Research, Society and Development, v. 13, n. 11, e41131146916, 2024
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# Critical evaluation of in natura sashimi products quality during Covid-19 pandemic

## Avaliação crítica da qualidade dos produtos de sashimi in natura durante a pandemia de Covid-19

## Evaluación crítica de la calidad de los productos de sashimi in natura durante la pandemia de Covid-19

Received: 09/09/2024 | Revised: 10/27/2024 | Accepted: 11/04/2024 | Published: 11/08/2024

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**Abstract**
To emphasize the importance of quality food for health and immunity during COVID-19, this study evaluated raw fish quality from oriental cuisine delivery. From 75 orders, 29 samples of sashimi (salmon and tuna) suggested some deterioration, being subjected to quality analyses (pH, TVB-N, NH3, H2S, TBARs and biogenic amines). pH values varied between 5.7 to 8.4 in salmon and 5.4 to 6.6 in tuna. The values in salmon and tuna for TVB-N (between 10.00 and 40.00 mg/100gN), histamine (0.00 and 7.50 µg/g) and cadaverine (0.00 and 15.00 µg/g) was presented, respectively. Ammonia and H2S appeared in 93.1 and 31 % for salmon, and 15.8 and 10.5 % for tuna, respectively. while the lipid oxidation average was 0.60 and 1.14 mg MAEq /kg, respectively From the results obtained, refrigeration and freezing are essential for handling raw fish, preserving freshness, ensuring safety, and extending shelf life. Clearly, results of fish quality has shown a lack of organization in food delivered system. For that, simple and inexpensive methods can used to evaluate fish quality. Thus, sanitary surveillance can improve systemic efficiency to protect public health to be prepared for future crisis events.
**Keywords:** Delivery; Fish; Food safety; Public health.

**Resumo**
Para enfatizar a importância de alimentos de qualidade para a saúde e a imunidade durante a COVID-19, este estudo avaliou a qualidade do peixe cru proveniente de delivery da culinária oriental. De 75 pedidos, 29 amostras de sashimi (salmão e atum) sugeriram alguma deterioração, sendo submetidas a análises de qualidade (pH, TVB-N, NH3, H2S, TBARs e aminas biogênicas). Os valores de pH variaram entre 5,7 e 8 no salmão e 5,4 e 6,6 no atum. Os valores do salmão e do atum para TVB-N (entre 10,00 e 40,00 mg/100gN), histamina (0,00 e 7,50 µg/g) e cadaverina (0,00 e 15,00 µg/g) foram apresentados, respectivamente. A amônia e o H2S apareceram em 93,1 e 31% para o salmão e 15,8 e 10,5% para o atum, respectivamente, enquanto a média de oxidação lipídica foi de 0,60 e 1,14 mg MAEq/kg, respectivamente. Claramente, os resultados da qualidade do peixe mostraram uma falta de organização no sistema de entrega de alimentos. Para isso, métodos simples e baratos podem ser usados para avaliar a qualidade do peixe. Assim, a vigilância sanitária pode melhorar a eficiência sistêmica para proteger a saúde pública e estar preparada para futuras crises.
**Palavras-chave:** Entrega à domicílio; Peixe; Segurança alimentar; Saúde pública.

**Resumen**
Para resaltar la importancia de la calidad de los alimentos para la salud y la inmunidad durante el COVID-19, este estudio evaluó la calidad del pescado crudo procedente de la entrega de cocina oriental. De 75 pedidos, 29 muestras de sashimi (salmón y atún) sugerían algún deterioro, siendo sometidas a análisis de calidad (pH, TVB-N, NH3, H2S, TBARs y aminas biógenas). Los valores de pH variaron entre 5,7 y 8 en el salmón y entre 5,4 y 6,6 en el atún. En salmón y atún se presentaron valores de TVB-N (entre 10,00 y 40,00 mg/100gN), histamina (0,00 y 7,50 µg/g) y cadaverina (0,00 y 15,00 µg/g), respectivamente. El amoníaco y el H2S aparecieron en un 93,1 y un 31 % en el salmón, y en un 15,8 y un 10,5 % en el atún, respectivamente. mientras que la media de oxidación lipídica fue de 0,60 y 1,14 mg MAEq /kg, respectivamente De los resultados obtenidos se desprende que la refrigeración y la congelación son esenciales para manipular el pescado crudo, preservar su frescura, garantizar su seguridad y prolongar su vida útil. Claramente, los resultados de la calidad del pescado han mostrado una falta de organización en el sistema de suministro de alimentos. Por ello, se pueden utilizar métodos sencillos y baratos para evaluar la calidad del pescado. Así, la vigilancia sanitaria puede mejorar la eficacia sistémica para proteger la salud pública y estar preparados para futuras crisis.
**Palabras clave:** Entrega a domicilio; Pescado; Seguridad alimentaria; Salud pública.

## 1. Introduction

The COVID-19 pandemic has had a significant impact on food quality around the world, as well as on peoples' eating behaviour (Laren et al., 2023). Brazil has the most powerful food delivery market in Latin America. The search for convenience and safety due to the COVID-19 pandemic has fueled the expansion of digital food delivery platforms (Frid et al., 2024; Horta et al., 2021). The pandemic has disrupted food supply chains, causing shortages of certain foods and leading to price increases. Additionally, many food processing and packaging facilities have had to reduce their production capacity or shut down temporarily due to virus outbreaks among their workers. These disruptions have made some food products less fresh, less nutritious, or unsafe than usual (Barman et al., 2021; Hobbs, 2020). Meat and other fresh food may have been harvested later than expected or stored for extended periods, decreasing nutritional value (Din et al., 2022). Similarly, meat and poultry may have been processed or packaged under less-than-ideal conditions, leading to concerns about food safety (Hobbs, 2021). In addition to these supply chain disruptions, the pandemic has also led to changes in consumer behaviour. With more people staying at home and cooking for themselves, there has been an increased demand for certain foods, such as pantry staples and comfort foods. This has pressured food producers and retailers to meet these changing demands, affecting the quality and variety of available food (Bakhsh et al., 2021; J. Balest & Stawinoga, 2022; López-Moreno et al., 2020; Pfeifer et al., 2021; Tribst et al., 2021).

The COVID-19 pandemic has presented significant challenges to maintaining high food quality standards. However, food safety regulators and industry leaders are working to address these challenges and ensure that consumers can access safe, nutritious, high-quality food during these challenging times (Djekic et al., 2021; Han et al., 2021). One criticism concerns the lack of preparation and rapid response capacity of health surveillance services during the pandemic (Lanyero et al., 2021). In Brazil, there was a lack of support laboratories in many municipalities, as well as professionals who did not receive the necessary support and training to deal with an emergency of the magnitude of COVID-19, which resulted in delays in implementing preventive measures and difficulties in coordinating and executing effective actions, especially in delivery services. This has resulted in a lack of consistent and effective application of health guidelines, and a lack of transparency and clarity in the guidelines for delivery services, compromising the quality of products and making it difficult to adhere to preventive measures. A critical analysis highlights the inability to deal efficiently with emerging demands and the lack of long-term strategic planning (Boschiero et al., 2021; Zanetta et al., 2021).

Fishery products are food commodities that quickly spoil because of the influence of water and nutrient content, fish matrix is a good environment for spoilage bacteria growth, accelerating this meat deterioration. Storage temperature is fundamental in the fish food industry chain, influencing the speed of reduction in fish freshness level and quality (Akerina et al., 2024). Fish and shellfish are important sources of high-quality lipids, especially omega-3 long-chain polyunsaturated fatty acids (Sasaki et al., 2024; Tutor et al., 2024). However, both cooking and storage processes can cause alterations in the lipid content and fatty acid profile of fish and shellfish (Chirstophe et al., 2024; Valentim et al., 2024).

During the COVID-19 pandemic, it is important to prioritize quality food to maintain good health and a robust immune system. Thus, this study aimed to evaluate tuna and salmon the quality of the Oriental cuisine delivery system during the pandemic, using rapid physical-chemical analyses.

## 2. Methodology

### *2.1 Sample collection*

This research was an ecological descriptive field study (Toassi & Petry, 2021), in which there were placed 75 orders of sushi and sashimi from Oriental cuisine restaurants via the cell phone app. in Niterói, RJ, Brazil, from June 2020 to March 2021 during the COVID-19 pandemic. From those, 29 orders suggested deterioration by visualization, smell, texture or taste, being secregated for quality analyses. A total of 29 samples of salmon (Salmo salar) and 19 of tuna (Thunnus sp.) were selected, kept individually in an insulated ice box and immediately transferred  to the physicochemical control laboratory for rapid and cost-effective analyses (pH, TVB-N, NH3, H2S, TBARs and biogenic amines).

### *2.2 pH determination*

pH determination was achieved using the method described by Huss et al.(1995) using 5 g of muscle fish with 50 mL of distilled water and a digital pH meter.

### *2.3 Determination of TVB-N*

The determination of total volatile basis nitrogen (TVB-N) was conducted following the methodology outlined by Liu et al. (2014). In this procedure, 3 g of the samples were homogenized with 3 mL of distilled water and 6 mL of 10% trichloroacetic acid for 2 minutes. After completion of the homogenization process, 18 mL of 5% trichloroacetic acid was added. The resulting mixture was then subjected to centrifugation at 3000 g and 4°C for 10 minutes. Subsequently, 5% trichloroacetic acid was added to achieve a total volume of 30 mL.

To determine TVB-N, 1 mL of the sample solution and 1 mL of a K2CO3 solution were placed in the outer section of a Conway microdiffusion cell, and the mixture was gently stirred. The cell was incubated at 37°C for 60 minutes, followed by titration against 0.02 N sulphuric acid. The results were expressed as milligrams of TVB-N per 100 g of fish muscle.

***2.4 Determination of NH3***

The protein content degradation of fish samples was analysed by a qualitative Nessler method according to IAL (2008). Briefly, 10 g of each fish sample was homogenised in 100 mL distilled water for 15 min, then filtered in a paper filter (Whatman nº1, Whatmantm, GE Healthcare UK Limited, Buckinghamshire, UK). In 2 mL Nessler reagent, it was dropped 10 drops of filtered fish solution. The result was determined by the solution color as orange/red for positive (NH3 presence in the sample indicating deterioration), or green for negative.

***2.5 Determination of H2S***

To approach the fish samples consertion, it was detected the presence of hydrogen sulfide (H2S) according to the Eber method described by IAL (2008). Briefly, 10 g of fish sample was put in an Erlenmeyer flask to be heated in a water bath for 10 min. A filter paper soaked in lead acetate was used to close the flask and the appearance of black spots indicated H2S vapor, meaning positivity of the analysis.

***2.6 Determination biogenic amines***

Three biogenic amines (histamine, putrescine and cadaverine) were determined according to Schutz et al. (1976) by thin layer chromatographic method, expressed in mg/g.

***2.7 Determination of lipid oxidation – TBARs***

The assessment of lipid oxidation was performed by measuring thiobarbituric acid-reactive substances (TBARs) using the method developed by Sinnhuber and Yu (1958); and Buege and Aust (1978). In this method, the sample solution was mixed with chloroform in a 1:1 volumetric ratio, and after reacting with the TBA reagent, it was vortexed. Following this, the mixture underwent centrifugation at 1800 xg for 10 minutes. The absorbance values at 532 nm were measured using a UV-1800 spectrophotometer (Shimadzu Corporation, Kyoto, Japan). The results were expressed as milligrams of malondialdehyde equivalent (MAEq) per kilogram of the sample and were calculated using the following equation:

$$\text{TBARS (mg/kg)} = (A532 / Ws) \times 9.48$$

where A532 represents the absorbance of the assay solution, Ws represents the weight of the sample (in grams), and "9.48" was a constant derived from the dilution factor and the molar extinction coefficient of the red TBA reaction product.

***2.8 Statistical evaluation***

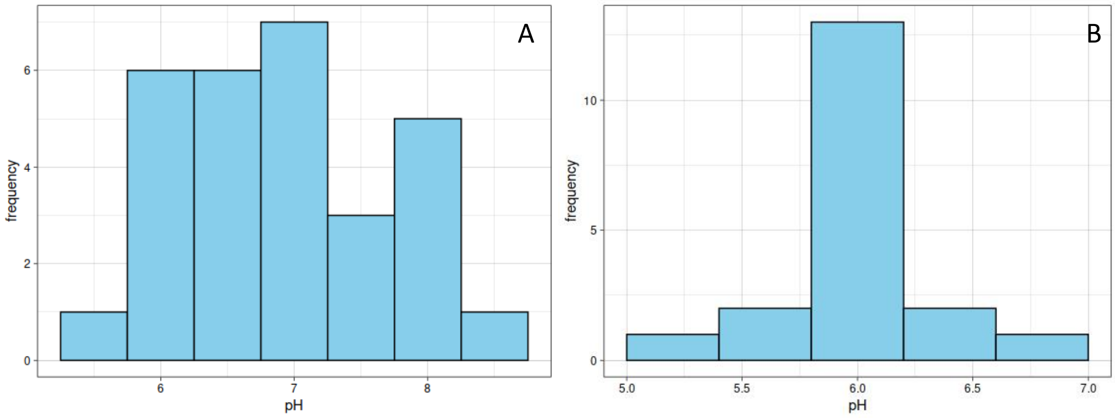
The analyses of all samples (29 salmon and 19 tuna) were performed in triplicate. Data were analyzed by one-way analysis of variance (ANOVA) and the means were compared using the Tukey test ($p > 0.05$ %) using the software XLSTAT 2017.1 (Adinsof, Paris, France).

## 3. Results and Discussion

Fish is regarded as a source of high-quality protein and low in saturated fat, along with other nutrients that, when properly prepared, are known to promote good health. During crises like the COVID-19 pandemic, it was crucial to adopt healthy eating habits to boost the immune system, maintain overall health, and enhance the capacity to recover and tackle new challenges (Brito et al., 2024).

The pH value varied between 5.7 to 8.4 (average = 6.9 ±0.75) in salmon, while it ranged from 5.4 to 6.6 (average = 6.0 ±0.26) in tuna (Figure1), revealing that 41.4% of salmon samples exhibited pH values exceeding the limits recommended by Brazilian legislation (pH below 7.0, BRASIL, 2017). The pH of fresh fish (6.5-7.0) is crucial for quality. A lower pH indicates degradation by lactic acid bacteria, causing bad tastes, odors, and a soft texture. In another hand, a higher pH signals protein decomposition, ammonia smells, and pathogen growth. Thus, proper cold storage (< 4°C) and hygiene practices during fish manipulation are fundamental to maintaining quality (Alamdari et al., 2021; Korkmaz, 2023).

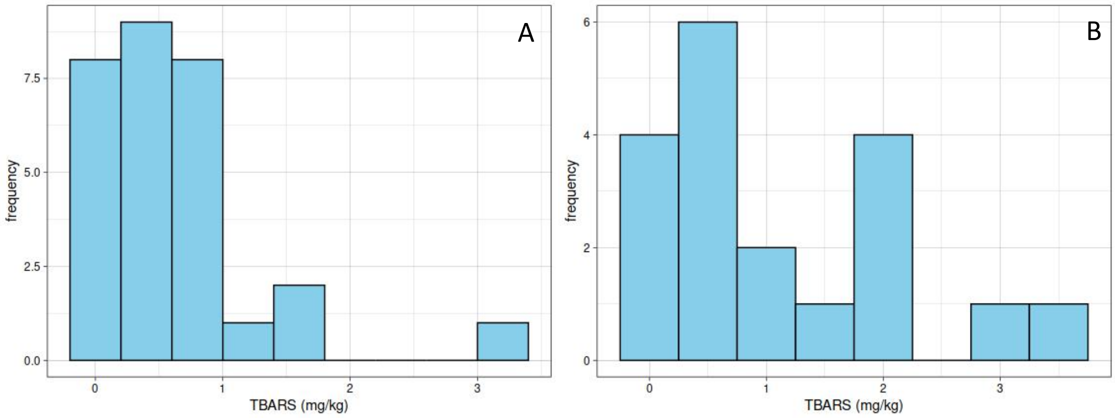
**Figure 1** - pH frequency in salmon (A) and tuna (B) sashimi samples from delivery during COVID-19.




Source: Authors.

Oxidized lipids can produce harmful compounds like aldehydes and peroxides, which may have numerous negative health effects, contributing to inflammation and oxidative sr[stress in humans, potentially impacting overall health. To evaluate lipid oxidation and determine if the unsaturated fatty acids had changed, TBARs analysis was conducted. For the salmon samples, the average results were 0.60 mg MAEq /kg ± 0.63, with values ranging from 0.09 to 3.15 mg MAEq/kg. Tuna presented higher lipid oxidation with the average was 1.14 mg MAEq /kg (0.15 to 3.43 mg MAEq /kg, Figure 2), indicating poor storage and handling conditions. Thiobarbituric acid reactive substances can be degraded or interact with other components, such as proteins, to form polymers that decrease the quality of salmon. Lipids and proteins do not react to form complexes unless the fat or fatty acids are oxidized (Christie & Harwood, 2020).

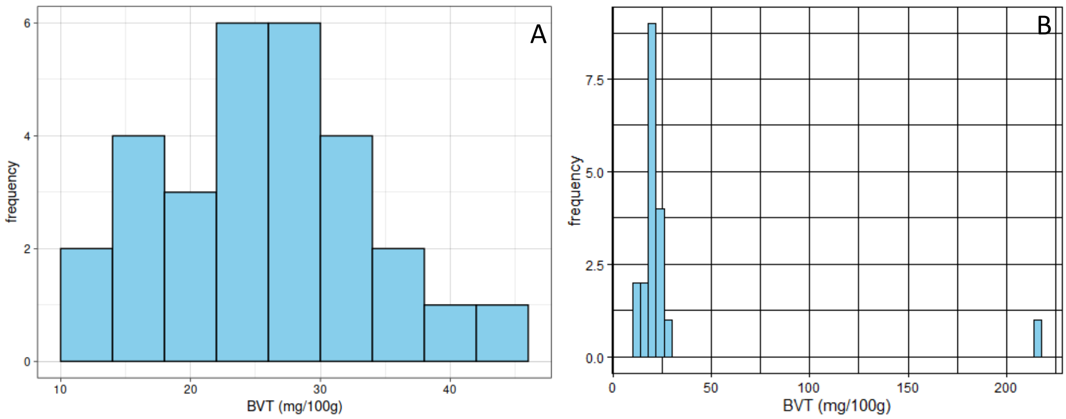
**Figure 2** - Lipid oxidation frequency in salmon (A) and tuna (B) sashimi samples from delivery during COVID-19.




Source: Authors.

The BVT analysis enables the identification of basic volatile nitrogen compounds, including trimethylamine, dimethylamine, and ammonia. These compounds are produced through the autolytic and microbial enzymatic breakdown of muscle proteins, along with other substances, and concentrations change over time, rising as fish spoilage advances (Parlapani et al., 2024). Thus, the TVB-N is an important indicator of fish freshness and spoilage. High levels indicate that fish has begun to spoil, resulting in off-flavors and unpleasant odors (Mohammadi et al., 2021) related to the quality and freshness of fish. Figure 3 appears the TVB-N frequency in salmon and tuna sashimi samples, their averages were 26.51 mg/100gN and 25.80 mg/100gN, respectively. It indicated that 27.6% salmon samples exceeding the 30 mg/100g nitrogen established by Brazilian legislation (Brasil, 2017), while just a single tuna sample presented TVB-N over than 200 mg/100g nitrogen. Keeping the TVB-N value under 30 mg/100g N is crucial to ensure the fish remains fresh, retains good sensory qualities, and is safe to eat (Ferreira et al., 2020). Meeting these standards is vital for satisfying consumer expectations and adhering to regulatory guidelines, thereby ensuring the fish is marketable (Fuentes-Amaya et al., 2015).

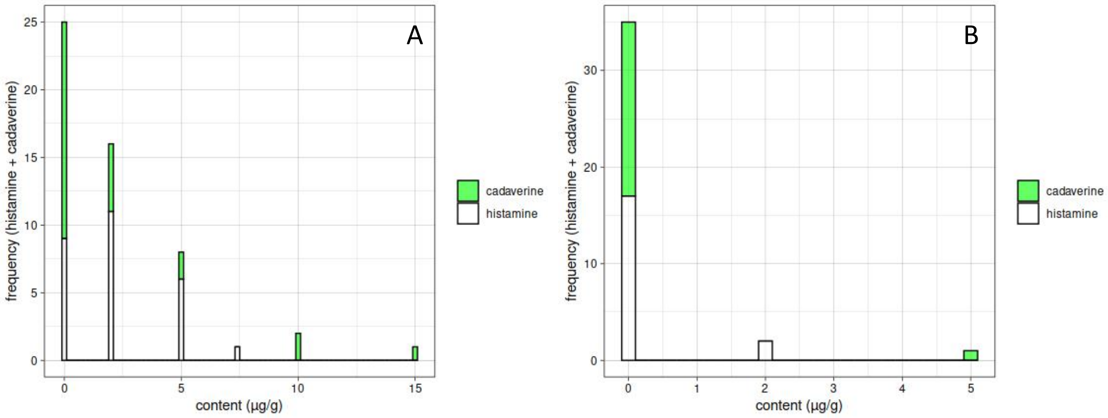
**Figure 3** - Total volatile basis nitrogen (TVB-N) frequency in salmon (A) and tuna (B) sashimi samples from delivery during COVID-19.




Source: Authors.

Biogenic amines are characterized as organic compounds naturally formed in foods through the microbial decarboxylation of amino acids, particularly significant in seafood due to the high susceptibility of these products to microbial contamination and improper storage conditions. heir presence in high levels can pose serious health risks to consumers, in addition to failing to provide the necessary amino acids to meet metabolic needs. The decarboxylation of the amino acids histidine and lysine, generating the biogenic amines histamine and cadaverine respectively (Figure 4), also indicated hygienic and cold chain failures. For the salmon samples, 31 % of the samples collected presented an average of 3.30 ± 2.14 µg/g histamine content, varying from 0.00 to 10.00 µg/g. Just two tuna samples were detected this biogenic amine, presenting 2.00 µg/g each one. In respect of cadaverine, it was detected in 55% samples of salmon, presenting 5.50 µg/g (2 to 10 µg/g); and just one sample of tuna presented 5.00 µg/g cadaverine. Based on these results, it can be inferred that the cold chain to which the tuna samples were subjected at all stages was more effective, whereas for the salmon samples, there may have been an interruption in cold chain storage.

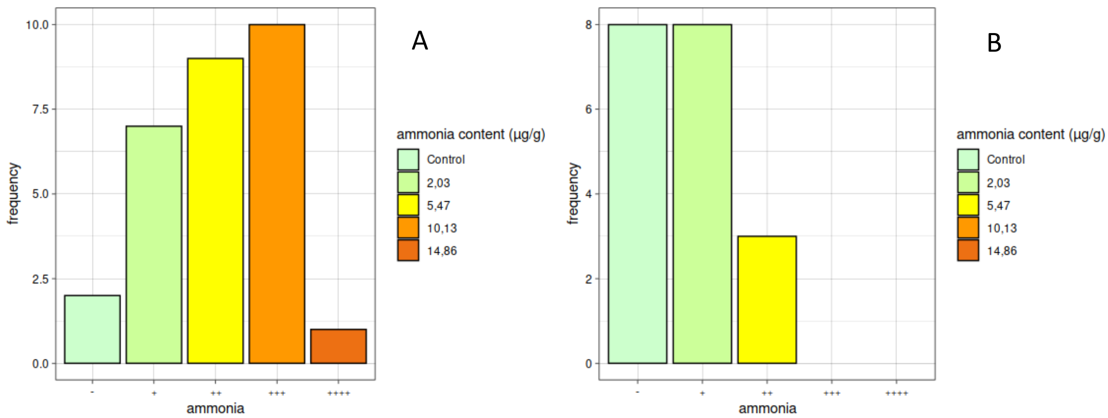
**Figure 4** - Main biogenic amines (cadaverine and histamine) frequencies in salmon (A) and tuna (B) sashimi samples from delivery during COVID-19.




Source: Authors.

Considering that ammonia (NH3) is one of the volatile bases produced by fish as a result of degradation by deamination in situations where there is a failure in the cold chain and inadequate hygiene practices, a qualitative analysis was carried out comparing the colorimetric standards generated with instrumental analysis, for greater reliability in the colorimetric complexes obtained (Figure 5). Additionally, 93.1 % of the salmon samples exhibited ammonia production, from which 27.6 % presented between 5 to 10 µg/g and 37.9 % more than 10 µg/g ammonia. While only 15.8 % tuna samples had results between 5 to 10 µg/g, and 42.1 % samples didn´t present any trace of that compound.

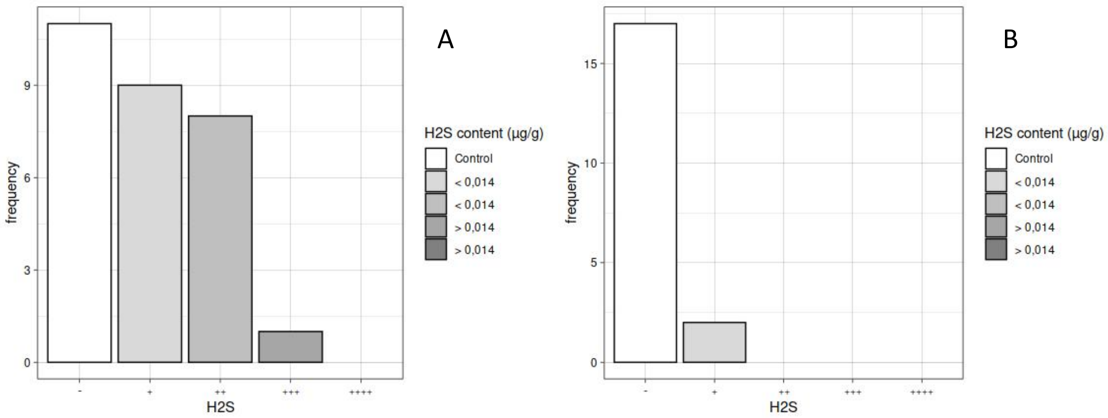
**Figure 5** - Ammonia frequency in salmon (A) and tuna (B) sashimi samples from delivery during COVID-19.




Source: Authors.

The same standard was used to interpret the H2S results from the degradation of sulphur amino acids, carrying out a qualitative analysis and generating a scale of colorimetric standards to indicate values (Figure 6). 31 % of salmon samples present more than 0.014 µg/g H2S, and in only 37.9 % samples the compound was absent. In counterpart, just two tuna samples (10.5 %) had H2S in concentrations below 0.014 µg/g. Considering the results obtained, it was clear that there were problems with the cold chain at some stage of production in the salmon samples. To avoid fish products deterioration, it is recommended two days of storage under refrigeration (< 4 °C, USDA, 2024) or, at least, five months depending on the type of fish and the frozen storage temperature (< -18 °C, FAO, 1994).

**Figure 6** - H2S frequency in salmon (A) and tuna (B) sashimi samples from delivery during COVID-19.




Source: Authors.

## 4. Conclusion

Clearly, the findings on fish quality have revealed disorganization within the food delivery system. Because refrigeration and freezing are considered indispensable practices in the handling of raw fish products. Refrigeration at or below 4 °C (39°F) and freezing at -18 °C (0°F) or lower play a vital role in preserving freshness, ensuring safety, maintaining quality, extending shelf life, providing economic benefits, and satisfying consumer expectations.

It could be inferred that with simple, fast and inexpensive methods, it was possible to evaluate the quality of fish products. Implementing this analytical support is the responsibility of sanitary surveillance with a strictly political nature. It is crucial to recognize the challenges and seek systemic improvements to ensure more efficient action during pandemics and other emerging crises, as a way of protecting the health of the population.

Another important point to consider is that fish is considered a noble food, whose consumption is aligned with the concept of healthiness and, precisely because of these factors, it is often chosen as the main source of protein, especially as it was during the pandemic. On the other hand, if efforts and monitoring by health organizations and quality control services fail to guarantee this quality, all this quality is transformed into possible causes of various pathologies, as well as inefficiency in carrying out fundamental processes, such as muscle protein synthesis and neurotransmitter production, weakening of the immune system and various other metabolic disorders.

## Acknowledgments

We thank the financial support of the Carlos Chagas Filho Foundation for Research Support in the State of Rio de Janeiro (FAPERJ / BRASIL). Research grants numbers: 23038.007363 / 2011-13, E-26/112.485/2012 and E-26/200.231/2024.

## Conflict of Interest

Authors declare no conflict of interest.

## References

Akerina, F. O., Kour, F., & Hibata, Y. L. (2024). Quality of Demersal Fish sold at Tobelo Traditional Market, North Halmahera based on pH and Organoleptic Values. *Jurnal Ilmiah PLATAX*, *12*(1), 132-140.

Alamdari, N., Aksoy, B., Aksoy, M., Beck, B., & Jiang, Z. (2021). A novel paper-based and pH-sensitive intelligent detector in meat and seafood packaging.. *Talanta*, 224, 121913. https://doi.org/10.1016/j.talanta.2020.121913

Bakhsh, M. A., Khawandanah, J., Naaman, R. K., & Alashmali, S. (2021). The impact of COVID-19 quarantine on dietary habits and physical activity in Saudi Arabia: A cross-sectional study. *BMC Public Health*, *21*(1), 1487. https://doi.org/10.1186/s12889-021-11540-y

Balest, J., & Stawinoga, A. E. (2022). Social practices and energy use at home during the first Italian lockdown due to Covid-19. *Sustainable Cities and Society*, *78*, 103536. https://doi.org/10.1016/j.scs.2021.103536

Barman, A., Das, R., & De, P. K. (2021). Impact of COVID-19 in food supply chain: Disruptions and recovery strategy. *Current Research in Behavioral Sciences*, *2*, 100017. https://doi.org/10.1016/j.crbeha.2021.100017

Boschiero, M. N., Palamim, C. V. C., Ortega, M. M., Mauch, R. M., & Marson, F. A. L. (2021). One year of coronavirus disease 2019 (COVID-19) in Brazil: a political and social overview. *Annals of global health*, *87*(1).

Brasil. (2017). Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal - RIISPOA. Diário Oficial [da] União, Ministério da Agricultura, Pecuária e Abastecimento, Brasília, DF..

Brito, L., Lima, V., Carli, M., Mota, J., Leite, N., & Boguszewski, M. (2024). Physical activity, eating and sleep in athletes one year after the covid-19 pandemic. Revista Brasileira de Medicina do Esporte. https://doi.org/10.1590/1517-8692202430022022_0128i.

Christie, W., & Harwood, J. (2020). Oxidation of polyunsaturated fatty acids to produce lipid mediators. *Essays in Biochemistry*, 64, 401 - 421. https://doi.org/10.1042/EBC20190082.

Christophe, M. K. J., Marlène, Y. T., François, N. V. J., Merlin, N. N., Inocent, G., & Mathieu, N. (2024). Assessment of cooking methods and freezing on the nutritional value and health risks of heavy metals in four fish species consumed in Douala, Cameroon. *Heliyon*, *10*(7).

Din, A. U., Han, H., Ariza-Montes, A., Vega-Muñoz, A., Raposo, A., & Mohapatra, S. (2022). The impact of COVID-19 on the food supply chain and the role of e-commerce for food purchasing. *Sustainability*, *14*(5), 3074. https://doi.org/10.3390/su14053074

Djekic, I., Nikolić, A., Uzunović, M., Marijke, A., Liu, A., Han, J., & Tomasevic, I. (2021). Covid-19 pandemic effects on food safety-Multi-country survey study. *Food control*, *122*, 107800.

FAO. (1994). *FAO Fisheries Technical Paper – 340*. Food and Agriculture Organization of the United Nations, Rome.

Ferreira, E. M., da Silva Lopes, I., de Matos Pereira, D., Leôncio, G. G., Pereira, L. E. C., Queiroz, M. L. M., & Costa, F. N. (2020). Alterações sensoriais, microbiológicas e químicas da pescada amarela (*Cynoscion acoupa*) e do peixe-serra (*Scomberomorus brasiliensis*) desembarcados em portos no Maranhão. *Brazilian Journal of Development*, *6*(5), 26662-26676.

Frid, M., Pinheiro-Machado, R., Mayworm Perrut, I., & Pertierra, A. C. (2024). Digital comfort amidst precarity: New middle classes' experience of well-being and hardship in pandemic times in Brazil. *Journal of Consumer Culture*, 14695405241243203.

Fuentes-Amaya, L., Munyard, S., Fernandez-Piquer, J., & Howieson, J. (2015). Sensory, Microbiological and Chemical Changes in Vacuum-Packaged Blue Spotted Emperor (Lethrinus sp), Saddletail Snapper (Lutjanus malabaricus), Crimson Snapper (Lutjanus erythropterus), Barramundi (Lates calcarifer) and Atlantic Salmon (Salmo salar) Fillets Stored at 4°C. *Food Science & Nutrition*, 4, 479 - 489. https://doi.org/10.1002/fsn3.309.

Han, S., Roy, P. K., Hossain, M. I., Byun, K. H., Choi, C., & Ha, S. D. (2021). COVID-19 pandemic crisis and food safety: Implications and inactivation strategies. *Trends in food science & technology*, *109*, 25-36.

Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, *68*(2), 171-176. https://doi.org/10.1111/cjag.12237

Hobbs, J. E. (2021). The Covid-19 pandemic and meat supply chains. *Meat science*, *181*, 108459. https://doi.org/10.1016/j.meatsci.2021.108459

Horta, P. M., de Paula Matos, J., & Mendes, L. L. (2021). Digital food environment during the coronavirus disease 2019 (COVID-19) pandemic in Brazil: an analysis of food advertising in an online food delivery platform. *British Journal of Nutrition*, *126*(5), 767-772. https://doi.org/10.1017/S0007114520004560

IAL. (2008). Instituto Adolfo Lutz. Métodos físico-químicos para análise de alimentos. 4th Ed. São Paulo, Brazil: Instituto Adolfo Lutz, 1020p.

Korkmaz, K. (2023). The Effect of Sodium Bicarbonate Injection on the Physico-Chemical Quality of Post-Harvest Trout. *Foods*, 12. https://doi.org/10.3390/foods12132437.

Lanyero, B., Edea, Z. A., Musa, E. O., Watare, S. H., Mandalia, M. L., Livinus, M. C., ... & Abate, E. (2021). Readiness and early response to COVID-19: achievements, challenges and lessons learnt in Ethiopia. *BMJ global health*, *6*(6), e005581.

López-Moreno, M., López, M. T. I., Miguel, M., & Garcés-Rimón, M. (2020). Physical and psychological effects related to food habits and lifestyle changes derived from COVID-19 home confinement in the Spanish population. *Nutrients*, *12*(11), 3445. https://doi.org/10.3390/nu12113445

Mohammadi, M., Mirza Alizadeh, A., & Mollakhalili Meybodi, N. (2021). Off-flavors in fish: A review of potential development mechanisms, identification and prevention methods. *Journal of Human Environment and Health Promotion*, *7*(3), 120-128.

Parlapani, F. F., Boziaris, I. S., & Drosinos, E. H. (2024). Detection of Fish Spoilage. In *Handbook of Seafood and Seafood Products Analysis* (pp. 560-585). CRC Press.

Pfeifer, D., Rešetar, J., Gajdoš Kljusurić, J., Panjkota Krbavčić, I., Vranešić Bender, D., Rodríguez-Pérez, C., ... & Šatalić, Z. (2021). Cooking at home and adherence to the Mediterranean diet during the COVID-19 confinement: the experience from the Croatian COVIDiet study. *Frontiers in nutrition*, *8*, 617721. https://doi.org/10.3389/fnut.2021.617721

Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal Brasil. (2017). *Regulamento da Inspeção Industrial e Sanitária de Produtos de Origem Animal.* Diário Oficial [da] União, Ministério da Agricultura, Pecuária e Abastecimento, Brasília, DF.

Sasaki, N., Jones, L. E., & Carpenter, D. O. (2024). Fish consumption and omega-3 polyunsaturated fatty acids from diet are positively associated with cognitive function in older adults even in the presence of exposure to lead, cadmium, selenium, and methylmercury: a cross-sectional study using NHANES 2011–2014 data. *The American Journal of Clinical Nutrition*, *119*(2), 283-293.

Schutz, D. E., Chang, G. W., & Bjeldanes, L. F. (1976). Rapid thin layer chromatographic method for the detection of histamine in fish products. Journal - Association of Official Analytical Chemists, 59(6), 1224–1225.

Toassi, R. F. C. & Petry, P. C. (2021). Metodologia científica aplicada à área da Saúde. (2. ed.). Editora da UFRGS.

Tribst, A. A. L., Tramontt, C. R., & Baraldi, L. G. (2021). Factors associated with diet changes during the COVID-19 pandemic period in Brazilian adults: Time, skills, habits, feelings and beliefs. *Appetite*, *163*, 105220. https://doi.org/10.1016/j.appet.2021.105220

Tutor, A., O'Keefe, E. L., Lavie, C. J., Elagizi, A., Milani, R., & O'Keefe, J. (2024). Omega-3 fatty acids in primary and secondary prevention of cardiovascular diseases. *Progress in Cardiovascular Diseases*, 84, 19-26. https://doi.org/10.1016/j.pcad.2024.03.009

USDA. (2024). *Safe Selection and Handling of Fish and Shellfish.* Food Safety and Inspection Service of the U.S. Department of Agriculture. https://www.foodsafety.gov/blog/safe-selection-and-handling-fish-and-shellfish#:~:text=Keep%20Fish%20and%20Shellfish%20Cold&text=If%20seafood%20will%20be%20used,store%20it%20in%20the%20freezer

Valentim, J., Afonso, C., Gomes, R., Gomes-Bispo, A., Prates, J. A., Bandarra, N. M., & Cardoso, C. (2024). Influence of cooking methods and storage time on colour, texture, and fatty acid profile of a novel fish burger for the prevention of cognitive decline. *Heliyon*, *10*(5).

Zanetta, L. D. A., Hakim, M. P., Gastaldi, G. B., Seabra, L. M. A. J., Rolim, P. M., Nascimento, L. G. P., ... & da Cunha, D. T. (2021). The use of food delivery apps during the COVID-19 pandemic in Brazil: The role of solidarity, perceived risk, and regional aspects. *Food Research International*, *149*, 110671.