Advance in Biological Research, 2023, 4(1), 1-8
https://www.hillpublisher.com/journals/abr/
ISSN Online: 2635-0319

DNA Barcoding Identification Exposes Mislabeled Salted Cod (*Gadus spp.*) Products Retailedat Porto Alegre, Brazil

Natália da Conceição Noll[1], Michele Bertoni Mann[2], Ana Paula Guedes Frazzon[3], Jeverson Frazzon[1,*]

[1]Laboratory of Biochemistry of Microorganisms, Institute of Food Science and Technology (ICTA), Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul (RS), Brazil.
[2]Institute of Biosciences (IB), Federal Universityof Mato Grosso do Sul (UFMS), Campo Grande, Mato Grosso do Sul (MS), Brazil.
[3]Department of Microbiology, Institute of Healthy Basic Science (ICBS), UFRGS, RS, Brazil.

How to cite this paper: Natália da Conceição Noll, Michele Bertoni Mann, Ana Paula Guedes Frazzon, Jeverson Frazzon. (2023). DNA Barcoding Identification Exposes Mislabeled Salted Cod (*Gadus spp.*) Products Retailedat Porto Alegre, Brazil. *Advance in Biological Research*, 4(1), 1-8.
DOI: 10.26855/abr.2023.06.001

Received: December 28, 2022
Accepted: January 26, 2023
Published: March 1, 2023

Corresponding author: Jeverson Frazzon, Laboratory of Biochemistry of Microorganisms, Institute of Food Science and Technology (ICTA), Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul (RS), Brazil.

Abstract

Fish fraud is a worldwide problem, mainly due to the characteristics of the production chain, which includes prior processing of fish on the ship, in addition to the morphological similarities between species. Salted cod, an important commodity imported into Brazil, is one example in which the fish ends up being morphologically mischaracterized due to both salting processes used for its conservation, and, later, due to handling by retailers. Thus, the aim of the present study was to evaluate legal aspects related to commercialization of salted cod, through the evaluation of sale presentation, label information and species involved. Collected samples were handled by retailers previously to sale. DNA barcode sequencing was used as a molecular tool in order to identify species traded under the name "cod". The target was the mitochondrial cytochrome c oxidase gene (COI). Labeling problems were observed in 91% of the analyzed products and species substitution was present in 13% of collected samples. Continuous inspection actions on products sold by retailers are important to reduce the occurrence of fraud in salted fish products.

Keywords

COI, Consumer, Fish products, Mislabeling, DNA barcode, Cod, Retailers

1. Introduction

Brazil is one of the biggest consumers and importers of cod (bacalhau in Portuguese language), perhaps due to the influence of Portuguese colonization, and since Portugal is one of the main cod exporting countries. However, the expression "bacalhau" (cod) is commonly used to designate dried salted fish products. This expression ends up confusing the consumers. Thus, according to Brazilian Normative Instruction nº53, of 2020, of the Ministry of Agriculture, Livestock and Supply (MAPA), only fish of the species *Gadus morhua* (Atlantic cod), *Gadus macrocephalus* (Pacific cod) and *Gadusogac* (Greenland cod) can receive the name cod [1] Other fish prepared using this technique may mislead the consumer, for example, the preparation of the native fish pirarucu (Arapaima gigas), which is known as "Amazonian cod" [2]. Dried salted cod marketed in Brazil originates mainly from Norway and Portugal, and in 2021, this was the 5th most imported seafood product [3]. Due to the high labour costs, Norway usually exports whole flattened dried salted cod [4], resulting in the need for handling and portioning by the retailer.

Fish substitution fraud is documented in several studies and can be as significant as 30% in some countries [5]. Mislabelling is associated with several factors, including economic fraud, illegal trade in protected species or even unintentional errors caused by lack of traceability [6]. Although studies carried out in Brazil have shown a high incidence of labelling errors in dried salted cod products offered for sale [7-9], data from MAPA's Official Fish Fraud Control Subprogram, using DNA barcoding, indicate that exporting traders are not responsible for this kind of fraud [10], which raises doubts about the fulfilment of the links in the chain, after the importation.

Thus, the aim of present study was to collected data that could elucidate aspects related to dried salted cod offered to the final consumer. What legal aspects are violated during the sale of dried salted cod, how often mislabelling occurs and, which species are used as substitute.

2. Materials and Methods

2.1 Sample Collection

Forty-five salted fish products labelled as cod were purchased from 15 distinct sellers, covering supermarkets, specialized food emporiums, the city's public market and one importer distributor, from March 2021 to January 2022. Two criteria were considered for sampling: (a) the sample was shredded, and (b) the sample has been portioned by retailers. The purchase spots reached all the different retailers that portion salted cod themselves in Porto Alegre. To avoid collecting the same product batch, the time between samples from the same retailer was 60 days or more. All samples were desalted through immersion in filtered water for 48 h, and the water was changed every twelve hours. Desalted tissues were then frozen at -20 ℃ until DNA extraction. The samples were named with numbers from 1 to 15 representing the retailer and a letter from A to C. Table 1 brings the information available about the samples at purchasing time.

2.2 Molecular Identification

DNA extraction was conducted using the E.Z.N.A.® Tissue DNA kit (Omega Bio-Tek, 2019) following the manufacturer's instructions. The product was quantified using Qubit Fluorometer (Thermo Fisher Scientific®). A fragment of approximately 650 base pairs (bp) of the COI mitochondrial gene was amplified using the degenerated primers FISHCO1LBC: 5' – TCA ACY AAT CAY AAA GAT ATY GGC AC – 3', and FISHCO1HBC: 5' – ACT TCY GGG TGR CCR AAR AAT CA – 3' [11]. The amplifications were carried out in a 25 μL reaction consisting of 1,25 μL of each primer (10 μmol), 2,50 μL of buffer (10X), 1,0 μL of MgCl2 (2 mM), 0,50 μL of dNTP (0,2 mM), 0,20 μL of Taq polymerase (1 U), and 14 to 34 ng/μL of DNA template. PCR conditions comprised an initial denaturation step of 94 ℃ for 12 min, followed by 40 cycles of 30 s at 94 ℃, 30 s at 64 ℃ and 30 s at 72 ℃, and a final step of 72 ℃ for10 min [9]. The PCR products were verified by electrophoresis in an agarose gel and sequenced by Sanger method at the Biotechnology Center (CBiot) from the Federal University of Rio Grande do Sul.

2.3 Data Analysis

DNA sequences were compared to the Barcode of Life Data System (BOLD) database for molecular identification. Top matches recovered from searches using the Species Level Barcode Records on BOLD identification website were annotated, considering a threshold of 99% for species identification. Latin scientific names were associated to the corresponding market names following the official Brazilian governmental regulatory list of species [12].

3. Results and Discussions

3.1 Sale Presentation and Label Evaluation

The Brazilian Normative Instruction n º1 of 2019 of MAPA determines that salted dried fish must be marketed properly packaged and kept under refrigeration conditions. In turn, the label must bring the common name of the fish used and the expression "salted" or "dried salted", according to the product's moisture content. Furthermore, when the fish used are from Salmonidae or Gadidae families, Latin scientific names must be present [13].

Popularly, for Brazilian consumers, the city's public markets are considered the best places to buy the higher quality fish, including salted cod [4]. However, regarding the exposure for sale, all of the 12 (26%) samples purchased from retailers in the public market of the city of Porto Alegre were neither packaged nor chilled, also, one (2%) sample from a specialized emporium was packaged placed at room temperature. All of them contrary to legal provisions. In addition to Brazilian regulations, the Norwegian Food Research Institute (NOFIMA) and label from original producer's packaging advise on the need for refrigeration for proper conservation and product's safety.

Table 1. Sample characteristics and label information available at purchase

Sample Id	Retailer Classification	Selling Exposure	Price (US$/Kg)	Product Description	Species Expected
1A	Public Market	B*, RT*	26,84	BACALHAU PORTO	*G. morhua*
1B	Public Market	B*, RT*	22,41	BACALHAU PORTO	*G. morhua*
1C	Public Market	B*, RT*	23,96	BACALHAU PORTO	*G. morhua*
2A	Public Market	B*, RT*	23,66	BACALHAU PORTO	*G. morhua*
2B	Public Market	B*, RT*	22,41	BACALHAU PORTO	*G. morhua*
2C	Public Market	B*, RT*	23,96	BACALHAU PORTO	*G. morhua*
3A	Specialized Emporium	P*, RT*	12,62	BACALHAU DA NORUEGA	*G. morhua*
3B	Specialized Emporium	P*, Re*	16,40	BACALHAU DESFIADO 2 ª	*G. morhua*
3C	Specialized Emporium	P*, Re	18,55	BACALHAU DESFIADO 2 ª	*G. morhua*
4A	Public Market	B*, RT*	17,70	GADUS MORHUA	*G. morhua*
4B	Public Market	B*, RT*	16,76	APARAS GADUS MORHUA	*G. morhua*
4C	Public Market	B*, RT*	18,63	APARAS GADUS MORHUA	*G. morhua*
5A	Public Market	B*, RT*	23,84	BACALHAU PORTO	*G. morhua*
5B	Public Market	B*, RT*	22,41	BACALHAU PORTO	*G. morhua*
5C	Public Market	B*, RT*	23,96	BACALHAU PORTO	*G. morhua*
6A	Supermarket	P*, Re	26,79	BACALHAU PORTO	*G. morhua*
6B	Supermarket	P*, Re	31,61	BACALHAU PORTO	*G. morhua*
6C	Supermarket	P*, Re	33,59	BACALHAU PORTO	*G. morhua*
7A	Supermarket	P*, Re	25,05	BACALHAU PORTO	*G. morhua*
7B	Supermarket	P*, Re	31,63	BACALHAU PORTO	*G. morhua*
7C	Supermarket	P*, Re	33,15	BACALHAU PORTO	*G. morhua*
8A	Supermarket	P*, Re	13,99	BACALHAU SALGADO MACRO	*G. macrocephalus*
8B	Supermarket	P*, Re	18,01	BACALHAU PORTO MORHUA	*G. morhua*
8C	Supermarket	P*, Re	14,96	BACALHAU IMPERIAL	*G. morhua*
9A	Importer Distributor	P*, Re	18,67	BACALHAU IMPERIAL	*G. morhua*
9B	Importer Distributor	P*, Re	24,34	BACALHAU SALGADO MACRO	*G. macrocephalus*
9C	Importer Distributor	P*, Re	18,59	BACALHAU PORTO MORHUA	*G. morhua*
10A	Supermarket	P*, Re	16,11	BACALHAU PORTO MORHUA	*G. morhua*
10B	Supermarket	P*, Re	19,99	BACALHAU IMPERIAL	*G. morhua*
10C	Supermarket	P*, Re	18,74	BACALHAU PORTO MORHUA	*G. morhua*
11A	Supermarket	P*, Re	31,68	BACALHAU PORTO	*G. morhua*
11B	Supermarket	P*, Re	31,27	BACALHAU PORTO	*G. morhua*
11C	Supermarket	P*, Re	33,23	BACALHAU PORTO	*G. morhua*
12A	Supermarket	P*, Re	29,05	BACALHAU PORTO	*G. morhua*
12B	Supermarket	P*, Re	31,27	BACALHAU PORTO	*G. morhua*
12C	Supermarket	P*, Re	33,59	BACALHAU PORTO	*G. morhua*
13A	Supermarket	P*, Re	27,78	BACALHAU PORTO	*G. morhua*
13B	Supermarket	P*, Re	31,12	BACALHAU PORTO	*G. morhua*
13C	Supermarket	P*, Re	23,58	BACALHAU PORTO	*G. morhua*
14A	Supermarket	P*, Re	26,70	BACALHAU PORTO	*G. morhua*
14B	Supermarket	P*, Re	31,43	BACALHAU PORTO	*G. morhua*
14C	Supermarket	P*, Re	33,15	BACALHAU PORTO	*G. morhua*
15A	Supermarket	P*, Re	30,99	BACALHAU PORTO	*G. morhua*
15B	Supermarket	P*, Re	31,38	BACALHAU PORTO	*G. morhua*
15C	Supermarket	P*, Re	33,28	BACALHAU PORTO	*G. morhua*

*B**- in bulk; *P**- packaged; *RT**- room temperature; Re*- refrigerated

Only four (9%) samples were labelled according to the Brazilian legislation. Of these, three samples were acquired from an importer distributor (9A, 9B and 9C) and one sample was obtained from a supermarket (8A). Table 2 brings the summary of results of the presentation and label evaluations and Graphics 1 and 2 bring the percentage of compliance of each evaluation. Both selling exposure and labelling problems raise questions regarding the frequency and rigor of inspections and health education actions that are directed at salted cod, once these aspects are easy to identify and available at retailers.

Inspection actions and the existence of regulatory directives are effective in inhibiting mislabelling, consistent with European findings, in which retail establishments are more rigorously supervised than restaurants and showed minors fraud rates [14].

3.2 Species Identification

Of the 45 samples analysed, 29 were successfully identified at the species level. Of the 16 samples left, three of them had successful amplification, but were not able to be identified at sequencing, and the other 13 samples did not have successful amplification. An attempt of amplification was carried out with 18S primer, also with no success, which may indicate DNA degradation, presumably due to the salt used in product preparation [14].

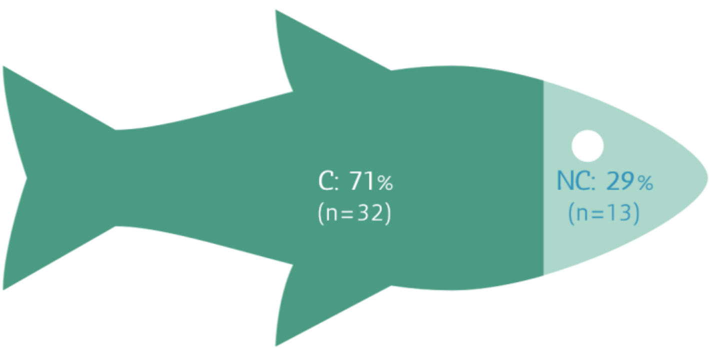
From the 29 samples successfully identified, 25 were identified as *G. morhua* or *G. macrocephalus*, therefore complying to the use of the expression "bacalhau" (cod). However, one sample (10C) was identified in the sequencing as *G. macrocephalus*, but was labelled as "Codfish Porto Morhua" and was expected to be *G. morhua*. While species replacement has been confirmed, a question is asked about intentional fraud, since the price of the mislabelled sample (US$ 18,74) has the same average price of samples declared and confirmed as *G. macrocephalus* (US$ 19,17).

One of the possible reasons for the accidental mislabelling is the fact that two (or more) species share common names, leading the food handler to believe that it is the same product [15]. In this specific case, where both species involved, the declared and the used, can be called "cod". Three other samples were identified as fraudulent. 6A, 10A and 10B. The species used were actually *Molvamolva*, *Pollachiusviren*s and *Brosmebrosme*, respectively. Table 3 brings all the sequencing results for the samples and Graphic 3 brings the summary of results on species identification compliance.

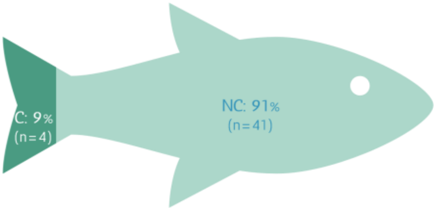
The incorrectly labeled samples 10A, 10B and 10C originate from the same supermarket and sample 6A from another. In both places the fish used for substitution were also sold with the correct label, raising, once again, questions about the intention of fraud. Regarding accidental labeling, all the other 14 retailers sold cod and other North Atlantic salted products, even so there was no substitution of species in their products. Thus, it can be inferred that, although it is possible that the labeling errors found do not have the real intention of economic fraud, there is, at the very least, an omission on the part of the responsible retailers, with regard to the training of employees on identification and product labelling.

Studies have showed lack of regulation about common names and scientific Latin names allowed for commercially important species, as well as when the product's label does not include the scientific Latin name of the species used are facilitating factors for species substitution [5, 16]. Brazilian legislation on the commercialization of salted cod contemplates these two issues, reinforcing, once again, the need to enforce the provisions of legislation.

Research carried out in Brazilian retailers found a replacement rate of salted cod of 10% [9], 22% [8] and 30% [7]. The differences between the findings, including those of the present study, suggest that more control measures, population information and research on the subject are still needed.



Graphic 1. Percentage of compliant and non-compliant samples regarding temperature of selling presentation.



Graphic 2. Percentage of compliant and non-compliant samples regarding label information.

Table 2. Summary of presentation and label evaluation results

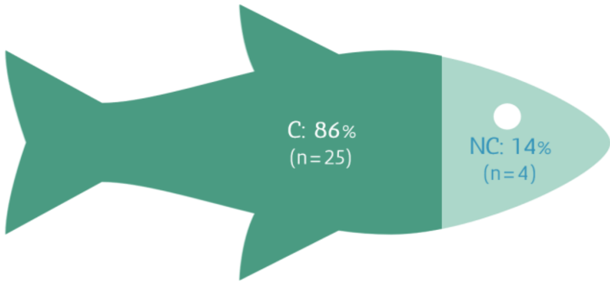
Sample Id	Selling Presentation		Label Information	
	packaging	conservation	common name + salted/dried salted	scientific name
1A	NC	NC	NC	NC
1B	NC	NC	NC	NC
1C	NC	NC	NC	NC
2A	NC	NC	NC	NC
2B	NC	NC	NC	NC
2C	NC	NC	NC	NC
3A	C	NC	NC	NC
3B	C	C	NC	NC
3C	C	C	NC	NC
4A	NC	NC	NC	**C**
4B	NC	NC	NC	**C**
4C	NC	NC	NC	**C**
5A	NC	NC	NC	NC
5B	NC	NC	NC	NC
5C	NC	NC	NC	NC
6A	C	C	NC	NC
6B	C	C	NC	NC
6C	C	C	NC	NC
7A	C	C	NC	NC
7B	C	C	NC	NC
7C	C	C	NC	NC
8A	**C**	**C**	**C**	**C**
8B	C	C	NC	NC
8C	C	C	NC	NC
9A	**C**	**C**	**C**	**C**
9B	**C**	**C**	**C**	**C**
9C	**C**	**C**	**C**	**C**
10A	C	C	NC	NC
10B	C	C	NC	NC
10C	C	C	NC	NC
11A	C	C	NC	NC
11B	C	C	NC	NC
11C	C	C	NC	NC
12A	C	C	NC	NC
12B	C	C	NC	NC
12C	C	C	NC	NC
13A	C	C	NC	NC
13B	C	C	NC	NC
13C	C	C	NC	NC
14A	C	C	NC	NC
14B	C	C	NC	NC
14C	C	C	NC	NC
15A	C	C	NC	NC
15B	C	C	NC	NC
15C	C	C	NC	NC

*C**- compliant; NC*- non-compliant

Table 3. Sequencing results and BOLD percentage of similarity with samples

Sample Id	Product Description	Species Expected	Barcode Identification	% BOLD Similarity
1A	BACALHAU PORTO	*G. morhua*	n/a	-
1B	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
1C	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
2A	BACALHAU PORTO	*G. morhua*	no match	-
2B	BACALHAU PORTO	*G. morhua*	n/a	-
2C	BACALHAU PORTO	*G. morhua*	n/a	-
3A	BACALHAU DA NORUEGA	*G. morhua*	*G. morhua*	100
3B	BACALHAU DESFIADO 2 ª	*G. morhua*	n/a	-
3C	BACALHAU DESFIADO 2 ª	*G. morhua*	*G. morhua*	100
4A	GADUS MORHUA	*G. morhua*	*G. morhua*	100
4B	APARAS GADUS MORHUA	*G. morhua*	n/a	-
4C	APARAS GADUS MORHUA	*G. morhua*	*G. morhua*	100
5A	BACALHAU PORTO	*G. morhua*	Sf	-
5B	BACALHAU PORTO	*G. morhua*	n/a	-
5C	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
6A	BACALHAU PORTO	*G. morhua*	*M. molva*	100
6B	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
6C	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
7A	BACALHAU PORTO	*G. morhua*	*G. morhua*	99,83
7B	BACALHAU PORTO	*G. morhua*	n/a	-
7C	BACALHAU PORTO	*G. morhua*	n/a	-
8A	BACALHAU SALGADO MACRO	*G. macrocephalus*	*G. macrocephalus*	100
8B	BACALHAU PORTO MORHUA	*G. morhua*	Sf	-
8C	BACALHAU IMPERIAL	*G. morhua*	n/a	-
9A	BACALHAU IMPERIAL	*G. morhua*	*G. morhua*	100
9B	BACALHAU SALGADO MACRO	*G. macrocephalus*	*G. macrocephalus*	100
9C	BACALHAU PORTO MORHUA	*G. morhua*	*G. morhua*	100
10A	BACALHAU PORTO MORHUA	*G. morhua*	*P. virens*	100
10B	BACALHAU IMPERIAL	*G. morhua*	*B. brosme*	100
10C	BACALHAU PORTO MORHUA	*G. morhua*	*G. macrocephalus*	100
11A	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
11B	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
11C	BACALHAU PORTO	*G. morhua*	n/a	-
12A	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
12B	BACALHAU PORTO	*G. morhua*	n/a	-
12C	BACALHAU PORTO	*G. morhua*	n/a	-
13A	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
13B	BACALHAU PORTO	*G. morhua*	n/a	-
13C	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
14A	BACALHAU PORTO	*G. morhua*	*G. morhua*	99,39
14B	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
14C	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
15A	BACALHAU PORTO	*G. morhua*	*G. morhua*	100
15B	BACALHAU PORTO	*G. morhua*	*G. morhua*	99,61
15C	BACALHAU PORTO	*G. morhua*	*G. morhua*	100

n/a- no amplification; Sf- sequencing failure



Graphic 3. Percentage of compliant and non-compliant samples regarding species identification.

4. Conclusion

The present study revealed significant flaws in the labeling of commercialized salted cod, in addition to a relatively high rate (13%) of fraudulent species substitution, especially for species cheaper than cod. The identification of three fraudulent samples from the same location suggests intentional fraud and relative carelessness in the handling of salted fish. As the data collected by MAPA point to adequate labeling and speciation of imported salted cod, it is concluded that the following links in the chain are compromising the reliability of this important food until it reaches the consumer's table. Although it is necessary to expand inspections of fisheries products through more accurate techniques that involve DNA analysis, ensuring the authenticity of the product purchased by the consumer. However, for this, several barriers must be overcome, ranging from the proper conservation of the samples, through the costs and time required to obtain the results of analysis, which makes punitive actions difficult, although not impossible. On the other hand, verifying the labeling of these products through more frequent inspection actions and imposing more rigorous punishments on counterfeiters is a relatively simpler task, and can bring positive results, even in the short term. The data obtained highlight the importance of inspection actions that already exist in the country and reinforce the quality of existing legal standards. At the same time, the information suggests the need to impose greater rigor on retailers. Finally, this study could serve as a basis for further research on the subject.

Acknowledgements

This paper supported by Brazilian National Council for Scientific and Technological Development (CNPq) (Grant No. 307810/2021-6).

References

[1] Brasil: Instrução Normativa nº 53 de 1º de setembro de 2020. Ministério da Agricultura, Pecuária e Abastecimento, Brasil (2020).

[2] Chicrala, P.C.M.S., Kato, H. de A., Franco de Lima, L.K.: Pirarucu salgado seco. (2017).

[3] Seafood Brasil: 7ºAnuário - Seafood Brasil. (2021).

[4] Costa Figueira Pinto, J.: Country of origin and its effect on consumers' purchase intention of Norwegian salted and dried cod: A study of the Brazilian market.!, https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2598706, (2018).

[5] Munguia-Vega, A., Terrazas-Tapia, R., Dominguez-Contreras, J.F., Reyna-Fabian, M., Zapata-Morales, P.: DNA barcoding reveals global and local influences on patterns of mislabeling and substitution in the trade of fish in Mexico. (2022). https://doi.org/10.1371/journal.pone.0265960.

[6] Donlan, C.J., Luque, G.M.: Exploring the causes of seafood fraud: A meta-analysis on mislabeling and price. Mar Policy. 100, 258-264, (2019). https://doi.org/10.1016/J.MARPOL.2018.11.022.

[7] Calegari, B.B., Avila, E.F., Reis, R.E., Alho, C.S.: DNA barcode authentication reveals highly fraudulent Cod commerce in Porto Alegre, Brazil. Forensic Science International: Reports. 2, 100072 (2020). https://doi.org/10.1016/j.fsir.2020.100072.

[8] Carvalho, D.C., Palhares, R.M., Drummond, M.G., Frigo, T.B.: DNA Barcoding identification of commercialized seafood in South Brazil: A governmental regulatory forensic program. Food Control. 50, 784-788 (2015). https://doi.org/10.1016/j.foodcont.2014.10.025.

[9] Carvalho, D.C., Guedes, D., da Gloria Trindade, M., Coelho, R.M.S., de Lima Araujo, P.H.: Nationwide Brazilian governmental forensic programme reveals seafood mislabelling trends and rates using DNA barcoding. Fish Res. 191, 30-35, (2017).

https://doi.org/10.1016/j.fishres.2017.02.021.

[10] MAPA: Anuário dos Programas de Controle de Alimentos de Origem Animal do DIPOA. , Brasília (2020),

[11] Handy, S.M., Deeds, J.R., Ivanova, N. v, Hebert, P.D.N., Hanner, R.H., Ormos, A., Weigt, L.A., Moore, M.M., Yancy, H.F.: A Single-Laboratory Validated Method for the Generation of DNA Barcodes for the Identification of Fish for Regulatory Compliance. J AOAC Int. 94, 201-210, (2011). https://doi.org/10.1093/jaoac/94.1.201.

[12] Brasil: Anexo da IN MAPA nº 53, de 1º de setembro de 2020. (2022).

[13] Brasil: Instrução Normativa nº 1, de 15 de janeiro de 2019. Ministério da Agricultura, Pecuária e Abastecimento, Brasil. (2019).

[14] Helgoe, J., Oswald, K.J., Quattro, J.M.: A comprehensiveanalysisofthemislabelingofAtlanticcod (Gadus morhua) products in Spain. Fish Res. 222, 105400 (2020). https://doi.org/10.1016/j.fishres.2019.105400.

[15] Delpiani, G., Delpiani, S.M., Deli Antoni, M.Y., Covatti Ale, M., Fischer, L., Lucifora, L.O., Díaz de Astarloa, J.M.: Are we sure we eat what we buy? Fish mislabelling in Buenos Aires province, the largest sea food market in Argentina. Fish Res. 221, (2020). https://doi.org/10.1016/j.fishres.2019.105373.

[16] Panprommin, D., Manosri, R.: DNA barcoding as an approach for species traceability and labeling accuracy of fish fillet products in Thailand. Food Control. 136, (2022). https://doi.org/10.1016/j.foodcont.2022.108895.