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Data Article

Data on metals, nonmetal, and metalloid in the samples of the canned tuna and canned sardines sold in Brazil

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ABSTRACT

The safety of food is a matter of global concern today. Continuous monitoring of canned tuna and canned sardines quality is essential regarding metal, nonmetal, and metalloid content. In this article, we present the data on the elemental content obtained in canned tuna and canned sardines by using inductively coupled plasma optical spectrometry (ICP OES), as well as the data on Pollution Index (PI) and Health Risk Index (HRI). Pollution index and health risk index are tools used to assess elemental contamination in the environment and food. A total of 6 metals (Al, Ba, Ca, Cu, Fe, and Zn), one nonmetal (Se), and one metalloid (As) were quantified in the samples of the canned tuna and canned sardines. For elements as Al, Cu, Fe, and Se, PI > 1. In addition, Cd, Co, Cr, Ni, Zn, and Pb have PI values less than 1. The HRI values for some canned tuna samples were above 1 for elements such as Al, Ba, Ca, and As. For canned sardines, the elements Cr, Ni, and As showed HRI values >1.

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Specifications Table

Subject	Biochemistry
Specific subject area	Chemistry, medicine
Type of data	Table
How data was acquired	Microwave Digestion (Speedwave four, Berghof, Eningen, BW, Germany) and ICP OES (iCAP 6300 Duo, Thermo Fisher Scientific, Bremen, Germany)
Data format	Raw, analyzed
Parameters for data collection	The liquid content (oil or sauce) from the canned tuna and canned sardine were drained. The meat samples were ground in a food blender with stainless steel cutters. The following method of pretreatment of meat digestion and calculations were performed: (i) 1.0 mL of HNO_3 (65%, Merck), 3.0 mL of high-purity water, and 1.0 mL of H_2O_2 (35%, Merck) were added to 400 mg canned tuna and 400 mg of canned sardines. (ii) After determining the concentration of metals, nonmetals, and metalloids in canned tuna and canned sardines, pollution indices were calculated. (iii) The concentrations of metals, nonmetals, and metalloids quantified in canned tuna using mg/kg were converted to 130 g portions. The concentrations of elements in canned sardines in mg/kg were converted to 84 g portions. After the conversion factor to portion sizes, the Health Risk Index (*HRI*) was calculated.
Description of data collection	We used the ICP OES instrument mentioned above to determine the concentration levels of metals (Al, Ca, Cd, Co, Cr, Cu, Fe, Ni, Pb, and Zn), nonmetal (Se), and metalloid (As) in canned tuna and canned sardines.
Data source location	Institution: School of Medicine, Federal University of Mato Grosso do Sul, Campo Grande/MS, Brazil. City: Campo Grande, Mato Grosso do Sul, Midwest region. Country: Brazil.
Data accessibility	Repository name: Mendeley data Data identification number: 10.17632/zf95gwjjmk.1 Direct URL to data: https://data.mendeley.com/datasets/zf95gwjjmk/1

Value of the Data

- Contamination of canned tuna or canned sardines with metals, nonmetals, and metalloids is a significant problem; therefore, continuous monitoring is essential in several countries.
- The data obtained of heavy metals, nonmetals, and metalloids in canned tuna or canned sardines can be compared with other data published in the literature on canned fish (i.e., countries outside Brazil).
- Pollution Index (*PI*) is a useful tool for the comprehensive evaluation of the degree of contamination of soil, water, food, and, principally, the environment.
- The value of the Health Risk Index (*HRI*) depends upon the daily intake of metals (*DIM*), nonmetals or metalloids, and oral reference dose (*RfD*), so data on heavy metals, nonmetals, and metalloids are useful in preventing possible human toxicities.
- Data from the Pollution Index (*PI*) and the Health Risk Index (IHR) value deliver information on the anthropogenic impact necessary for the management of public environmental and health policies. Also, the data provides significant knowledge and applications to other research centers.

1. Data Description

Canned fish has been processed and kept in an airtight container, such as a tin or an aluminum can. Salt, broth, brine, olive oil, soy oil, or other sauces are added to the fish and subjected to heat (sterilized) [1]. However, according to data obtained in the USA [2], Ghana [3], Turkey [4,5], and Poland [6], canned fish accumulate heavy metals. Besides, research on the quantification of heavy metals, nonmetals, and metalloids in canned fish is scarce and not carried out periodically in Brazil.

In subsection 1.1, we present data on elemental content in canned tuna and canned sardines detected by an inductively coupled plasma atomic emission spectrometer - ICP OES.

In subsection 1.2, we display data on the *Pollution Index (PI)* of the metals, nonmetals, and metalloids in canned tuna (Table 3) and canned sardines (Table 4) obtained using Eq. 1. The latter data (subsection 1.3, Tables 5-6) includes calculating the Health Risk Index (*HRI*) using Eq. 3 for each metal, nonmetal, and metalloid caused by the canned tuna and canned sardines.

The raw data set and methodology details used in this data article have been designed and available in Mendeley's data https://data.mendeley.com/datasets/zf95gwjjmk/1. Besides, Mendeley's data includes the raw data on samples of the canned tuna and canned sardines obtained by ICP OES. The raw data on samples' content is presented in triplicates.

1.1. Data analysis by ICP OES: metals, nonmetals, and metalloids in canned tuna and canned sardines

This data shows a total of 6 metals (Al, Ba, Ca, Cu, Fe, and Zn), one nonmetal (Se), and one metalloid (As) quantified in the samples of the canned tuna (Table 1). Table 1 shows Cd, Co, Cr, Ni, and Pb levels below the limit of detection ($<$ LOD) in canned tuna samples.

Table 2 presents the quantification of 7 metals (Al, Ba, Ca, Cr, Cu, Fe, and Zn), one nonmetal (Se), and one metalloid (As) in samples of the canned sardines (Table 2). In addition, the elements Cd, Co, Pb, and Ni were not detected in canned sardines ($<$ LOD).

All experiments described above were analyzed in ICP OES after digestion procedures (Subsection 2.2, Table 9).

1.2. Data on Pollution index (PI) of the metals or metalloid in the *canned tuna and canned sardines*

The data presented in Tables 3 and 4 show the *PI* calculation results in each sample obtained using Eq. 1. For the calculation of *PI*, the allowable limit of each element in fish fillet was considered. The *PI* values superior to one show that canned tuna and canned sardine samples are contaminated with heavy metals (Al, Cu, Fe, and Se) and metalloid (As), which consequently can be considered toxic [7,8]. On the other hand, other analyzed metals (Cd, Co, Cr, Ni, Pb, and Zn) do not display toxicity once *PI* values are below 1. The data presented in Tables 3 and 4 on the results of the *PI* calculation in each sample can be compared with the Pi values obtained from wild fish caught in China [9].

1.3. Data on health risk index (HRI)

For the calculation of obtaining of *HRI* (Eq. 3), the following considerations are noteworthy: the data on metals, nonmetals, and metalloids in canned tuna obtained in Table 1 (in units of mg/kg $\pm$ standard deviation of triplicate) were converted to 130 g edible portions, that is; mg/130 g (Table 5); on the other hand, in Table 2, metals, nonmetal and metalloid in canned

Table 1
Analytical data on elemental content present in canned tuna detected in ICP OES (in units of mg/Kg ± standard deviation of triplicate).

	Natural grated tuna (mg/kg) (NGT)				Oil grated tuna (mg/kg) (OGT)				Solid natural tuna (mg/kg) (SNT)				Solid tuna in oil (mg/kg) (STO)			
Elements	NGT -G	NGT -C	NGT -O	NGT -P	OGT -G	OGT -C	OGT -O	OGT -P	SNT-G	SNT -C	SNT -O	SNT -P	STO -G	STO -C	STO -O	STO-P
Al	14.386 ± 3.22	10.254 ± 0.02	18.281 ± 3.38	13.102 ± 2.50	< LOD	< LOD	< LOD	< LOD	19.932 ± 0.26	20.451 ± 3.04	47.337 ± 3.32	25.025 ± 4.12	<LOD	<LOD	<LOD	0.005 ± 0.0001
As	1.943 ± 0.088	1.612 ± 0.054	1.642 ± 0.034	1.473 ± 0.084	1.783 ± 0.011	1.693 ± 0.098	1.379 ± 0.049	1.610 ± 0.012	1.330 ± 0.018	1.538 ± 0.089	1.278 ± 0.025	1.671 ± 0.048	1.875 ± 0.044	1.684 ± 0.007	1.756 ± 0.111	1.864 ± 0.153
Ba	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.030 ± 0.114	0.013 ± 0.003	<LOD	116.566 ± 30.779	74.192 ± 36.955	<LOD	0.059 ± 0.020	0.232 ± 0.056	0.133 ± 0.217	0.132 ± 0.031
Ca	0.568 ± 0.201	0.113 ± 0.021	0.209 ± 0.023	0.219 ± 0.046	<LOD	<LOD	<LOD	0.2915 ± 0.075	41.860 ± 1.890	40.472 ± 0.260	44.118 ± 0.824	47.801 ± 0.275	68.898 ± 1.752	63.047 ± 3.020	70.940 ± 20.277	67.765 ± 2.915
Cd	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Co	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cu	0.642 ± 0.033	0.516 ± 0.262	0.670 ± 0.090	0.290 ± 0.108	0.461 ± 0.150	0.237 ± 0.035	0.319 ± 0.049	0.798 ± 0.097	<LOD	0.064 ± 0.003	<LOD	0.138 ± 0.031	0.338 ± 0.029	0.170 ± 0.020	0.192 ± 0.042	0.209 ± 0.029
Fe	29.333 ± 3.611	25.444 ± 0.239	25.221 ± 0.436	30.517 ± 1.912	17.514 ± 4.679	10.897 ± 1.055	14.221 ± 5.530	21.311 ± 1.483	7.935 ± 0.456	15.178 ± 0.278	8.243 ± 0.420	16.702 ± 1.235	9.285 ± 0.187	8.450 ± 0.287	8.916 ± 0.071	10.92 ± 0.817
Ni	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Se	2.604 ± 0.161	1.729 ± 0.024	1.998 ± 0.042	1.893 ± 0.106	1.733 ± 0.124	1.942 ± 0.132	2.030 ± 0.376	1.972 ± 0.069	1.269 ± 0.006	1.463 ± 0.100	1.477 ± 0.007	1.256 ± 0.039	1.536 ± 0.086	1.996 ± 0.035	1.997 ± 0.111	2.041 ± 0.174
Zn	0.408 ± 0.038	0.176 ± 0.002	0.278 ± 0.004	0.253 ± 0.006	0.256 ± 0.011	0.120 ± 0.007	0.196 ± 0.028	0.376 ± 0.009	0.101 ± 0.00003	0.166 ± 0.009	0.091 ± 0.0004	0.134 ± 0.004	0.161 ± 0.001	0.111 ± 0.005	0.125 ± 0.019	0.100 ± 0.004

<LOD - Analyte concentrations were below the limits of detection

Table 2
Analytical data on elemental content present in canned sardines detected in ICP OES (in units of mg/kg ± standard deviation of triplicate).

	Sardines canned in oil (mg/kg) (SO)					Sardines canned in tomato sauce (mg/kg) (ST)				
Elements	SO-G	SO-C	SO-O	SO-P	SO-Pa	STS-G	STS-C	STS-O	STS-P	STS-Pa
Al	0.018 ± 0.004	<LOD	0.023 ± 0.006	0.010 ± 0.006	0.031 ± 0.002	0.028 ± 0.006	0.013 ± 0.001	0.091 ± 0.028	0.014 ± 0.002	0.027 ± 0.006
As	3.224 ± 0.108	3.053 ± 0.347	3.069 ± 0.224	4.493 ± 0.387	3.112 ± 0.322	3.790 ± 0.025	3.839 ± 0.045	2.676 ± 1.044	3.345 ± 0.169	2.467 ± 0.266
Ba	0.436 ± 0.006	0.364 ± 0.172	0.393 ± 0.096	0.565 ± 0.004	0.239 ± 0.020	0.745 ± 0.240	0.730 ± 0.001	0.598 ± 0.346	0.781 ± 0.044	1.627 ± 0.008
Ca	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Co	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.018 ± 0.002	0.018 ± 0.031	0.026 ± 0.024	0.027 ± 0.010	0.016 ± 0.007	0.007 ± 0.011	0.012 ± 0.017	0.110 ± 0.081	<LOD	0.014 ± 0.029
Cu	0.788 ± 0.118	0.647 ± 0.064	0.742 ± 0.001	2.624 ± 0.232	1.130 ± 0.180	1.096 ± 0.016	1.350 ± 0.452	0.739 ± 1.008	0.999 ± 0.318	1.172 ± 0.570
Fe	27.621 ± 1.693	17.447 ± 0.991	23.762 ± 0.579	33.565 ± 2.612	23.156 ± 1.962	31.081 ± 2.434	30.565 ± 3.526	41.745 ± 23.033	17.420 ± 4.926	21.753 ± 7.584
Ni	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	<LOD	0.007 ± 0.007	0.005 ± 0.002	0.009 ± 0.0003	<LOD	<LOD	<LOD	0.011 ± 0.013	<LOD	<LOD
Se	2.164 ± 0.060	2.272 ± 0.190	2.177 ± 0.111	2.378 ± 0.120	2.045 ± 0.109	1.984 ± 0.220	2.086 ± 0.356	2.422 ± 0.841	1.873 ± 0.117	2.095 ± 0.221
Zn	0.434 ± 0.064	0.318 ± 0.102	0.340 ± 0.063	0.465 ± 0.018	0.203 ± 0.006	0.398 ± 0.031	0.457 ± 0.113	0.395 ± 0.201	0.234 ± 0.050	0.270 ± 0.093

<LOD - Analyte concentrations were below the limits of detection; ND = not determined, the Ca concentrations were higher than the values of the calibration curves 2.0 mg/kg.

Table 3
Data on pollution indexes in canned tuna.

Type of canned tuna-company	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Ni	Pb	Se	Zn
NGT-G	<1	3.8	-	-	<1	<1	<1	21.4	293.3	<1	<1	1.3	<1
NGT -C	<1	3.2	-	-	<1	<1	<1	17.2	254.4	<1	<1	<1	<1
NGT -O	1.21	3.2	-	-	<1	<1	<1	22.3	252.2	<1	<1	<1	<1
NGT -P	<1	2.9	-	-	<1	<1	<1	9.6	305.1	<1	<1	<1	<1
OGT-G	<1	3.56	-	-	<1	<1	<1	15.38	175.14	<1	<1	<1	<1
OGT-C	<1	3.38	-	-	<1	<1	<1	9.91	108.97	<1	<1	<1	<1
OGT-O	<1	2.75	-	-	<1	<1	<1	10.63	142.21	<1	<1	1.01	<1
OGT-P	<1	3.22	-	-	<1	<1	<1	26.61	213.11	<1	<1	<1	<1
SNT-G	1.3	2.6	-	-	<1	<1	<1	<1	79.35	<1	<1	<1	<1
SNT-C	1.3	3.0	-	-	<1	<1	<1	2.15	151.78	<1	<1	<1	<1
SNT-O	3.1	2.5	-	-	<1	<1	<1	<1	82.43	<1	<1	<1	<1
SNT-P	1.6	3.3	-	-	<1	<1	<1	4.62	167.02	<1	<1	<1	<1
STO-G	<1	3.7	-	-	<1	<1	<1	11.2	92.8	<1	<1	<1	<1
STO-C	<1	3.3	-	-	<1	<1	<1	5.6	84.5	<1	<1	<1	<1
STO-O	<1	3.5	-	-	<1	<1	<1	6.4	89.1	<1	<1	<1	<1
STO-P	<1	3.7	-	-	<1	<1	<1	6.9	109.2	<1	<1	1.0	<1

*There are no values established by the FAO for the elements Ba and Ca in fish fillet.

Table 4
Data on pollution indexes in canned sardines.

Type of canned sardines-company	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Ni	Pb	Se	Zn
SO-G	<1	6.44	-	-	<1	<1	<1	26.28	276.21	<1	<1	1.08	<1
SO-C	<1	6.10	-	-	<1	<1	<1	21.58	174.47	<1	<1	1.13	<1
SO-O	<1	6.13	-	-	<1	<1	<1	24.75	237.62	<1	<1	1.08	<1
SO-P	<1	8.98	-	-	<1	<1	<1	87.49	335.65	<1	<1	1.18	<1
SO-Pa	<1	6.22	-	-	<1	<1	<1	37.68	231.56	<1	<1	1.02	<1
STS-G	<1	7.58	-	-	<1	<1	<1	36.68	310.81	<1	<1	<1	<1
STS-C	<1	7.67	-	-	<1	<1	<1	45.00	305.65	<1	<1	1.04	<1
STS-O	<1	5.35	-	-	<1	<1	<1	24.64	417.45	<1	<1	1.21	<1
STS-P	<1	6.69	-	-	<1	<1	<1	33.32	174.20	<1	<1	<1	<1
STS-Pa	<1	4.93	-	-	<1	<1	<1	39.00	217.53	<1	<1	1.04	<1

*There are no values established by the FAO for the elements Ba and Ca in fish fillet.

Table 5
Health risk index (*HRI*) for individual heavy metals and metalloid caused by the canned tuna.

Type of canned sardines-company	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Ni	Pb	Se	Zn
NGT-G	13.3	2.4	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
NGT-C	9.5	1.9	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
NGT-O	16.9	2.0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
NGT-P	12.1	1.8	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
OGT-G	<1	2.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
OGT-C	<1	2.0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
OGT-O	<1	1.7	5.14	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
OGT-P	<1	1.0	2.56	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
SNT-G	18.5	1.6	<1	15.54	<1	<1	<1	<1	<1	<1	<1	<1	<1
SNT-C	18.9	1.9	<1	15.03	<1	<1	<1	<1	<1	<1	<1	<1	<1
SNT-O	43.9	1.5	<1	16.38	<1	<1	<1	<1	<1	<1	<1	<1	<1
SNT-P	23.2	2.0	<1	17.75	<1	<1	<1	<1	<1	<1	<1	<1	<1
STO-G	<1	2.3	<1	25.59	<1	<1	<1	<1	<1	<1	<1	<1	<1
STO-C	<1	2.0	<1	23.41	<1	<1	<1	<1	<1	<1	<1	<1	<1
STO-O	<1	2.1	<1	26.34	<1	<1	<1	<1	<1	<1	<1	<1	<1
STO-P	<1	2.3	<1	25.16	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table 6
Health risk index (*HRI*) for individual heavy metals metalloid caused by the canned sardines.

Type of canned sardines-company	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Ni	Pb	Se	Zn
SO-G	<1	3.99	<1	ND	<1	<1	4.53	<1	<1	<1	<1	<1	<1
SO-C	<1	3.78	<1	ND	<1	<1	2.77	<1	<1	<1	<1	<1	<1
SO-O	<1	3.80	<1	ND	<1	<1	6.5	<1	<1	<1	<1	<1	<1
SO-P	<1	5.56	<1	ND	<1	<1	6.7	<1	<1	<1	<1	<1	<1
SO-Pa	<1	3.85	<1	ND	<1	<1	3.96	<1	<1	<1	<1	<1	<1
STS-G	<1	4.69	<1	ND	<1	<1	1.53	<1	<1	<1	<1	<1	<1
STS-C	<1	4.75	<1	ND	<1	<1	2.77	<1	<1	<1	<1	<1	<1
STS-O	<1	3.31	<1	ND	<1	<1	2.74	<1	<1	4.08	<1	<1	<1
STS-P	<1	4.14	<1	ND	<1	<1	<1	<1	<1	<1	<1	<1	<1
STS-Pa	<1	3.05	<1	ND	<1	<1	1.98	<1	<1	<1	<1	<1	<1

ND = not determined. Ca concentrations were higher than the calibration curves' values of 2.0 mg/kg.

Table 7
Canned tuna and the Brazilian company.

Type of canned grated tuna - company	Type of canned solid tuna -company
NGT-G	SNT-G
NGT-C	SNT-C
NGT-P	SNT-P
NGT-O	SNT-O
OGT-G	STO -G
OGT-C	STO-C
OGT-P	STO-P
OGT-O	STO-O

sardines detected by ICP OES (in units of mg/kg ± standard deviation of triplicate) were converted to 84 g edible portions, that is; mg/84 g (Table 6).

In Table 5, the *HRI* for individual heavy metals (Al, Ba, Ca) and metalloid (As) in canned tuna is not safe; that is, *HI* > 1. Also, *HRI* for individual heavy metals (Cr and Ni) and metalloid (As) in canned sardines is not safe as well (Table 6). On the other hand, an *HRI* of < 1 means the exposed population is assumed to be safe [7,8]. The results obtained in Tables 5 and 6 can be compared with those published by Soheil Sobhanardakani on Tuna fish and common kilka [10].

2. Experimental Design, Materials and Methods

2.1. Sampling

Canned tuna and canned sardine samples of different brands were purchased from popular supermarkets in Campo Grande, Brazil. Also, there are two main types of canned tuna: grated and solid. Four brands of companies that sell canned tuna (G, C, O, and P) were selected. For each one, there are for types of samples: natural grated tuna (NGT), oil grated tuna (OGT), solid natural tuna (SNT), and solid tuna in oil (STO). We used ten canned tuna (three cans of each tuna type/brand) in our research. Table 7 shows the type of canned tuna and the Brazilian company that markets it. Besides, ten samples of canned sardines (two cans of each sardine type/brand) were purchased from five brands (G, C, O, P, and Pa).

The samples of canned sardines were placed into two groups: sardines canned in oil (SO) and sardines canned in tomato sauce (STS). Table 8 lists the types of canned sardines and companies. Five different lots from each sample were purchased from each Brazilian company.

After opening each can, all liquids were drained (oil or sauce), and the meat was ground in a food blender with stainless steel cutters for 2 minutes. Samples were taken to microwave-assisted digestion.

Table 8
Canned sardines and Brazilian companies.

Type of canned sardine in oil - company	Type of canned sardines in tomato sauce - company
SO-G	STS-G
SO-C	STS-C
SO-P	STS-P
SO-O	STS-O
SO-Pa	STS-Pa

Table 9
Operating program for the microwave digestion system.

Step	Power (W)	Temperature (°C)	Time (min)	Pressure (Bar)
1	1160	100	5	30
2	1160	150	10	30
3	0	50	1	25

2.2. Microwave-assisted digestion

Proximate to 400 mg of canned tuna and canned sardines were weighed separately into DAP-60+ Tubes and digested as follows: 1.0 mL of HNO_3 (65%, Merck), 3.0 mL of high-purity water (18 MΩ cm, Milli-Q, Millipore, Bedford, MA, USA) and 1.0 mL of H_2O_2 (35%, Merck) were added to de DAP tubes and placed in the microwave digestion system (Speedwave four, Berghof, Eningen, BW, Germany). Table 9 presents the microwave setting program. The resulting solutions were cooled and diluted to 5 mL with high-purity water. Identical digestion was performed for blank.

Determination of heavy metals and metalloids levels using the ICP OES occurred after digestion.

2.3. Process of data analysis by ICP OES

An ICP OES (iCAP 6300 Duo, Thermo Fisher Scientific, Bremen, Germany) was used for Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Na, Ni, Pb, Se, and Zn determination in samples of canned tuna and canned sardines. The multi-elementary standard solution was prepared after successive dilutions from 100 mg L^{-1} Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Ni, Pb, Se, and Zn stock solutions (Specsol, São Paulo, Brazil) for ICP OES analysis. The range of calibration curves for external standard calibration was between 0.005 - 2.0 ppm for each evaluated analyte. The instrumental configuration and experimental conditions are summarized in Table 10.

Analytical calibration procedures were performed for NGT and SNT samples (Table 11) and in sequence for OGT, STO, SO, and STS (Table 12). Thus, Tables 11 and 12 show the limit of detection (LODs) calculated according to IUPAC as three times the standard deviation from the blank signal (SB) divided by calibration curve slope [11]. SB was subtracted from all metal and metalloid detection since it cannot be considered part of the metal sampling. The limits of quantification (LOQs) were calculated according to Reference [11]. The correlation coefficient (R^2) obtained from the calibration curves reached values from 0.991 to 0.999 for all analytes based on the reading of 3 blanks.

Spike-and-recovery is important methods for validating and assessing the accuracy of the analytical techniques used by ICP OES. Thus, the accuracy of the measurements was determined by a spike-and-recovery test by adding 0.5 mg/kg of each metal in samples NGT, SNT, OGT, STO, SO, and STS (Table 13). As can be seen, the method has good accuracy and the recoveries were between 95% and 117.

Table 10
The operating conditions for ICP OES analysis.

Parameter	Setting
RF Power (W)	1250
Sample flow (L min^{-1})	0.35
Replicates	3
Plasma flow rate (L min^{-1})	12
Integration time (s)	5
Stabilization time (s)	20
Nebulization pressure(psi)	30
Plasma View	Axial
Analites/λ	Al 167.079 nm, As 189.042 nm, Ba 455.403 nm, Ca 393.366 nm, Cd 228.802 nm, Co 228.616 nm, Cr 283.563 nm, Cu 324.754 nm, Fe 259.940 nm, Na 588.995 nm, Ni 221.647 nm, Pb 220.353 nm, Se 196.090 nm, Zn 213.856 nm

Table 11
Analytical characteristics of ICP OES method: elements, equation external calibration (y = ax + I)*, Limit of Detection (LODs), Limit of Quantification (LOQs), and correlation coefficient (R^2): Samples NGT and SNT.

Elements	Equation external calibration	LOD (mg/L)	LOQ (mg/L)	R^2
Al	y=7.4718x – 0.2835	0.096787	0.3226234	0.991
As	y=462x + 8.6587	0.0062769	0.020923	0.999
Ba	y=747004x + 13615	0.0004565	0.0015216	0.999
Ca	y=2E+06x + 64456	0.0252596	0.0841985	0.993
Cd	y=14252x + 88.246	0.0010316	0.0034385	0.999
Co	y=5637.1x + 97.994	0.0020218	0.0067393	0.999
Cr	y= 17834x + 108.53	0.0014799	0.004933	0.999
Cu	y= 20947x + 408.35	0.0033587	0.0111956	0.999
Fe	y= 10966x + 164.11	0.0032018	0.0106726	0.999
Ni	y= 5002.4x + 85.714	0.0025072	0.0083572	0.999
Pb	y= 1060.1x + 20.8	0.0100022	0.0333407	0.999
Se	y= 357.52x + 6.3534	0.0111318	0.0371058	0.999
Zn	y= 10212x + 205.41	0.0014453	0.0048177	0.999

* y = absorbance; a = slope; x = concentration (g/kg); I = intercept.

Table 12
Analytical characteristics of ICP OES method: elements, equation external calibration (y = ax + I)*, Limit of Detection (LODs), Limit of Quantification (LOQs), and correlation coefficient (R^2): Samples OGT, STO, SO, and STS.

Elements	Equation external calibration	LOD (mg/Kg)	LOQ (mg/Kg)	R^2
Al	y= 135x – 0.8678	0.0044351	0.0147838	0.9989
As	y= 492.89x + 7.4355	0.0036706	0.0122353	0.9993
Ba	y= 812405x + 7228.5	0.0001898	0.0006326	0.9994
Ca	y= 1E+06x + 15956	0.1824088	0.6080292	0.9999
Cd	y= 14521x + 54.642	0.0006265	0.0020884	0.9996
Co	y= 6264,2x + 80.017	0.0009556	0.0031855	0.9993
Cr	y= 14916x + 38.422	0.0008094	0.0026981	0.9997
Cu	y= 16232x + 184.49	0.0017386	0.0057954	0.9995
Fe	y= 11400x + 101.45	0.0169013	0.0563375	0.9994
Ni	y= 5542.7x + 66.307	0.0011056	0.0036853	0.9993
Pb	y= 1095.1x + 18.876	0.0050957	0.0169856	0.9994
Se	y= 376.77x + 5.7012	0.0052757	0.0175856	0.9994
Zn	y= 10918x + 127.6	0.0031463	0.0104878	0.9994

* y = intensity; a = slope; x = concentration (g/kg); I = intercept.

Table 13
Spike and recovery (%) of elements in samples NGT, SNT, OGT, STO, SO, and STS.

Elements	Recovery (%)
Al	95
As	100
Ba	98
Ca	105
Cd	103
Co	99
Cr	101
Cu	97
Fe	103
Ni	98
Pb	100
Se	117
Zn	100

2.4. Pollution index (PI) calculation

We considered PI as the ratio of the metals, nonmetals (or metalloids) concentration in canned tuna, and canned sardines samples to the element's maximum permissible level [7].

$$PI = \frac{\text{Metal (nonmetal or methaloid) concentration in the sample}}{\text{Permissible limit or background value}} \quad (1)$$

In Eq. 1 the limits allowed for each metal (metalloid) in fish fillet are established by FAO/WHO (2009), which are Al 15 $\mu g\ /\ g$; As 0.5 $\mu g/g$; Cd 0.2 $\mu g/g$; Cr 1 $\mu g/g$; Cu 0.03 $\mu g/g$; Fe 0.1 $\mu g/g$; Ni 0.4 $\mu g/g$; Pb 6 $\mu g/g$; Se 2 $\mu g/g$; Zn 40 $\mu g/g$. When $PI > 1$, it implies that the contamination of canned tuna and canned sardines by the element is high and may be toxic at the level present in the sample 7,12].

2.5. Estimation of average daily intake of metals and metalloid (DIM)

The average daily intake of metal (DIM) was calculated as described by Guo et al. [8]. The Equation calculated DIM values:

$$DIM = \frac{C_r x D_r}{BW} \quad (2)$$

where r = canned tuna or canned sardines consumption rate.

DIM is the estimated daily intake of heavy metal or metalloids (mg/kg/day), C_r is the average concentration of heavy metals in contaminated canned tuna or canned sardines (µg/g, fresh weight), and D_r is the daily canned tuna or canned sardines consumption rate (a 0.026 kg/person/day) [13]. The average adult body weights (*BW*) for the Brazilian population were considered to be 70 kg, respectively [14].

2.6. Health risk index (HRI)

The health risk index (*HRI*) for the local population due to canned tuna or canned sardines consumption was assessed using Eq. 3 [8]. The *HRI* value is calculated by dividing the *EDI* value by the Reference Dose (*RfD*) for each element [8,15]. Therefore, if $HRI < 1$, the exposed population is assumed to be safe [8].

$$HRI = \frac{MDI}{RfD} \quad (3)$$

In the *HRI* calculations, the following *RfD* values were used: Al 0.0004 mg/kg per day; As 0.0003 mg/kg per day; Ba 0.2 mg/kg per day; Ca 0.001 mg/kg per day; Cd 0.001 mg/kg per day; Co 0.03 mg/kg per day; Cr 1.5 mg/ kg per day; Cu 0.04mg/kg per day; Fe 0.7 mg/kg per day; Ni 0.02 mg/kg per day; Pb 0,0004 mg/kg per day; Se 0.005 mg/kg per day; Zn 0.3 mg/kg per day [16].

Credit Author Statement

N.V. Lima: Conceptualization, Investigation, Project administration. **E.S.P. Melo**: Methodology, Data curation. **D.G. Arakaki**: Formal analysis, Visualization. **P.F.S. Tschinkel**: Conceptualization. **I.D. Souza**: Investigation. **M.O.O Ulbrecht:** Visualization. **F.J.M. Reis**: Conceptualization. **A.C.G. Rosa**: Validation. **R.H. Rosa**: Data curation. H.M. **V.A. Nascimento**: Supervision, Writing –original draft.

Declaration of Competing Interest

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

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