary objective of conducting regular health checks, vaccination programs, and disease prevention measures is to minimize the occurrence of disease outbreaks and ensure the overall well-being of the fish population [51]. This proactive approach not only safeguards the fisheries industry but also fosters responsible and ethical practices in aquaculture. Additionally, continuous monitoring and research are conducted to stay updated on emerging threats or challenges that may affect fish health, allowing for timely adjustments to be made in the industry's practices [52].

In Saudi Arabia, as in other regions, it is crucial to employ sustainable fishing methods to protect fish stocks and mitigate ecological consequences. These techniques encompass establishing catch thresholds, instituting fishing seasons, and utilizing selective fishing equipment to avoid capturing non-target species [53]. Moreover, Saudi Arabia has enforced stringent regulations and monitoring systems to guarantee adherence to sustainable fishing methods and preclude overfishing within its territorial waters [53]. By implementing fishing regulations such as size limitations, catch quotas, and seasonal prohibitions, the depletion of fish populations can be prevented, ensuring their long-term viability. The Saudi government has made significant investments in conducting research and scientific investigations aimed at enhancing their comprehension of the marine ecosystem and the repercussions of fishing activities (United Nations Development Programme [54]. This acquired knowledge empowers them to make well-informed judgments and adjust their regulatory measures, accordingly, thereby guaranteeing the sustained well-being and efficiency of their fisheries [54].

Processing

After the fish are harvested or caught, it is crucial to employ appropriate handling and processing methods to ensure the

preservation of the quality of fish hamour and harid [55]. Swift chilling or freezing immediately after capture plays a vital role in maintaining freshness by impeding the growth of bacteria [56]. Additionally, the utilization of ice slurry or refrigerated seawater during transportation serves to guarantee that the fish are kept at optimal temperatures.

While processing, stringent hygiene protocols are adhered to mitigate the risk of cross-contamination and microbial proliferation [57]. These protocols encompass regular maintenance and disinfection of processing equipment, adherence to proper handwashing procedures, and the utilization of personal protective equipment by workers [56]. Furthermore, the implementation of Hazard Analysis Critical Control Point (HACCP) systems aids in the identification of potential hazards and the establishment of control measures aimed at preventing foodborne illnesses.

Packaging and storage

The preservation of fish hamour and harid during storage and transportation heavily relies on appropriate packaging methods. Vacuum packaging and modified atmosphere packaging (MAP) are widely employed techniques to prolong the shelf life of these products by minimizing oxygen levels and impeding the growth of microorganisms [58]. Furthermore, labeling regulations encompassing product details, expiration dates, and storage instructions play a crucial role in providing consumers with vital information for the safe consumption of these items [59].

The preservation of fish products heavily relies on the appropriate storage conditions [60]. Cold storage facilities equipped with temperature control mechanisms are essential in ensuring the freshness and prevention of spoilage in fish [59]. Consistent monitoring of storage conditions, encompassing temperature and humidity levels, is crucial in averting any potential degradation in quality.

Quality control testing

To ensure adherence to established quality standards, regular testing must be carried out at different stages of the supply chain. Conduct microbiological analysis is to evaluate the presence of harmful microorganisms such as *Salmonella*, *Escherichia coli*, and *Listeria monocytogenes* [61]. Additionally, perform chemical analysis to monitor the levels of contaminants including heavy

metals, pesticides, antibiotics, and histamine [62]. Sensory evaluation also plays a crucial role in quality control testing. In the Kingdom of Saudi Arabia, there are trained panelists who assess the visual appearance, smell, texture, and taste of fish hamour and harid to identify any abnormalities or off-flavors that may indicate spoilage or substandard quality.

Regulatory framework

Government regulations are of utmost importance in guaranteeing the assurance of quality in fish hamour and harid [5]. Regulatory entities establish benchmarks for the practices involved in production, the facilities used for processing, the requirements for labeling, and the maximum allowable limits for contaminants [5]. Routine inspections are carried out to ensure adherence to these standards, and any operations found to be non-compliant may be subject to penalties or even forced closure [5].

Consumer awareness and education

The promotion of consumer awareness and education plays a crucial role in guaranteeing the sustenance of the demand for fish products that meet high-quality standards [63]. It is imperative to educate consumers about the significance of procuring fish from reputable sources, carefully reading product labels, and adopting appropriate storage and handling practices [64]. By doing so, the potential hazards associated with foodborne illnesses can be mitigated.

Conclusion and Future Perspectives

The quality assurance of fish hamour and harid entails a holistic methodology that encompasses various aspects such as production, processing, packaging, storage, quality control testing, and regulatory oversight. Through the implementation of rigorous measures at each stage of the supply chain, producers and regulators can guarantee that these seafood products adhere to the most elevated standards of quality and safety. However, additional data, particularly genomic information pertaining to the microbiota of hamour (*Epinephelus Summana*) and harid (*Scarus Frenatus*) fish products, is required to conduct a comprehensive risk assessment. Several unresolved inquiries persist, such as: (i) What are the optimal storage conditions for these specific fish species? (ii) How does water quality impact the microbiota of these fisheries? and (iii) Could the microbiota potentially pose a pathogenic threat to humans? Further investigation is necessary to address these queries.

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