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Fish consumption in Brazil: State of the art and effects of the COVID-19 pandemic

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A B S T R A C T

The offer and consumption of fish and other aquatic organisms in Brazil comprise a great complexity of interacting factors, from the origin and production of these goods, to their processing and marketing. Unexpected factors such as the COVID-19 pandemic might contribute for increasing the complexity of such interactions and shift consumption patterns. This study aimed at characterizing the consumption of fish in the Brazilian territory, identifying factors that influence such consumption and investigating how the COVID-19 pandemic affected the country's consumption pattern. A closed and semi-structured questionnaire was applied and gathered responses from 1763 Brazilian participants from all the country's macro-regions, regarding fish consumption and factors affecting it. Data were presented descriptively and analyzed by means of a multivariate approach. Three patterns of fish meat consumption were identified in the study. Northern participants consume this foodstuff in recommended amounts by dietary guidelines in higher proportions than other regions. In general, during the pandemic most respondents did not change their fish consumption (59.7%) and declared that no risks were associated with consuming this foodstuff (65.6%). It was found that the origin of fish is a major driver of consumption, whereas from 49.2% (Southeast and Midwest) to 58.2% (North) of the population would increase their consumption in case the origin of the foodstuff was declared. Fish consumption in Brazil is influenced by multiple factors and it can be stimulated by exploring differences existing among the territory's macro-regions.

1. Introduction

The world supply of fish and other products derived from fisheries and aquaculture grew exponentially over the last decades. The production of fish reached almost 178 million tons in 2020, with approximately 88.5% of this total being destined for human consumption, while the remaining is used for the production of meals, oil and other products (FAO, 2022). Aquaculture production is constantly increasing worldwide and representing a larger share of fish provision year after year. Considering a current world population of 8.0 billion people, the production of fish destined for human consumption represents approximately 20 kg *per capita* per year, which certainly does not reflect in an equivalent rhythm of production and consumption worldwide, as highlighted in the last FAO report (FAO, 2022).

Brazil is one of the largest fish producers in the world and Brazilian aquaculture grows exponentially in the country, which already overcame 860 thousand tons in 2022 (PeixeBR, 2023). Thus, this activity is a relevant part of the provision of fish for the country's population. Even so, the high demands from the domestic market and the fact that the country still exports part of the national production results in a trade deficit in relation to this foodstuff, mostly due to the large volumes of imported fish (Barone et al., 2017). In addition, fish production in Brazil is customarily focused on high-value species and large shares of the production are destined to cities instead of rural, low-income areas where the foodstuffs are produced, leading to consumption deficits by part of the population.

Fish consumption among and within countries is highly variable and affected by distinct factors, such as socioeconomic condition, availability of products and food preferences (Can et al., 2015). In addition, individual factors also accounts for its patterns, as reported by Verbeke and Vackier (2005). According to those authors, people tend to consume higher quantities of fish due to its flavor and health aspect, while the abundance of bones and its eventual high market price constitute negative factors in relation to the consumption of this protein source.

In Brazil, the consumption of fish among the five macro-regions of the country was described by Lopes et al. (2016). The authors reported it

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to be highly different among those geographical areas, with a preference for this meat source in relation to others by the inhabitants of the North region, where more than 70% of the participants of that study declared a preference for fish in comparison to other protein sources. Sartori and Amancio (2012) reported that the South, Southeast and Midwest regions of Brazil consume lower quantities in relation to the national average, with this difference being marked by the availability of fish in distinct regions. Similarly, the supply of fish and related products is a determinant factor for understanding the patterns of fish consumption among regions (Silva et al., 2020).

Considering that the consumption of animal-origin proteins is highly variable among regions and depends on multiple market-related, economic and individual factors (Schneider et al., 2014; Leandro et al., 2018; Ribeiro et al., 2018; Verbeke and Vackier, 2005), studying and updating the data referring to the factors that characterize and influence this consumption is of paramount importance. Furthermore, with the decree of the COVID-19 pandemic in March 2020 by the World Health Organization, the sectors of fisheries and aquaculture suddenly underwent major challenges and in many places, the production was affected. It is likely that the pandemics also reflected in the consumption of products derived from these activities in the country (Kato et al., 2021), as reported by other foodstuffs in other regions (Eftimov et al., 2020; Güney and Sangün, 2021).

Fish industries can greatly benefit from the provision of data regarding fish consumption, as well as policy-makers. Therefore, understanding the population's consumption patterns, which factors affect it and how the industry can explore such factors can enable greater success in decision-making, while increasing the sustainability of the fish industry as a whole. In addition, unexpected occurrences affecting the industry, such as the COVID-19 outbreak brings unprecedented challenges to be overcome, which can be more easily tackled when an overview of the new circumstances are clearly understood. Based on the hypothesis that the COVID-19 pandemic altered the purchase and consumption of fish in Brazil, this study aimed to carry out a survey on fish consumption in the country and characterize its patterns before and after the disease outbreak that affected the country and the world.

2. Material and methods

A semi-structured closed questionnaire was used for data collection, which was presented to the participants in online form, using the Google Forms research management application. The research instrument was disseminated *via* email and social media using the snowball approach, with the aim of reaching out to the highest number possible of participants throughout the country. The survey was made available from April 15 to May 31, 2021. This research was approved by the Research Ethics Committee involving human being of the University Nilton Lins (CEP/NiltonLins), under protocol number CAAE 44407621.1.0000.5015. The only criteria established for participation in this study were the age of participants (under 18 years of age did not participate in data collection), the consent of the participants to make their data available for the elaboration of this study and the signing of the Informed Consent Form.

2.1. Research instrument

The questionnaire presented to the participants consisted of seven questions about social and demographic data, elaborated with the aim of identifying in which macro-region of the country the person was living, how many members lived in the same residence and what was the family's income range. Then, ten questions were presented to the participants on the topic of food preferences, designed with the objective of identifying preferences for different proteins of animal origin between regions, processing and preparation methods, in addition to the frequency of consumption of fish by the participants. Subsequently, the participants were surveyed about their knowledge on the origin of fish they consume in their region. Then, a specific section was designed to assess how the COVID-19 pandemic affected fish consumption by the population. Finally, a last section was composed of three questions to identify the most consumed species in each region. The complete research instrument can be accessed in the Supplementary Material 1.

2.2. Statistical analysis

The data obtained in this study were analyzed by a data scientist in R software with the RStudio integrated development environment (Version 4.1.0, RStudio, Inc.). The functions and packages used were presented as 'function{package}' according to the R programming language. In a complementary way, the data were also analyzed and presented based on the frequency distribution of answers in each outlined question. Thus, a significant part of the obtained results was presented descriptively.

The first step of the statistical analysis was to separate the total set of data in three distinct groups, in order to allow the optimization of analyses according to the aims proposed in the study. The first group of data was named "CONSUMPTION" and gathered questions related the consumption of fish *per se*. The second group of data was called "PANDEMIC", which was composed by the questions related to the possible changes in the patterns of fish consumption throughout the COVID-19 pandemic, while the third group was named "POST-COVID" and gathered questions on possible shifts in the consumption patterns after the pandemic – being presented to participants as the time when the pandemic is decreed as over. The questions that composed each of these groups of data in the statistical analysis are presented in the Supplementary Material 2.

In order to identify profiles among the respondents of the total dataset, a multiple correspondence analysis was performed (MCA; 'MAC{FactoMineR}') with the group "CONSUMPTION", and other MCA was carried out the with groups "PANDEMIC" and "POST-COVID", aiming to investigate the impact of the COVID-19 pandemic in fish consumption and the prospects for change in this consumption. The MCA is a multivariate statistical technique designed to analyze the interdependencies (concurrent and frequent occurrences) among qualitative variables (Agresti, 2007). It is worth mentioning that only the participants who reported themselves as fish consumers were admitted at this stage of the statistical analysis. The data matrices formed by the questions of each dataset were converted into two Burt tables (representing the multiplication of a transposed matrix by its original representation; X'X; 'burt{GDAtools}'). The Burt's table is a union of several contingency tables in a single table, enabling their multiple analysis, and the MCAs were carried out from these tables.

In order to find the profiles exclusively in the "CONSUMPTION" dataset, the individual scores of each participant ('get_mca_ind{factoextra}') from the two first dimensions of the MCA were extracted. The individual score of the MCA is a coefficient that represents the multiple interdependencies among variables for each dimension. The Euclidian distance ('dist'{stats}) between such scores was calculated and submitted to a hierarchical cluster analysis by the 'Ward D' method, and by a visual judgement of the dendrogram, the three largest clusters were determined as profiles ('hclust{stats}'). Then, the individual scores of the MCA were submitted to a K-means cluster analysis for three groups ('kmeans{stats}') and the respondents profile formed by the clusters was included in the Burt table referring to the "CONSUMPTION" dataset.

The Burt tables from both datasets were submitted to the chi-square test ('chisq.test{stats}') to investigate the existence of a non-random relation between lines and columns of the matrix, as well as to extract the residuals (observed minus expected values) that were adjusted and standardized by the z-normal scale (observed value subtracted from the expected value, divided by the residual's square root). When the occurrence of an answer option was increased concomitantly with other response option or group (profile) by the cluster analysis, it was understood and assumed as being a significant interdependency among qualitative variables. Therefore, the residuals standardized by the z-normal scale (z-value >1.96) determined the existence of interdependencies with a 5% significance level, and the greater the distance from the cut-off point established by the z-value, the greatest the magnitude of interdependency (Agresti, 2007).

The interdependencies of the "CONSUMPTION" dataset among the profiles established by the cluster analysis and the response options were used to establish the profiles composition. Similarly, the interdependencies of the questions related to COVID of the "PANDEMIC" and "POST-COVID" datasets with the other response options were used to understand the impact of the COVID-19 pandemic in the current and future fish consumption. Finally, in order to illustrate the interdependencies of interest pointed out by the z-values, bidimensional perceptual maps were created ('fviz_mca_biplot{factoextra}') and convex ellipses were constructed to highlight response options of interest. In addition to the multivariate statistics, a correlation analysis was performed between the responses related product cost and the reduction of consumption during the pandemic. Also, selected data were also presented descriptively in the text and in tables, aiming to facilitate the comprehension of some of the objectives outlined in this study.

3. Results

The survey reached 1802 participants, of which 29 were under 18 years old and were excluded from the dataset, as well as 10 respondents whom, at the end of their participation, opted not to allow the use of the data provided, thus totaling 1763 valid respondents in the study. Of this total, 646 were men, 1019 were women, 8 were non-binary and other 90 participants preferred not to declare their gender identity. In relation to the macro-region that the participants lived in at the time of data collection, 835 (47.36%) were from the Southeast region, 294 (17.57%) from the North region, 232 (13.16%) from the Northeast region, 221 (12.53%) from the South region and 181 (10.27%) from the Midwest region of Brazil (Table 1). The survey was established at a confidence level of 90% and a margin of error of 6%, so that all macro-regions studied would be placed within the same confidence and errors level for the data acquired (see details in Supplementary Material 3).

The average income of the participants was classified according to the data presented by the Instituto Locomotiva (click here (https://g1.globo.com/economia/noticia/2021/04/17/classe-media-encolhe-na-pandemia-e-ja-tem-mesmo-tamanho-da-classe-baixa.ghtml) for seeing the press release, in Portuguese), which divides the population in three classes of household income: lower class who earns between R$262.02 and R$2238.00 (47% of the total population in 2021), average income who earns between R$2917.37 and R$7202.57 and upper class who earns more than R$7202.57 every month (53% of the total population in 2021, put together). Thus, 264 participants were classified as of lower class, 624 of average class and 824 of upper class, while 51 respondents opted not to declare their income. In addition, the level of schooling of the participants was heterogeneous, with 22.6% of the participants not having completed higher education and 77.4% with a higher education degree (Table 2).

Considering the total number of participants and the data on the preference by certain types of animal protein, it was possible to verify that the Brazilian population has a strong preference for bovine meat (44.3%), followed by poultry (27.1%) and fish (14.3%) (Fig. 1A). The region with the highest preference for fish meat was the North region, in which 22.8% of the participants declared that they preferentially consume fish over other meat options. However, bovine meat was chosen with higher frequencies by participants of all regions of the country, varying from 36.6% in the Northeast region to 50.0% in the North. The least preferred option was pork meat, with preferences varying between 3.7% in the North and 10.5% in the Midwest region. Regardless of protein-source preference, the frequency of fish consumption declared by participants across regions was also variable. Fish consumption was defined as "low" when the participants declare to consume fish meat only in special occasions, once or twice a month or once a week, "adequate" when the consumption occurs twice a week, and as "high" when above two times per week, with the latter two categories meeting the world's dietary guidelines (Fig. 1B). These assumptions were based on a report by FAO and the World Health Organization, in which fish consumption is classified based on the nutritional requirements by different populations (FAO/WHO, 2022). Based on the collected data, it was possible to verify that in Brazil, people generally consume low quantities of fish (72.2% of the respondents), while 22.5% consume amounts that meet the dietary guidelines.

Most of the fish consumed by the participants is acquired in supermarkets (over 60% of the respondents in all macro-regions, with an exception of the North region, in which 49.7% declared to purchase fish meat in supermarkets) (Fig. 1C). More than 43% of the participants buy fish in fish markets, apart from the Southeast (28.1%). The least accessed place of purchase is directly from fishermen or in street markets, for which only northern participants have greater preferences for those places, namely 23.5% and 35.0%, respectively. Regardless of the place of purchase, more than half of the respondents declared to know how to identify a fresh fish in the moment of purchase.

The origin of fish meat was another determinant factor for its consumption. In total, 61.7% of the respondents are not aware of the origin of the fish they consume, and 51.9% declared they would increase consumption if this information was disclosed when purchasing this foodstuff (Table 3). In addition, while 32.5% of the participants prefer consuming farmed fish, only 25.0% have a preference for wild-caught fish. Finally, over 92.6% of the participants are either in favor of aquaculture practice or still do not have an opinion about this activity yet. Less than half of the respondents are aware of the origin of the fish they consume, with the lowest proportion found in the Southeast (27.0%) and the highest in the North region (45.6%). Regarding the stated reasons, other than origin, for not increasing fish consumption among the participants, product's cost was the most prominent (48.2% of the participants), then the presence of spines (33.8%) and the difficulty in preparing this foodstuff (24.1%). Only 13.4% of the respondents declared that they did not consume more fish because they did not find

Table 1
Demographics of the Brazilian population and survey respondents, in relation to the total number of habitants, division of the population by gender and estimated population above 18 years old. Data are presented in total numbers and percentages.

	Brazilian population		Survey repondents		Brazilian population by gender (%)		Percentage of the survey respondents by gender		Estimated Population > 18 years old	
	Millions	%	Total	%	M (%)	W (%)	M (%)	W (%)	Millions	%
Brazil	212.65		1763		48.9	51.1	36.5	57.8	190.67	89.6
North	18.58	8.7	294	16.7	50.6	49.4	31.6	57.5	14.72	79.3
Northeast	57.52	27.1	232	13.2	48.4	51.6	43.1	50.0	49.37	85.8
Southeast	89.61	42.1	835	47.4	48.5	51.5	37.5	58.7	84.18	93.9
South	30.36	14.3	221	12.5	49.6	50.4	30.8	62.9	28.12	92.6
Middle-East	16.58	7.8	181	10.3	49.3	50.7	37.6	57.5	14.24	85.9

Brazilian Institute of Geography and Statistics (IBGE) data – resident population by groups of age (databases 6407 IBGE, 2022a); resident population by sex (database 6786 IBGE, 2022b).

Table 2
Demographics data related to the education and income level of the Brazilian population and the respondents of the survey, separated by total population and divided per macro-region. No instruction – NI*; incomplete higher education – IHE; complete higher education – CHE; minimum wage – Mw.

	Illiterate Brazilian population (millions)	Education level of the population > 14 years old (%)			Survey respondents by education level (%)		Average monthly income	Brazilian families monthly income range (%)			Family's monthly income range of survey respondents		
		NI	*IHE*	*CHE*	*IHE*	*CHE*	*R$*	*<1 Mw*	*2–4 Mw*	*>4 Mw*	*< 1 Mw*	*2 a 4 Mw*	*> 4 Mw*
Brazil	(100.5)	4.8	80.8	14.4	(398)	(1361)	2265	20.0	60.0	20.0	4.8 (88)	29.4 (503)	65.8 (1127)
North	9.4 (9.37)	5.2	84.4	10.4	22.6 (117)	77.2 (175)	1644	30.0	60.0	10.0	2.3 (39)	6.3 (108)	8.2 (140)
Northeast	56.6 (56.78)	9.4	80.8	9.8	39.6 (50)	59.5 (181)	1497	30.0	60.0	10.0	0.9 (16)	3.6 (62)	8.6 (147)
Southeast	21.7 (21.68)	2.7	80.0	17.3	2.6 (163)	78.0 (672)	2667	10.0	70.0	20.0	1.1 (18)	11.7 (20)	34.6 (593)
South	7.2 (7.18)	2.7	81.8	15.5	19.5 (38)	80.5 (182)	2556	10.0	70.0	20.0	0.3 (5)	4.2 (72)	8.0 (137)
Middle-East	5.6 (553)	4.2	78.8	17.0	17.2 (30)	82.4 (151)	2565	10.0	70.0	20.0	0.2 (4)	3.5 (60)	6.4 (110)

Brazilian Institute of Geography and Statistics (IBGE) data – Illiterate Brazilian population (2019), population above 14 years old by the education level (2019), Average monthly income (2021) and Brazilian family's monthly income range (2021) were obtained from the IBGE datasets 7111 (IBGE, 2022c), 7128 (IBGE, 2022d), 7437 (IBGE, 2022e) and 7438 (IBGE, 2022f). NI* = only one survey respondent declared to have no education, belonging to the South region, therefore a column with NI participants was excluded from the table. Minimum wage = R$1100.00.

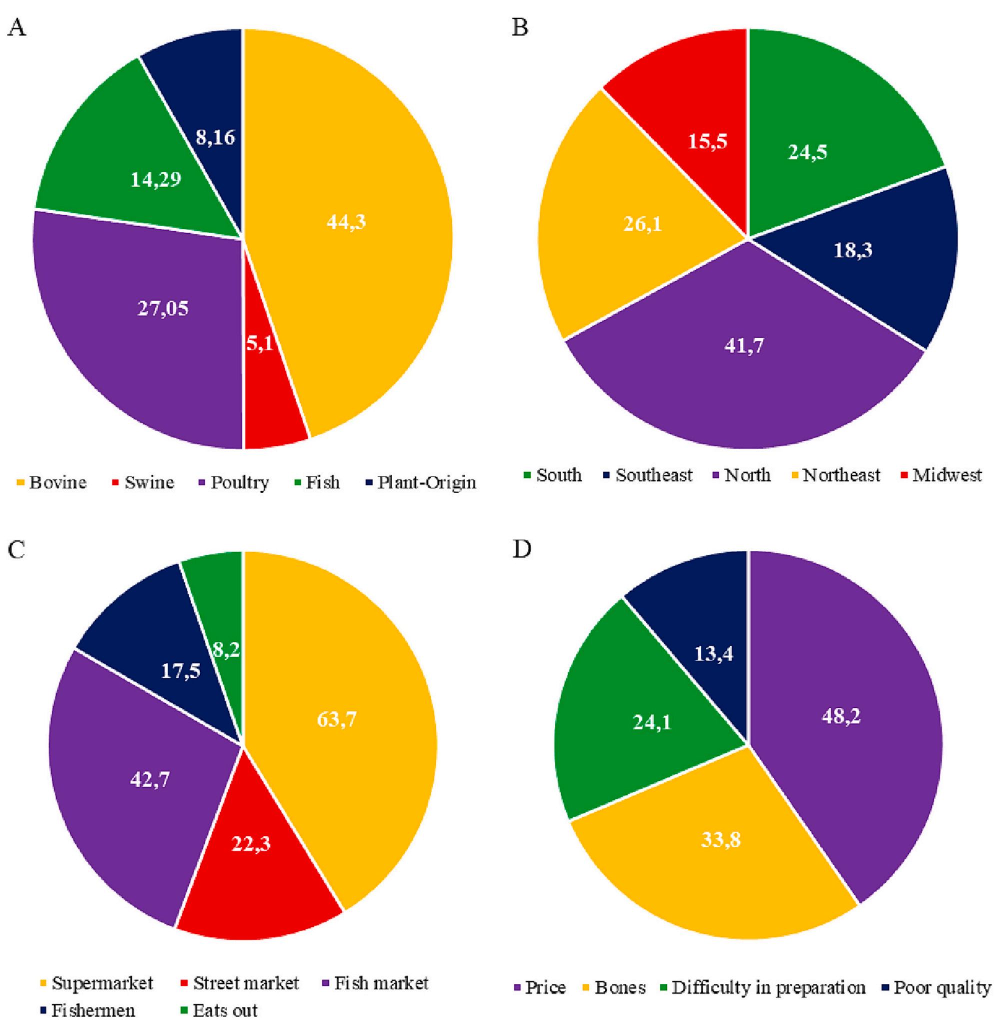

Fig. 1. Preference for type of protein by the Brazilian population in general (A); participants whose fish meat consumption meet the dietary guidelines, per region (B); main places of purchase of fish meat by Brazilian consumers (C); main reasons why research participants identified themselves in not increasing their fish consumption (D). Values presented in percentage.

Table 3
Percentages of the total number of survey respondents (1763) and participants divided per macro-region related to the consumption of fish during the COVID-19 pandemic, and to the origin of fish meat.

	Risk in consuming fish during COVID-19			Change in fish consumption[1]			Acquisition of fish meat throughout the COVID pandemic			Information about origin of fish meat[2]			
	Yes	No	Maybe	Increased	Decreased	Unchanged	Increased	Same quantity	No relation	Known	Unknown	Increase	Unchanged
All respondents	9.2	65.6	25.2	11.2	24.2	59.7	18.2	52.9	24.0	33.6	61.7	51.9	43.3
North	16.3	59.2	24.5	13.6	30.3	52.7	24.5	50.7	21.8	45.6	51.7	58.2	38.4
Northeast	10.3	73.3	16.4	12.9	22.8	58.6	21.6	50.0	22.0	38.4	56.5	57.8	37.1
Southeast	8.3	64.4	27.3	9.9	24.4	60.8	15.1	56.3	23.6	27.1	67.8	49.2	45.9
South	6.8	65.1	28.1	10.4	22.2	60.2	19.0	48.9	25.8	41.6	52.0	50.2	43.9
Middle-East	3.9	72.4	24.3	12.2	17.7	66.9	17.1	29.8	49.2	28.2	68.0	49.2	47.0

[1] Responses related to the change in fish consumption during the COVID-19 pandemic;
[2] responses related to the participants' knowledge on the origin of the fish they consume (known and unknown origin), and participants who would increase or keep their consumption patterns in case the origin of fish was disclosed in the moment of purchase.

the quality of fish in their regions adequate for consumption (Fig. 1D).

Based on the "CONSUMPTION" dataset analyzed by the MCA, it was possible to observe that the two first dimensions of the MCA captured 21.2% of the total variance of the data, making it possible to segregate the individual score of the respondents into three groups. Despite the contribution of all response options to the construction of these profiles, only some response alternatives showed significant interdependencies with the profiles unraveled by the MCA, being considered as elementary factors to distinguish the profiles (Supplementary Material 4). The first profile is made up of participants who mostly consume fish in restaurants or away from home, restricting it to quick preparations such as raw fish or hamburgers, thus it was named "Practical-HI" (people who puts low efforts in preparing food and has high income). On the other hand, the second profile is composed mostly by individuals from the North and Northeast region, with high consumption of fish and willing to buy whole/fresh fish, but for lower prices (between R$5.00 and R$20.00 per kg), preferably purchased in street markets or directly from fishermen. These profile was named "Home-LI", by comprising low-income respondents that consumes fish at home, dedicating time to preparing the foodstuff. Those respondents belonging to the Home-LI profile typically know how to identify a fresh fish. As for the participants identified as belonging to a third profile, they were mostly from the Southeast and Midwest regions, which are willing to purchase fish processed into fillets, fresh or frozen, paying higher values for these products (R $30.00–60.00 per kg), in supermarkets. This third profile was called "Quality-MI/HI", as they have middle-to-high incomes and expect well-processed, high-quality products such as fillets (Supplementary Material 4; Fig. 2B).

When participants were segregated by region in relation to their fish consumption, it was possible to observe a higher trend of increased consumption by the respondents from the North region, with an opposite behavior in relation to the Southeast region (yellow and mild-blue dots in Fig. 2C, revealing a separation between these two regions). On the other hand, consumption frequency (Fig. 2D) did not seem to follow the same pattern (seen in Fig. 2C), with this frequency being related to the proportional number of participants per region who consume fish in distinct frequencies, regardless of their preference or other factors, distributed homogeneously among the macro-regions (high, low and middle frequencies all mixed together as seen in Fig. 2D). Among the participants whose fish meat consumption meet the dietary guidelines according to the established thresholds (Fig. 1B), the North stands out by comprising 40.5% of its respondents, in comparison to 17.2% of the Southeast, 14.9% of the Midwest, 24.6% of the Northeast and 23.0% of the South region, revealing that the frequency of consumption varies less among regions, as displayed in Fig. 2D.

Most respondents who consume fish meat (58.8%) reported that their consumption will not be altered after the pandemics (Fig. 3A-B). On the other hand, participants who declared that they had reduced fish consumption throughout the COVID-19 pandemic had interdependence with the North region, with the fact that they received low wages and were willing to pay up to R$10.00 per kilogram of fish, preferably whole in detriment of processed products (Fig. 3C). The correlation analysis carried out exclusively between the responses related to the price paid per kilogram of fish and the reduction of such consumption during the pandemic revealed a positive correlation between the willingness to pay low prices for fish meat and reductions in the consumption of this foodstuff ($R^2 = 0.732$).

The participants who consumed less fish declared that they might increase their fish consumption after the pandemic is over, whilst the ones who increased their consumption throughout the pandemic already consumed this foodstuff in high amounts, preferentially whole, fresh or frozen and purchased in street markets or directly from fishermen (Fig. 3D). Finally, the participants who declared that there had been no changes in their consumption of fish during the COVID-19 pandemic also reported that they did not reduce the consumption of other meats, and that they do not intend to increase their consumption after the

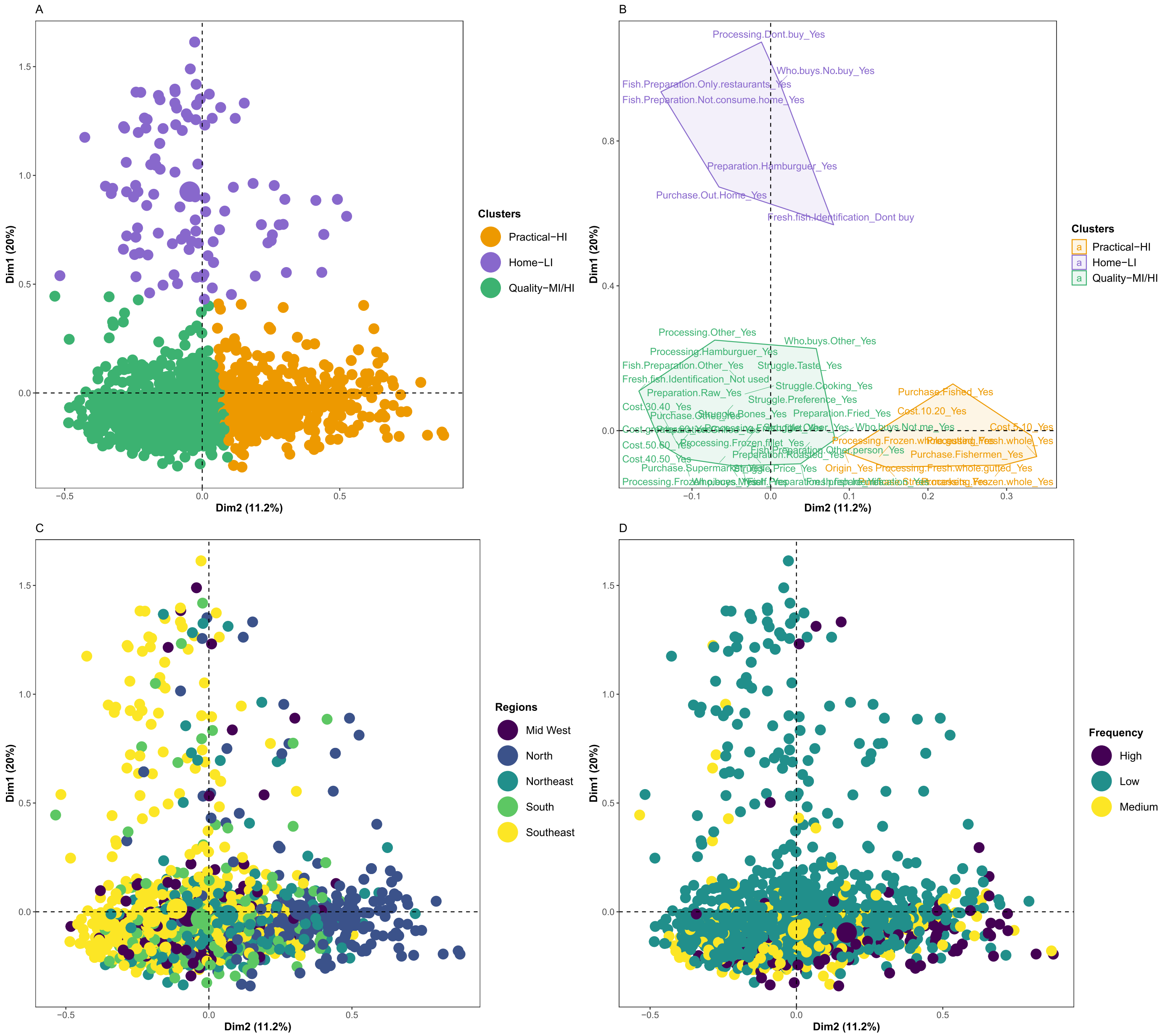

Fig. 2. Bidimensional perceptual map of the multiple correspondence analysis, showing the segregation of respondents into three profiles, considering all questions applied in the questionnaire (A), considering the influential response options in the identified profiles, meaning the survey response options that presented statistically significant interdependencies with the profiles discovered in the MCA (B), the identified profiles for fish consumption segregated by region (C) and by frequency of fish meat consumption (D). Profile groupings were conducted using K-means cluster analysis, applying the individual scores of the first two dimensions of the multiple correspondence analysis.

pandemics (Fig. 3; Table 3; Supplementary Material 5).

Most of the participants that declared the COVID-19 pandemic may have brought risks to the health of those who consume fish meat (9.2% of the total of respondents) were from the North region (many classified in the profile Home-LI), received up to one minimum wage and reduced their consumption of fish. Conversely, the ones who reported that consuming fish meat would not bring risks to human health (65.6% of the participants) or that it could bring some kind of risk (25.2%) were mostly upper-class individuals who consumed fish-based products of higher added value (profiles Quality-MI/HI and Practical-HI), such as frozen fillets (Table 3, Supplementary Material 5).

The future prospects for fish consumption in Brazil according to the collected data reveal a tendency for people who already consumed fish meat in high quantities in their daily lives to even increase such consumption after the pandemic is over, with a significant interdependency for the opinion that the pandemic brought some risk to the health of consumers of this animal protein. The respondents that will not increase their fish meat consumption after the pandemic reported that they are consuming the same amounts of fish during this period, in relation to before the COVID-19 pandemic was decreed, as well as in relation to the consumption of other meat sources. Conversely, participants who had no opinion about this possibility of increased consumption were the ones who are not used to buying fish and consume this food source outside their homes (Supplementary Material 5). Among the five macro-regions of Brazil, participants from the North declared in a higher frequency than other regions (30.3%) to have consumed less fish meat during the pandemics.

Regarding the types of fish consumed by the participants of the study, 8.4% of the respondents declared consuming exclusively freshwater fish, being mostly from the North (29.9% of that region's

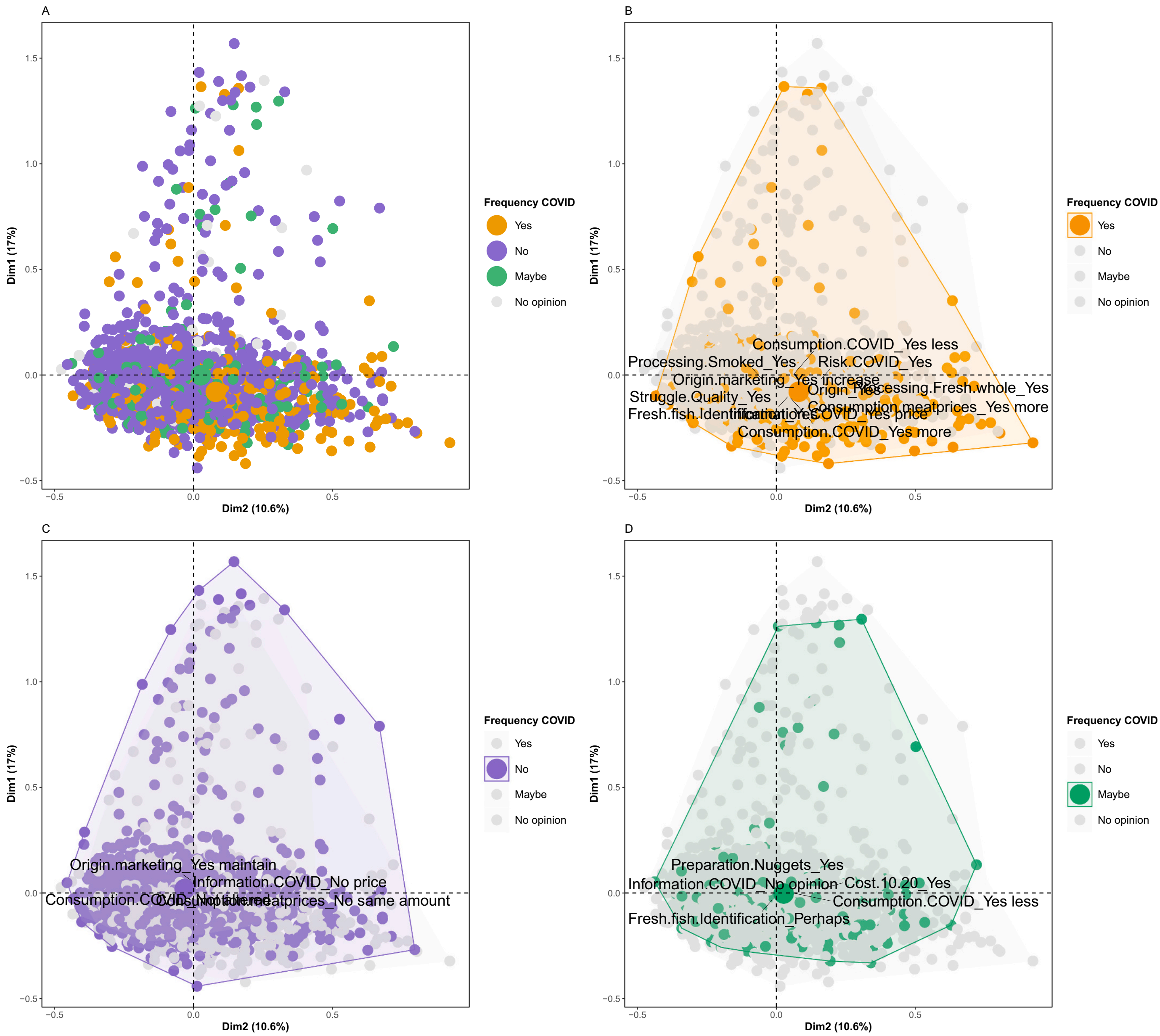

Fig. 3. Bidimensional perceptual map of the multiple correspondence analysis showing the interdependencies related to the impact of the COVID-19 pandemic in the consumption of fish by the Brazilian population. (A) representation with all response options separated by colors; (B) highlighted in yellow are the participants who declared that the consumption remained unaltered throughout the pandemic; (C) highlighted in purple are the ones who consumed less fish during the pandemic; (D) highlighted in green the respondents who consumed more fish in that period. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

participants) and only 2.8% declared to consume exclusively marine fish. The most consumed freshwater species were tilapia (*Oreochromis niloticus*) (consumed by 76.0% of the participants), followed by tambaqui (*Colossoma macropomum*) with 26.8% of the respondents and pacu (*Piaractus mesopotamicus*) with 16.9% of the respondents claiming to consume it. The most consumed marine species are salmon (*Salmo salar*) (61.0% of the participants declared consuming it), tuna (46.0%), cod (35.7%) and sardines (32.5%). It was noticed that 41.3% of the participants that consume fish prefer aquaculture-derived products in comparison to 26.2% of the ones who prefer fish from extractive fisheries (other 26.0% declared not having any preference in relation to the origin of the products). Of the people who prefer fish from aquaculture, the smallest proportional share was from the North region (22.4%) and the largest from the Southeast (36.3%), and of those who prefer fish from fisheries, the North region stood out positively with 39.1% of the respondents, while in the Southeast region it had the lowest preference proportional to the number of participants in that region (18.3%).

4. Discussion

The fact that the survey was carried out exclusively online may have influenced the composition of responses from participants considered to be of middle and upper class and with high level of education (Table 2), seen that the internet access in Brazil is not egalitarian and many low-income families do not have such access (Schiavon and Moreira, 2022). This is an established, well-known limiting factor in studies that are based on the application of questionnaires, especially throughout the COVID-19 pandemic and the consequent mobility limitations due to social isolation. However, as reported in the studies of Lopes et al. (2016) and Hassen et al. (2021), data which are collected exclusively online are valid and enable relevant overviews of the subject addressed. In addition, it is noteworthy that all macrorregions of Brazil are historically unequal in terms of income distribution. For instance, according to Trovão (2020), the macro-region with the highest share of the population that possess the lowest incomes in the country is the Northeast region (53.5% of the poorest people of Brazil lives in that region), followed by Southeast and North. However, that author highlighted that income distribution inequalities in Brazil are extremely pronounced, so for instance the Southeast region holds the 10% richest people in the country, while also accounts for more than 20% of the poorest populations. Due to such a heterogeneity in the country's population, it is challenging to access all social groups in one single study; nevertheless, once considering details of the data collection and the existing limitations, survey-acquired data is still highly valuable for understanding the dynamics of a population with subjects such as food consumption.

The separation of participants into three profiles of fish meat consumption enabled an effective visualization of how the consumption of this foodstuff in Brazil is taken (Fig. 2A-B). The general preference of the respondents in relation to animal proteins was clearly for bovine meat, including in the North region, partially contradicting the results presented by Lopes et al. (2016), seen that among the regions studied, the participants from the North demonstrated the greatest proportional preference for fish meat in comparison to other macro-regions. Complementarily, those participants consume quantities that meet the dietary guidelines of fish meat in the highest proportion (40.5%) in relation to the other four regions studied, evidencing a greater preference for this type of protein. According to Can et al. (2015), the quantity and frequency of consumption of fish meat are positively correlated with the level of education and individual income. Maciel et al. (2016) identified relations between fish consumption and the perceptions about the foodstuff and its preparation, preservation and form of presentation. Our results suggest that the profile of consumption is highly complex and involves several variables beyond income and education, but also cultural values, options of purchase site, type of processing, final value of products and random events, such as the decree of a pandemic.

It was possible to observe that the profiles of fish consumption in different regions in Brazil do not follow a well-established pattern among the five macro-regions studied (Fig. 2C), even considering a wide range of variables influencing this consumption. Feil et al. (2020) evaluated the consumption of varied food items derived from organic productions in Brazil (which tend to be more expensive in comparison to conventional productions), and verified that the consumption of these products is typically not correlated with socioeconomic characteristics of the population, as well as with the demographic profiles of the country. Those results help understanding the data obtained in the present study, even when dealing with a different and less selective foodstuff. In fact, it is noteworthy that the questions that outlined these three profiles belonged to distinct subjects and were related with factors beyond the socioeconomic profile of participants, such as the way of preparing fish, place of purchase and consumption, among others (Fig. 2B).

The decree of the COVID-19 pandemic does not seem to have changed the intention of consumption of fish meat among the participants in general, with the exception for the North region, which had the highest frequency of respondents who declared to have been consuming lower amounts of fish meat during the COVID-19 outbreak (30.3%). This lower frequency, declared mostly by low-income respondents, was positively correlated as well with the willingness to pay low prices for fish (between R$5.00 and R$10.00). It is noteworthy that the fish processing plants in the North, Northeast and Midwest regions were not strongly affected during the pandemics, and were able to maintain the provision of fish meat in formal markets during 2020 and 2021 (Chicrala et al., 2021). Therefore, it is feasible to hypothesize that such a lower consumption in the North, which has a large fish marketing network in informal markets (*e.g.,* street markets and directly from fishermen), was likely caused by the negative effects of the pandemics in those informal markets. A reduction in people's income throughout the pandemic affected the way they interacted with food (Profeta et al., 2021), corroborating our findings for the North region. Those participants however, mostly of low-income, declared that they might increase their consumption after the pandemic. Chenarides et al. (2021) applied a questionnaire aiming to understand how the consumption of foodstuffs in the United States was happening throughout the COVID-19 pandemic, and observed that almost 75% of the respondents declared that they were consuming whatever was available at the places of food purchase, with no choice criteria. Eftimov et al. (2020) reported a great shift in the pattern of food consumption in the beginning of the pandemic by the world population, directed towards the consumption of grains and seeds, canned foodstuffs and ready-to-eat meals, to the specific detriment of fish consumption. In the study by Hassen et al. (2021) performed in Russia, the authors also reported a strong trend of change in the way people purchased their food throughout the COVID-19 pandemic, in addition to the strong preference for non-perishable foodstuffs with long shelf life. Thus, we also hypothesize that due to the interruption of informal fish markets, the population would need to purchase fish meat from the unaffected formal markets, but due to their higher prices, the population could not access those products during the pandemics.

The participants who declared that they had not changed their consumption or even consumed more fish during the COVID-19 pandemic were mostly people with higher incomes and greater access to information, while lower-income individuals declared to think that risks could be associated with the consumption of fish meat during that period (Fig. 3, Supplementary Material 5). These result brings an alert for the fish production and processing industries, regarding the great need to disseminate information on the safety of consuming fish in periods such as the COVID-19 pandemic. In addition, it is evident that information on the origin of fish is a very relevant manner for the fish consumption by the Brazilian population, as it could guarantee increased consumption, as reported by Claret et al. (2012).

In the study by Velebit et al. (2021), the authors reported that the SARS-CoV-2 virus is adsorbed on the surface of frozen meats, but highlighted the lack of evidence that COVID-19 can be contracted through food consumption. Bailey et al. (2022) also demonstrated the survival of the virus during 30 days in salmon meat preserved at 4 °C and frozen at −20 °C. Similarly, Dai et al. (2021) confirmed the survival of the SARS-CoV-2 virus in salmon preserved at 4 °C for seven days, proving that this foodstuff could indeed serve as a bridge for the virus transmission, making it necessary to carefully inspect the products before those are marketed. Even though there is no evidence of contamination by the virus that causes COVID-19 *via* ingestion of contaminated food, and considering such even to be unlikely to happen (Godoy et al., 2021), this issue becomes delicate when it comes to consumer opinion, which can cause great losses to the market if the consumption is reduced. Our results point to a concern by part of the respondents, evidencing the need for investment in dissemination of data in Brazil on this subject.

Brazil is a country with continental dimensions and very significant differences between regions in terms of food production and consumption. Extractive fisheries is an activity performed for many decades in the country, while aquaculture is in constant growth, with the country occupying the thirteenth position in the ranking of world production (FAO, 2022). However, fish consumption by the Brazilian population (around 9 kg per person per year) is still considered low in relation to the rest of the world (FAO, 2022), with less than half of the fish consumed in the country deriving from aquaculture (PeixeBR, 2022). Our results point that such a low consumption occurs in specific regions of the country, while in the North region for instance there is a great share of inhabitants that consume this foodstuff in quantities that meet dietary guidelines (Fig. 1B). Brazilian aquaculture has an enormous potential to continue growing and the understanding of how the consumption of fish and other aquatic organisms occur can collaborate with this growth. However, as highlighted by Valenti et al. (2021), regional differences must be respected and taken into account, and both the public policies and rural extension actions should always consider the diversity of issues that are related to this market advance.

The global increase in fish farming is a trend that has also been observed in developing countries such as Brazil. However, as highlighted by Golden et al. (2016), it does not necessarily mean that its population is being benefited from it. Brazil's aquaculture production is highly focused on the production of expensive, invasive species such as Nile tilapia, which currently has elevated prices (R$45.00 – R$80.00 per kg) in the country (especially in comparison to wild-caught species, sometimes found by R$5.00 - R$10.00 per kg). This results in a limited access by most of the population because it targets wealthier consumers, mostly located in cities, rather than people living in rural areas, thus hampering the achievement of food security in such areas (Thilsted et al., 2016).

The Brazilian fish production is highly dependent on an invasive species, Nile tilapia (*O. niloticus*), which has a major impact in the world aquaculture (PeixeBR, 2023). Consequently, this is the most consumed freshwater species in the country according to the results presented herein, followed by the tambaqui (*C. macropomum*) and pacu (*P. mesopotamicus*) These two other species, native to the Brazilian fauna, have enormous productive potential and could certainly gain more space in the consumption patterns of the population if they were more studied and especially disseminated in the consumers' market (Hilsdorf et al., 2022). Regarding saltwater species, the Brazilian consumer has a great preference for salmon, tuna and sardines. Salmon is one of the most produced and consumed fish worldwide (Tacon, 2019), and in Brazil it is associated with a high marketing price. Curiously, this fish is highly consumed in the country and seem to have had low impacts in relation to its marketing throughout the COVID-19 pandemic, as reported by Straume et al. (2022). The other two highly consumed species (tuna and sardines) are fished in Brazilian waters and are highly valorized both in fisheries (*e.g.*, use of sardines as fishing bait) and by the consumers market itself.

It is worth mentioning the importance of the discussion about the origin of fish directed to the consumer market. In this study, it was possible to verify that the largest proportional number of participants who had knowledge on the origin of the fish they consume was from the North region, in comparison to only 27.0% of the Southeast respondents. This data shows a big difference between two regions of high fish consumption on Brazil; however, regardless of the region, most of the respondents declared that they would increase their consumption if they were informed on the origin of the product, especially considering that 61.4% of the participants are normally not aware about the origin of the fish they are consuming. The origin of fish and fish-based products was reported as one of the most relevant factors for the acquisition of these foodstuffs by Carlucci et al. (2015), followed by method of production. According to the answers obtained in this study, the participants are mostly favorable to the practice of aquaculture and prefer consuming farmed fish in detriment of wild-caught fish, reinforcing even more the potential of aquaculture in Brazil.

In addition to elucidating the origin of fish as an important factor to increase the consumption of this foodstuff in Brazil, another factor may have great relevance in this perspective, which is the aspect of healthiness and sustainability of consuming fish and fish-based products, with these factors being much relevant with regard to the choice of this foodstuff (Li et al., 2020). According to Bianchi et al. (2022), the consumption of both reared and wild-caught fish is directly related with a lower individual environmental impact in comparison to the consumption of other meats, especially red meat, while increasing nutritional gains in comparison to other protein sources. Considering the great attention and acceptance of the Brazilian population in relation to organic food, which many times are costly but less impacting (Feil et al., 2020), the healthiness and sustainability can be highlighted as well for fish products, in order to stimulate its consumption, which according to the results presented herein, might be possible.

5. Conclusions

Fish meat is not the preferred protein source by the Brazilian population, and its consumption occurs in all macro-regions of the country in a highly distinct manner. We identified three profiles of fish consumers that could assist decision-making by both the industry and public policies aiming to stimulate most sustainable practices such as aquaculture production, as well as fish consumption in general. These profiles are composed by people that look for practicality and are willing to pay higher prices for fish meat (Practical-HI), by groups that have lower incomes and purchase fish without being processed at lower prices (Home-LI) and people who look for highly processed fish of high quality (Quality-MI/HI profile).

While the North region presents the highest consumption in comparison to other regions, the Midwest region has the lowest. Multiple variables were identified as relevant characteristics of this consumption, as well as the reasons why people do not increase their consumption, changes in the consumption patterns due to the COVID-19 pandemic and future perspectives on this subject. Factors such as price, quality of fish, lack of information on its origin and presence of spines hamper the possibility of increasing consumption; thus, this data is valuable for directing public policies and market practices in the sectors of fisheries and aquaculture in Brazil.

The COVID-19 pandemic has affected the consumption of fish by the Brazilian population in different ways, with some respondents increasing their consumption due to increasing prices of other protein sources, while others reduced their consumption due to limited access to the foodstuffs, but overall the fish consumption in Brazil remained the same. A share of the lower income respondents, especially from the North, consumed less fish meat during the COVID-19 pandemic.

The majority of respondents were not aware of the origin of the fish they consume, and they declared that they would increase their consumption if the origin of the product was clear in the moment of purchase. In addition, respondents are generally in favor of aquaculture and a higher preference for farmed fish was observed in relation to wild-caught fish. The existence of data on the origin of marketed fish is necessary and could ensure the safety of fish consumption, while increasing farmed-fish consumption in Brazil. Even with a mild reduction of fish consumption throughout to the COVID-19 outbreak was seen in some places, an optimistic scenario was identified on the future consumption once the pandemic is over. Finally, the results presented herein put together (profiles of fish consumption, patterns and preferences, and the general overview for the near future) can assist in the decision-making by the Brazilian fish industry and policy-makers.

Author contributions

IGL: conceptualization, data collection and curation, data analysis, methodology, project administration, validation, writing original draft and reviewing.

TMF: conceptualization, data collection and curation, methodology, project administration, funding acquisition, resources, validation, writing original draft and reviewing.

CRediT authorship contribution statement

Ivã Guidini Lopes: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. **Thiago Mendes de Freitas:** Conceptualization, Data curation, Methodology, Project administration, Funding acquisition, Resources, Validation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data link for the datasets, published in Mendeley Data, can be found in https://data.mendeley.com/datasets/n369np4rk6/1.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aquaculture.2023.739615.

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