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Quality assessment of tuna and swordfish export products in the city of Santos, São Paulo

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Abstract

The quality of fish can be evaluated by sensory, chemical, and microbiological analyses, with sensory analysis being the most important to determine the fish freshness. The aim of this study was to assess the factors that influence the quality and freshness of swordfish and tuna, as well as their signs of deterioration, to develop a sensory analysis protocol using the Quality Index Method. As it is a specific method, it was necessary to analyze the characteristics of each species. In the period between October 2021 and October 2022, 14,512 swordfish units and 1,534 tuna units, received and sold fresh by a fish warehouse, located in the city of Santos-SP, were analyzed. The Quality Index Method score developed for the swordfish ranged from 0 to 24, and for tuna, ranged from 0 to 34, where values close to zero indicate the best quality and fish freshness. Using the Quality Index Method, swordfish and tuna were classified into four quality ranges, making it possible to add value according to the fish classification. New physicochemical and microbiological studies can be carried out to certify the results obtained.

Keywords: sensory analysis; fish; quality; freshness.

Practical Application: This study assessed the factors that influence the quality and freshness of swordfish and tuna, as well as their signs of deterioration, to develop a sensory analysis protocol using the Quality Index Method. Using the Quality Index Method, swordfish and tuna were classified into four quality ranges, making it possible to add value according to the fish classification.

1 INTRODUCTION

Fishing is the commercial activity practiced along the entire length of Brazil's coastline, which covers more than 8,500 km of the coastline, representing high social and economic importance (Brasil, 2019a).

Brazil's exports in the fish sector in 2021 summed US$202.7 million, marking a growth of 32.6% compared to the same period in 2020. Fresh or chilled fish exports increased from US$2.4 million in August 2020 to US$3.8 million in August 2021, an increase of US$1.4 million (Confederação da Agricultura e Pecuária do Brasil [CNA], 2021). These figures show that, in addition to the importance of its nutritional content, fishing is an important socioeconomic activity for Brazil.

Between 2008 and 2018, fish imports by the United States increased by 55% (Instituto Galego de Promoción Econômica [IGAPE], 2022). Both American and European consumers have the principle of selecting products with a high-quality level.

Since January 2018, exports to the European Union market have been suspended by the Ministry of Agriculture and Livestock (MAPA), following an audit by the European Community that identified non-compliance in the production chain of fish and its derivatives (Brasil, 2017). To meet the recommendations of the European Community's health authority and thus resume exports, MAPA has developed and implemented measures in the national fish production chain (Brasil, 2019b).

Fish is a food of high nutritional value, with great commercial and economic importance, but because it is a highly perishable product (Qiao et al., 2022), in order to guarantee its quality, its entire production process must be controlled, from the moment it is caught. Several aspects influence the deterioration of fish, such as the type of fishing, the species of fish, the conservation temperature from catch to storage, hygiene in handling, the quality of the ice and water used in conservation, and the time from catch to the start of processing, among others (Germano & Germano, 2001; Carvalho et al., 2019).

Fish quality can be assessed by sensory, chemical, and microbiological analyses. Sensory analysis is considered the most

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important to determine the freshness of fish, requiring only the senses of sight, smell, and touch to evaluate the appearance, texture, smell, and taste (Soares & Gonçalves, 2012).

As is already the case in the European Union, the application of the Quality Index Method (QIM) in inspection services makes it possible to increase the proportion of high-quality fish on the market, increasing export values and limiting losses due to fish spoilage (Amaral & Freitas, 2013).

This study aimed to evaluate the quality of fresh tuna (*Thunnus* spp.) and swordfish (*Xiphias gladius*) exported from a warehouse located in Santos, SP, using sensory methodology as a possible tool for quality control (QC) when receiving the fish, in addition to identifying and analyzing the influence of the fishing location on the quality of the fish, as well as the time from catching to receiving the fish at the warehouse.

1.1 Relevance of the work

Swordfish and tuna are fish of high commercial price, with migratory habits, and are widely distributed in Brazilian ocean waters. However, the requirements for exporting these species to the American market, which is their largest consumer market, are strict, demanding high quality. This study developed a species-specific sensory analysis protocol, the Quality Index Method, which uses only the senses of sight, smell, and touch to determine fish freshness.

2 MATERIAL AND METHODS

This study analyzed samples of tuna of the species *Thunnus alalunga*, *Thunnus albacares, Thunnus obesus,* and swordfish, *Xiphias gladius,* received and sold by the Villa fish warehouse, located in Santos-SP, from October 2021 to October 2022.

The following data were collected from the fishing boats' Log Books (which is the documentation that accompanies every tuna and fresh fish received): identification of the fish species, fishing location, and start and end dates of fishing, to describe the traceability of each unit of fish received.

The following data were collected from the sensory analysis forms carried out by the warehouse's QC: the date the fish was received at the warehouse, the temperature of the fish, and the score given to the characteristics of the fish according to the company's criteria.

First, the specific sensory characteristics of each species were identified and then the attributes used for each parameter were determined on the form drawn up for the QIM.

The QIM form developed was applied to both swordfish and tuna. The attributes of general appearance and skin are common to both swordfish and tuna. However, some attributes are not related to the two fish, representing the differences and specifications of each species as proposed by QIM, the species-specific method. The items abdominal cavity and lateral line were evaluated only for swordfish, while eyes, gills, anus, and internal flesh were evaluated only for tuna. All the swordfish received at the warehouse were headless and gutted.

The lateral line attribute used to evaluate the swordfish is an analysis of the color of the meat exposed near the caudal region when a transverse cut is made in the swordfish at the time of unloading. The intensity of the red color of swordfish meat depends on the concentration of muscle myoglobin and its oxidation–reduction state (Smulevich et al., 2007). As the state of deterioration progresses, the bright red color from the oxymyoglobin formed by the reaction of oxygen and myoglobin gradually turns brown due to the formation of metmyoglobin (Abril et al., 2001).

To classify the quality and freshness of the tuna, the technique that uses colorimetry as a criterion for evaluating the portion of its internal meat was also applied. By inserting a thin stainless steel tube close to the pectoral fin, called a "sashibo," the tuna was pierced to take a sample of the internal meat.

Parallel to the documentary analysis and the formulation of the QIM protocol, a team was formed comprising two analysts and eight employees who were trained, totaling 10 judges. This team was responsible for monitoring the receipt of tuna and swordfish and applying the QIM form developed to 1,534 units of tuna and 14,512 units of swordfish.

Using Microsoft Excel as a tool, we calculated the average of the quality ratings that each judge gave to the units of swordfish and/or tuna, and using these data in graphs, we carried out a comparative analysis with the place of origin of the catch and the time elapsed between the catch and its unloading at the warehouse.

3 RESULTS AND DISCUSSION

From October 2021 to October 2022, a total of 266 batches of tuna and 353 batches of swordfish were received at the Villa fish warehouse, corresponding to 3,021 and 25,117 units, respectively. When analyzing the monthly distribution of the quantities of tuna and swordfish units received, in Table 1, in the case of tuna, the highest values were in June and August 2022. As for the swordfish units, in addition to June and August 2022, July had the second-highest number of units received.

The QIM protocol developed was applied to 198 batches of swordfish received between October 2021 and October 2022, corresponding to 14,512 units. The quality index (QI) of the swordfish ranged from 0 to 24 and was divided into four groups, where the higher the sum of the points of the attributes, the worse the quality of the fish. The sum of the points of the attributes between 0 and 4 indicated the best quality fish, but if any individual attribute had a score of 3, the fish was rejected. Also, if the sum of the attribute points was above 17, the fish was rejected. The QIs obtained are distributed by the total quantity of batches and/or units per month, as described in Table 2.

The swordfish is sold whole, gutted without the head, and because it is a large fish, it is possible to evaluate the units individually. The best score obtained from the QIM protocol for the mollusks analyzed was recorded predominantly in July 2022, when 183 units received a QI between 0 and 4. But the month of August 2022 stood out for its large volume of units and QI, 923 units between 5–10, and 1,166 units between 11–16 as show in Graph 1.

Table 1. Quantities of tuna and swordfish units received per month from October 2021 to October 2022.

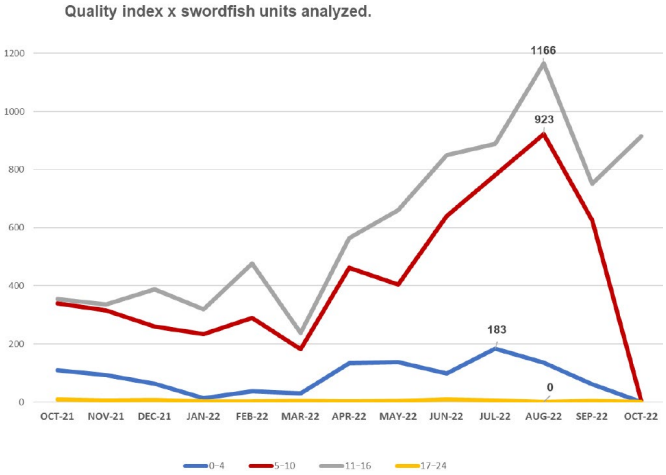
Units	2021			2022										
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Xiphias gladius Total Swordfish	1,372	1,307	1,215	948	1,357	758	1,958	2,008	3,093	3,096	3,717	2,758	1,530	25,117
Thunnus albacares	10	40	64	42	136	2	58	103	125	25	40	46	41	732
Thunnus alalunga	104	63	20	57	74	31	182	178	307	167	364	213	89	1,849
Thunnus obesus	18	94	96	80	20	1	5	8	10	28	22	16	41	439
Thunnus thynnus	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total Tuna	132	197	180	179	230	34	245	289	442	220	427	275	171	3,021

Source: The author, 2023.

Table 2. Quality indexes of the batches and/or swordfish units received per month from October 2021 to October 2022.

Month	Total		Quality index							
			0–4		5–10		11–16		17–24	
	Batches	Units	Batches	Units	Batches	Units	Batches	Units	Batches	Units
Oct/21	16	812	13	110	16	339	16	354	5	9
Nov/21	16	749	14	93	16	315	16	336	2	5
Dec/21	15	717	11	63	15	260	15	387	3	7
Jan/22	8	568	4	13	8	234	7	319	1	2
Feb/22	14	805	11	37	13	289	13	477	1	2
Mar/22	11	453	4	30	11	182	11	237	1	4
Apr/22	14	1,161	13	133	14	462	14	564	1	2
May/22	13	1,206	12	137	13	404	13	661	1	4
Jun/22	21	1,598	13	99	21	641	20	849	2	9
Jul/22	19	1,858	14	183	19	781	19	888	2	6
Ago/22	21	2,224	17	135	21	923	21	1,166	0	0
Sep/22	16	1,443	12	62	16	626	16	752	1	3
Oct/22	14	918	0	0	0	3	15	915	0	0
Total	198	14,512	138	1,095	183	5,459	196	7,905	20	53

Source: The author, 2023.



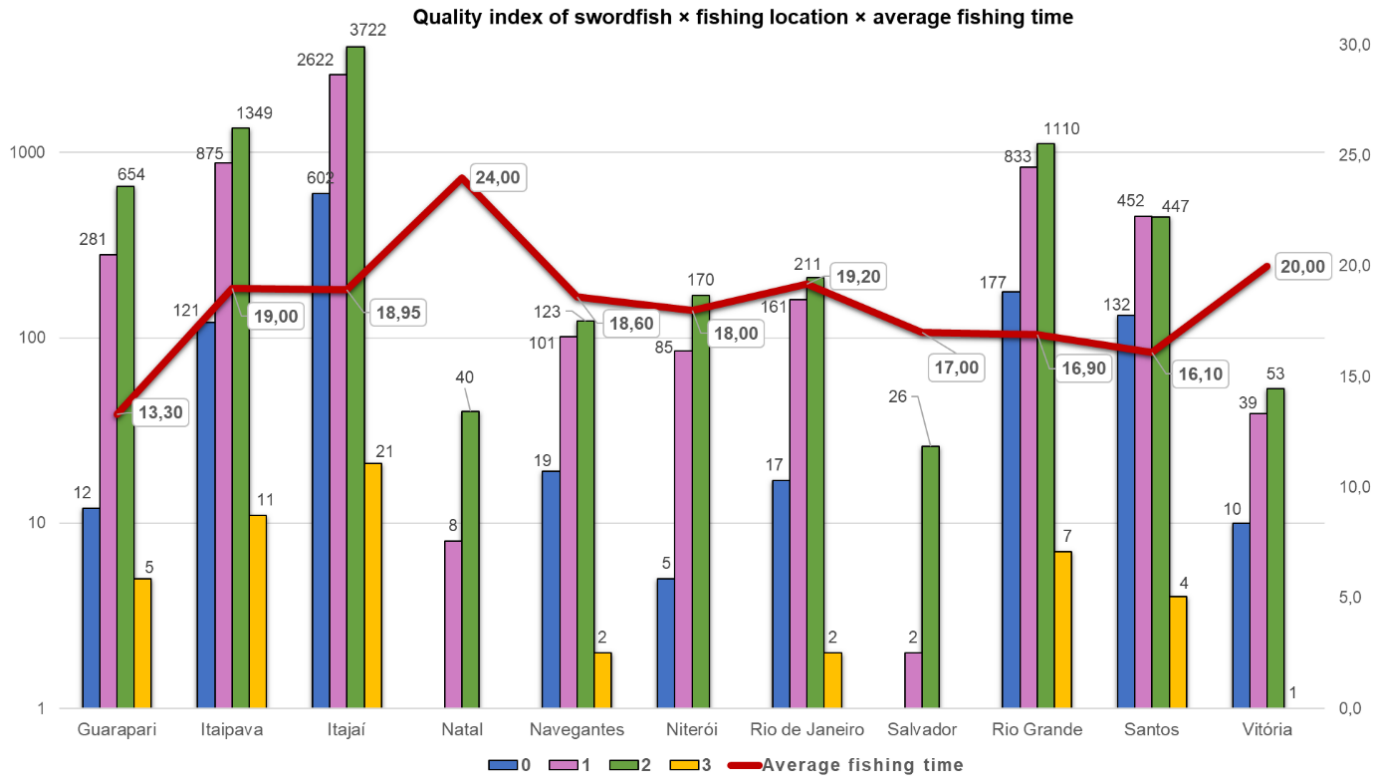
Source: The author, 2023.

Graph 1. Swordfish quality index × number of swordfish units analyzed per month of receipt, from October 2021 to October 2022.

In the period from October 2021 to October 2022, the boats responsible for catching the swordfish unloaded at the Villa warehouse took an average of 18.5 days at sea, from the start of catching the swordfish to unloading at the warehouse. The longest average was 24.0 days, when the catch took place in the Natal-RN region, and the shortest average was 13.3 days, in Guarapari-ES.

The average for discards from Itajaí was the same as that for Itaipava, 19.0 days, as shown in Graph 2. The percentages for Itaipava and Itajaí showed small differences when distributing the quantities of units of swordfish by their QI, according to the place of origin of the catch. For Itajaí, 8.64% achieved a QI between 0 and 4; the highest percentages were for a QI between 5 and 10, corresponding to 37.63% and, above all, a QI between 11 and 16, achieved by 53.42%, with only 0.30% corresponding to a QI between 17 and 24. And under the same behavior for Itaipava, 5.14% achieved the best QI; 37.14% achieved a QI between 5 and 10, while 57.26% achieved a QI between 11 and 16 and only .47% achieved a QI ≥ 17.

According to Ocaño-Higuera et al., 2011, the process of fish deterioration consists of four stages: mucus release, rigor mortis, autolysis, and bacterial decomposition, which can occur quickly or slowly and which not only affects the quality of fish meat but also reduces its shelf life. In fact, when analyzing the fishing location with the highest average number of days



Source: The author, 2023.

Graph 2. Quantity of swordfish units analyzed and their respective quality indexes distributed according to the fishing location, and the average fishing time in days, in the receiving period from October 2021 to October 2022.

between catching and unloading at the warehouse, this study demonstrated that no unit of swordfish received from the Natal region achieved a QI in the best range, between 0 and 4, and 83.33% of the units of swordfish achieved a QI between 5 and 10, showing the influence of time on the qualiy and freshness of the fish.

During the study period, the warehouse received swordfish whose boats predominantly departed from ports located in the southeast and south of Brazil, of which 48.01% of the swordfish units received and analyzed came from Itajaí-SC, corresponding to 6,967 units, and 16.23% (2,356 units) from Itaipava-ES and 14.66% (2,127 units) from Rio Grande-RS.

The swordfish make large migrations in search of the best conditions for feeding and reproduction (Mayer & Andrade, 2003). In September and October 2022, around 65% of the total number of swordfish received and analyzed originated from the city of Itajaí. This high figure is explained by the migration of the swordfish from warmer to colder waters, to the south of the Brazilian coast, where its distribution occurs mainly in the southeast and south of Brazil, at the end of the second quarter and during the third quarter of the year. In this period, the swordfish's migration is also related to its feeding, when there is an increase in the abundance of squid, which is its main prey, in the southeast and south regions due to the movement of the Subtropical Convergence (Hazin et al., 2021).

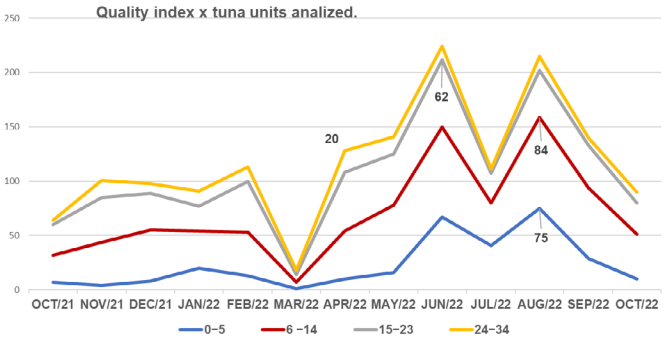
In August and September 2022, the seawater temperature in Itajaí was the lowest of the year, between 17 °C and 21 °C (Weather Spark, 2022). Swordfish prefer seawater temperatures between 14.57 °C and 22.83 °C (Boyce et al., 2008). This preference was confirmed in this study by the high percentages of mollusks received in September and October from the Itajaí region. In February 2022, sea temperatures were warmer in Itajaí, averaging 26.0 °C (Weather Spark, 2022). In February 2022, the number of swordfish units originating from Itajaí (16.02%) was the lowest of the year, while the percentage reached from Itaipava was 44.10%. Although the average sea temperature in the Itaipava region, 24.0 °C, is higher than the swordfish's preferred temperature, this is usually the lowest sea temperature among the other regions of the country at this time of year.

A total of 1,534 units of tuna received between October 2021 and October 2022 were subjected to sensory analysis using the QIM form developed. For tuna, the scale of the QIM form ranges from 0 to 34, divided into the following levels: 0 to 5; 6 to 14; 15 to 23; and 24 to 34.

The tuna species of the Atlantic and Pacific Oceans are classified as tropical (bigeye tuna and yellowfin tuna) and temperate (white albacore and the Atlantic, Pacific, and Southern tunas). Among the tuna species, white albacore is one of the most economically important and represents one of the most abundant fishing resources in the South Atlantic Ocean (Majkowski, 2007). This species, after its reproductive period in spring and summer, migrates south in search of a greater food supply; as a result, in winter, there is a greater abundance of yellowfin tuna

in the southern region of the country (Oliveira, 2010). Such a fact was proven in this study, where the predominant discharge was of yellowfin tuna from Itajaí, in the months of June, August, and September 2022.

According to Graph 3, the month of August 2022 shows the highest quantities of tuna units received and analyzed, which reached the best QIs, between the ranges of 0 and 5 and 6 and 14, respectively. The tuna received this month were caught in the southern region, predominantly Rio Grande and Itajaí.



Source: The author, 2023.

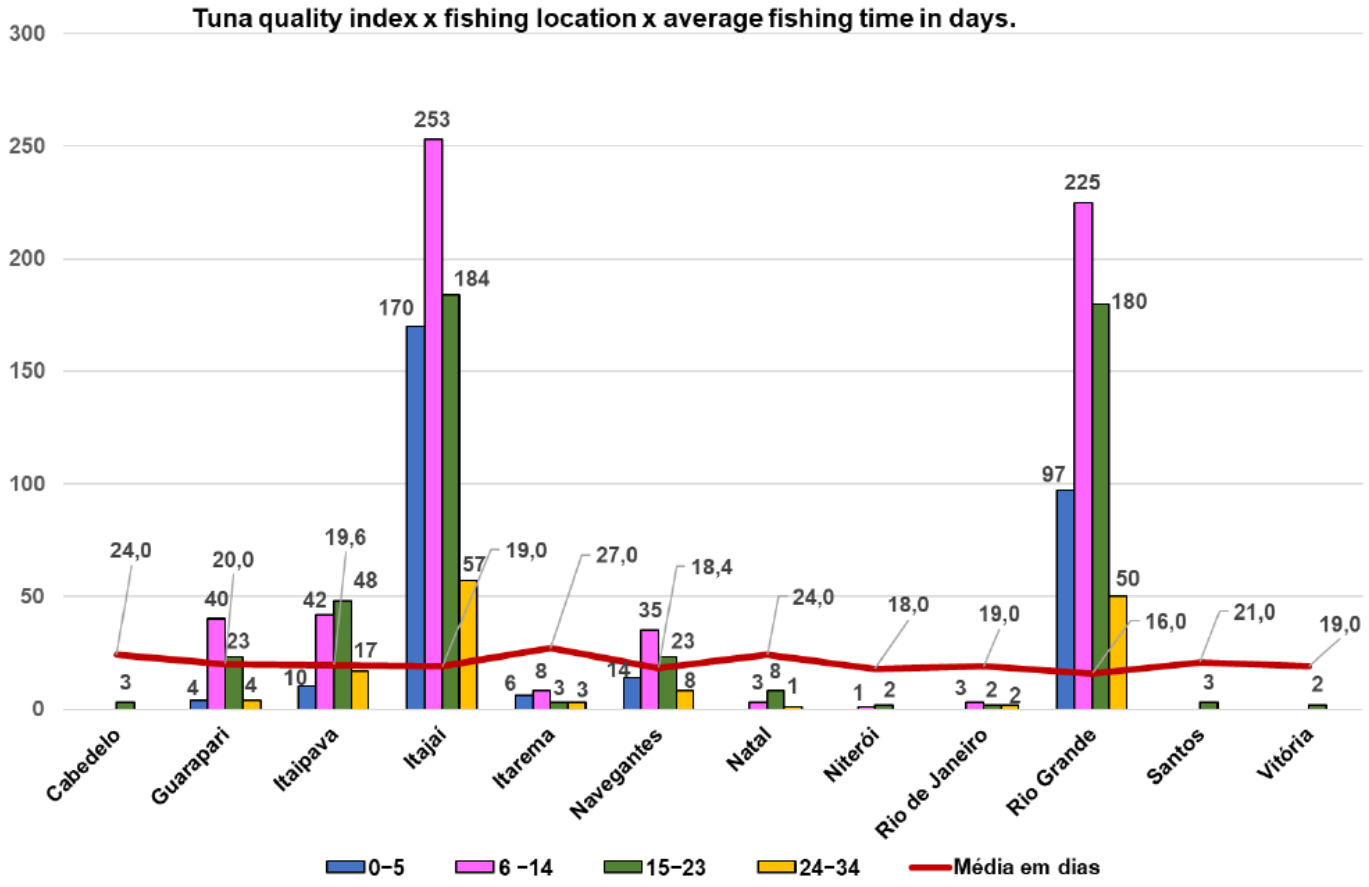
Graph 3. Number of units of tuna analyzed × quality index, distributed over the months of October 2021 to October 2022.

This period of year in Brazil is winter, sea water temperatures are colder, and there is a greater food supply and aggregation of tuna in surface waters. These characteristics not only make it easier to catch fish in quantity but also prevent the fish from using up a lot of glycogen, which slows down its deterioration (Oliveira, 2010).

In the period from October 2021 to October 2022, the boats responsible for fishing the tuna unloaded at the Villa fish warehouse took an average of 18.3 days from the start of the catch to unloading.

Graph 4 shows that the longest average fishing times recorded originated in the Northeast, in the cities of Itarema-CE, Cabedelo-PB, and Natal-RN, with 27, 24, and 24 days, respectively. However, these are sporadic landings, of just one batch from each city.

When analyzing the cities with the highest number of tuna units, Itajaí and Rio Grande stood out. Although the landings from Rio Grande had the lowest average number of fishing days, 16, when compared to Itajaí, whose average fishing time was 19 days, the percentage of tuna in the best QI range from Itajaí was higher than that from Rio Grande. Notably, 25.60% of the tuna received from Itajaí reached QIs in the 0–5 range, while only 17.57% of the tuna received from Rio Grande was in this range. This higher average fishing time in Itajaí is probably



Source: The author, 2023.

Graph 4. Number of tuna units analyzed and their respective quality indexes distributed according to fishing location, and average fishing time in days, in the receiving period from October 2021 to October 2022.

related to the greater quantity of tuna caught, which means that the fishing boats would have spent longer at sea. To minimize the effects of weather on fish quality, some extrinsic factors must have been adopted, such as satisfactory hygiene conditions in the fishing boat's facilities, proper handling, use of ice and good-quality water, keeping the fish cold from the moment it was caught, transport and unloading at the warehouse, and fishing methods (Blanc et al., 2005).

In 2021 and 2022, the warehouse received tuna whose boats predominantly departed from ports located in the southeast and south regions. Discharges from the ports of Rio Grande, Itajaí, and Itaipava showed the highest percentage rates.

In March and July 2022, 83.33% and 78.38% of the tuna units, respectively, came from the port of Itajaí, while, in April and June 2022, 68.75% and 49.11%, respectively, came from the port of Rio Grande. For the other regions where tuna originated, there was only one notable month and little distribution throughout the year. For example, in November 2021, Itaipava stood out, accounting for 45.54% of the total tuna unloaded that month.

In October 2021, the focal point was the 50.00% of tuna received from the Navegantes region. Although the largest concentration of tuna received originated in the south and southeast regions, in February 2022, many tuna units were received from the northeast region, in the Itarema-CE region.

In winter, in addition to the high food productivity, the influence of the Subtropical Convergence in southern Brazil increases the diversity of species of organisms that take advantage of this food supply, favoring the occurrence of large pelagic predators such as swordfish and tunas in this region (Schwingel & Mazzoleni, 2004), justifying the data obtained in this study in July 2022. However, the tuna's migratory behavior in search of suitable areas for reproduction and feeding provides seasonal variability in its distribution, which is apparently related to the fact that the stages of the tuna's life cycle seem to follow the circulation pattern of the South Atlantic surface currents (Travassos et al., 1999).

When comparing the QIM protocol developed with the Sensory Evaluation Form carried out by the Villa fish warehouse on receipt, the scale used to evaluate the quality criteria is reversed. While in the QIM the higher the QI value, the lower the quality of the fish, in the company's QC form, the lower the QI value, the lower the quality of the fish. The QIM developed follows the concept indicated by Hien et al. (2023), where when the QI is close to zero, the fish is considered fresh, and high QI values indicate the start of fish deterioration. The QIM made the data recording quicker, since, in practice, only the attributes that have demerits need to be recorded.

Despite carrying out a sensory analysis of various attributes, like the QIM, the company's Organoleptic Evaluation Form only classifies the fish for approval: accepted or rejected. With the use of the QIM developed, the units of swordfish and tuna were classified into four different QI ranges, which made it possible to add value to the fish according to its quality.

4 CONCLUSIONS

The factors that influence the deterioration of fish need more reliable data for more assertive conclusions. The on-board maps, which are one of the main sources of these data, have many errors in their completion.

The QIM developed in this study made it easier to record data and analyze the most significant characteristics that indicate fish deterioration. As the villa in this study is an establishment that sells fresh fish, where it is dispatched immediately after it is received, it was not possible to carry out more detailed studies on the deterioration of the fish during storage, nor to compare it with physicochemical and microbiological analyses, which would be interesting to ratify the quality classification established and propose a shelf life.

The application of the QIM using demerit points makes it possible to assess the freshness of fish reliably and quickly. It proves to be an objective, easy-to-train, and low-cost method. It also increases the proportion of high-quality fish marketed and raises export product prices.

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