Journal of Food Composition and Analysis 114 (2022) 104789

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Evaluation of trace and heavy metals in different varieties of sauces to characterize their impact on human health

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A R T I C L E I N F O

Keywords:
Food composition
Food safety
Food sauces
Heavy metals
Trace elements
Daily intake
Human health risk

A B S T R A C T

Food can be contaminated in various ways, as life is getting busier with the passing time and the demand for ready to use food is increasing. Trace and heavy metals are some of the predominant food chain contaminants which trigger the serious fitness effects in human beings even in the least concentration. The present work aimed to determine the heavy metals (HMs, Cd, and Pb) and trace metals (TMs, Cr, Mn, Co, Ni, Cu, and Zn) content in different available brands of sauces which are being used in Pakistan. During the analysis of these metals, the accuracy was ensured by analyzing the standard reference material (SRM, 2384). The recovery rates ranged from 98.6 % to 101.2 % whereas the precision of the method are presented in % RSD which were obtained in a range of 0.20–6.40. Ni, Co, and Cd concentration in all samples under investigation were above the permissible limits as defined by WHO/FAO whereas Cr was not detected in any of the samples. Estimated daily intake (EDI) of Cu ($5.9–8.2 \times 10^{-4}$) was the highest while Pb ($0.16–1.3 \times 10^{-4}$) was the lowest among the metals investigated. Target hazard quotient (THQ) values were obtained in the range of 0.9–1.0, 0.39–0.70, $1.48–2.05 \times 10^{-2}$, $0.40–3.25 \times 10^{-2}$, $1.5–5.5 \times 10^{-3}$, $3.0–3.1 \times 10^{-3}$, $8.0–9.0 \times 10^{-4}$ for Ni, Cd, Cu, Pb, Co, Mn and Zn respectively whereas the hazard index (HI) value of each brand was > 1. Carcinogenic risk (CR) values for Ni were obtained at the threshold level which is alarming when consuming the sauce for a long time.

1. Introduction

Heavy metals (HMs) including cadmium (Cd) and lead (Pb) are some of the predominant food chain contaminants triggering critical fitness consequences even consumed in the least amount because of their slow rate of metabolism in human bodies (Fathabad et al., 2018; Ismat et al., 2019). Urbanization, industrialization, mining, volcanic eruptions, and leaching from rocks and soil are the principle contributors to HMs contamination inside the food chain and are the main concern in food protection, human health, and quality assurance (Ahmad et al., 2021; Ahmed et al., 2016b; Shaheen et al., 2016). Trace metals (TMs) including Cr, Mn, Ni, Co, Cu, and Zn are very important to maintaining different physiological and biochemical functions in living organisms. But in case of long-time exposure, these metals can cause hazardous effects on human health (Ahmed et al., 2016a; Ali et al., 2019; Qadir et al., 2015).

Food can be contaminated in various ways, as life is getting busier with time, ready-to-eat food demand has rapidly increased. Processed food is prepared after a long chain of processing and at each step, there is a chance of chemical contamination. Essential nutrients can be removed from the body by taking contaminated food which results in a decrease in impaired psycho-social behavior, immunological defenses, upper

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https://doi.org/10.1016/j.jfca.2022.104789
Received 11 May 2022; Received in revised form 23 June 2022; Accepted 21 July 2022
Available online 25 July 2022

Table 1
EDI parameters and RfD values.

EDI parameters		RfD (mg/kg BW/day)
ED = Exposure duration	Pakistan population's 66.4 years, an average lifetime	Cr = 1.5
IR = Ingestion rate	10 g/day (standard size available in sachet as single serving)	Mn = 0.14
EFr = Exposure frequency	365 days	Co = 0.02
C = Concentration of metal	mg/kg	Ni = 0.0003
BW = Average body weight	Adult = 73 kg	Cu = 0.04
TA = Average exposure time	66.4 × 365 days	Zn = 0.30
		Cd = 0.001 Pb = 0.004

gastrointestinal cancer, malnutrition disabilities, and many other disorders (Abbasi et al., 2020; Rather et al., 2017).

At this instant in fast food industries, the crucial and boisterous demanding element in cuisines all over the globe is sauces. To effectuate the increasing demands various new brands have released in the market (Mumtaz et al., 2018). Sauces are usually semi-solid, creamy, or fluid composed of sodium chloride, carbohydrates, vinegar, spices, acetic acid, citric acid, sodium benzoate, sulfite, and natural food colors. Several cases of human diseases and the deformation of organs have been reported due to the intake of contaminated foodstuffs (Lenti et al., 2021). The preservatives have been used to retard its decomposition and to increase the shelf-life of the products. Due to the lack of awareness about the presence of heavy metals in food products many health concerns have arisen (Muniz et al., 2018; Roba et al., 2016).

Moreover, a prevailing advancement in ingredients of sauces is increasing day by day. The objective of this research is to initiate awareness regarding hygiene and to access safety health concerns related to their consumption. Thus, in this study, HMs and TMs content in different sauces of different brands were determined which are being used in Pakistan. Estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI), cancer risk (CR) and cumulative cancer risk associated with metals were also explored to characterize their impact on human health.

2. Materials and methods

2.1. Reagents and solutions

Analytical reagent grade (ACS specification, Sigma Aldrich, USA) nitric acid, (70 %), and hydrochloric acid (37 %) were purchased from a local vendor (Hajvery Scientific Store, Lahore-Pakistan). Certified reference standards (Merck, Germany) of each metal (1000 mg/L) under investigation were used to construct a calibration curve after making appropriate dilution with HNO3 (2 % v/v). GenPure water system (Thermo Scientific, USA) was used to prepare the water (18 MΩ.cm) for blank, standard, and sample preparations whereas HNO3 (20 % v/v) was employed to soak the glassware and consequently washed with water to avoid any contamination. NIST, SRM 2384 (baking chocolate) was used as reference material.

2.2. Sample collection and preparation

Thirty samples of different brands of sauces (Dipitt, Shangrila, Tabasco, American Garden, Mitchell's, Key, Salman's, National, Knorr, Shezan, and Young's) are available in different superstores in the provincial capital of Punjab province of Pakistan viz. Lahore. Three samples of each brand were collected, and transported to the lab for analysis of HMs (Cd, Pb) and TMs (Cr, Mn, Co, Ni, Cu, and Zn). An acid digestion procedure (Abbasi et al., 2020) was employed for the extraction of HMs and TMs in different brands of sauces, 10 mL of each sample was added into 10–15 mL aqua regia in a beaker and was placed aside for aging for an hour. Then, it was added to 100 mL distilled water and was heated on the hot plate (VELP Scientifica, Italy) at 150 °C inside the fume hood (BioTroll, Pakistan). When the color of the solution changed to yellow or black, it was filtered into a 100 mL volumetric flask and was filled with distilled water up to the mark and the samples were stored for analysis after coding such as SC1-SC30 and stored at 4 °C till further analysis. The presence of metals in these sauces' brands was determined by flame atomic absorption spectrometry (FAAS) and inductively coupled plasma spectrometry (ICP-OES). All the measurements were made in triplicate and presented in mg/kg.

2.3. Instrumentation

FAAS, Model: PG-990 equipped with auto-sampler from PG-instruments, UK, was utilized for Mn, Cu, Co, Ni, and Zn analysis after operational conditions optimization while interpreting of the data was done by using AA Win Lab® software (Ahmed et al., 2017a, 2014). Cr, Cd, and Pb were determined by iCAP 7400, ICP-OES (Thermo Fisher Scientific), equipped with echelle type 52.91 grooves/mm ruled grating with the plasma in radial viewed, under the optimized conditions (Ahmed et al., 2017a, 2017b; Saleem et al., 2021; Ul-Haq et al., 2021).

2.4. Analytical figures of merit

NIST, SRM 2384 (baking chocolate) was used to assess the accuracy and precision of the acid digestion method adopted for the analysis of HMs and TMs in sauce samples. Percentage recovery and relative standard deviation (% RSD) studies in replicates of ten ($n = 10$) were performed to assess the accuracy and precision respectively. In replicates of eighteen ($n = 18$), blank measurement was made to determine the detection limits ($LOD = 3\ \sigma/S$, $LOQ = 10\ \sigma/S$), while constructing the calibration curve ($y = mx + b$) (Ahmed et al., 2016b; Costa et al., 2020) over a linear dynamic range of 0.2–1.0 μg/mL for Mn, Cu, Co, Ni, and Zn, 0.01–500 μg/L for Cr, Cd, and while 0.02–1000 μg/L for Pb, where σ and S are SD (standard deviation) of blank and slope of calibration curve respectively.

2.5. Statistical analysis

Correlation among the HMs and TMs concentration was established by Pearson's correlation coefficient (r) while performing the statistical analysis by using SPSS version 15 (SPSS Inc., Chicago, IL, USA) for windows.

2.6. Calculation of impact on human health

The impact of HMs and TMs present in sauce samples on human health was calculated by considering the estimated daily intake (EDI), total hazard quotient (THQ), hazard index (HI), carcinogenic risk (CR) and cumulative cancer risk.

2.6.1. Estimated daily intake (EDI)

EDI is a totally commonplace idea in chemical threat assessment due to the fact the maximum quantity of a chemical to which someone may be uncovered may be ingested every day over a whole life without suffering a deleterious effect, and if the ingestion exceeds, this amount may additionally moreover cause poisonous outcomes. It is a numerical estimate of regular oral exposure to the human population, which incorporates sensitive subgroups like youngsters and it is expressed in mg/kg/day (Wexler et al., 2005). EDI in mg/kg/day of metals including Cr, Mn, Co, Ni, Cu, Zn, Cd, and Pb was calculated by using the formula (Rehman et al., 2018b), and the parameters are explained in Table 1.

Table 2
Measured and certified values of the metals in SRM 2384.

Metal	Certified value (mg/kg)	Measured value ($\overline{x} \pm ts/\sqrt{n}$)	% Recovery
Mn	20.8 ± 1.3	20.99 ± 0.17	100.9
Cu	23.9 ± 1.0	23.57 ± 0.21	98.6
Zn	37.6 ± 1.9	37.83 ± 0.31	100.6
Cd	0.0734 ± 0.0077	0.0743 ± 0.001	101.2
Pb	0.0357 ± 0.0046	0.0355 ± 0.001	99.4

($\overline{x} \pm ts/\sqrt{n}$) = mean ± CI ($p < 0.05$, n = 6), CI = Confidence interval

$$EDI = \frac{ED \text{ x } IR \text{ x } EFr \text{ x } C}{BWxTA} x10^{-3}$$

2.6.2. Target hazard quotient (THQ) and hazard index (HI)

THQ is the ratio of the potential exposure to a substance and the extent to which no negative consequences are predicted and calculated due to the fact the exposure is divided by means of the proper persistent or acute value. THQ method for hazard characterization had been applied in some research in which the estimation of hazard has been related to the concentrations of chemical substances in a particular meal object (Goumenou and Tsatsakis, 2019). THQ is typically used to estimate the potential non-carcinogenic hazard and was determined by the following formula, no significant health hazard is considered if the value of THQ < 1.

$$THQ = \frac{EDI}{RfD}$$

RfD values are given in Table 1 (USEPA, 2014). HI was calculated by sum up THQ of each element under investigation was determined by following formula.

$$HI = THQ_1 + THQ_2 + \cdot THQ_n$$

Where THQ1- n is target hazard quotients for 1-n metals.

2.6.3. Carcinogenic risk (CR)

CR by consuming contaminated sauce with Cr, As, Cd, and Pb for a lifetime exposure was calculated by the formula given below, where 0.5, 0.91, 0.38 and 0.0085 mg/kg/day is cancer slope factor (CSF) or Cr, Ni, Cd, and Pb respectively. 10^{-4} is a threshold, value $\geq 10^{-3}$ is a serious threat of cancer, and required attention at a higher priority (Kong et al., 2020).

CR=EDI x CSE (cancer slope factor)

3. Results and discussion

3.1. Analytical figure of merit

Accuracy is a very essential and high element in analytical results due to the fact these results are concerned with errors which reason the outcomes vary from the genuine concentration of determinants. The obtained results affect the ability of selections based mostly on those results. Different factors consist of purity of reagents, standards, the significance of matrices consequences, and environmental condition of the laboratory. To be able to make sure accuracy during the estimation

Table 4
Correlation coefficient matrix of HMs and TMs in sauce samples.

	Cr	Mn	Co	Ni	Cu	Zn	Cd	Pb
Cr	1	0.163	0.443	0.081	-0.081	-0.310	-0.161	0.054
Mn		1	0.240	0.024	0.141	-0.040	0.145	-0.102
Co			1	0.391	-0.150	-0.321	-0.030	-0.088
Ni				1	-0.260	-0.132	0.308	-0.170
Cu					1	0.272	-0.080	-0.382
Zn						1	0.067	-0.140
Cd							1	0.287
Pb								1

Table 3
TMs and HMs concentration (mg/kg) in different brand of sauce (n = 3).

Sample	Sauce Name	Cr	Mn	Co	Ni	Cu	Zn	Cd	Pb
SC1	Buffalo Hot	ND	3.04 ± 0.05	0.801 ± 0.058	2.04 ± 0.02	4.66 ± 1.31	1.82 ± 0.17	3.01 ± 0.78	0.121 ± 0.072
SC2	Hot	ND	3.10 ± 0.09	0.711 ± 0.046	2.07 ± 0.03	4.40 ± 1.07	1.76 ± 0.09	2.81 ± 0.64	0.171 ± 0.021
SC3	Habanero	ND	3.07 ± 0.05	0.722 ± 0.021	2.21 ± 0.12	4.13 ± 0.15	1.79 ± 0.06	2.29 ± 0.31	0.651 ± 0.192
SC4	Soy	ND	3.07 ± 0.10	0.833 ± 0.093	2.12 ± 0.07	4.66 ± 0.55	1.79 ± 0.11	2.39 ± 0.18	0.831 ± 0.111
SC5	Mint Coriander	ND	3.10 ± 0.09	0.651 ± 0.092	2.07 ± 0.02	5.28 ± 2.38	1.86 ± 0.27	3.53 ± 1.35	0.191 ± 0.062
SC6	Chili	ND	3.24 ± 0.26	0.833 ± 0.061	2.09 ± 0.06	4.75 ± 1.25	1.77 ± 0.07	3.22 ± 1.35	0.181 ± 0.006
SC7	Smoky BBQ	ND	3.10 ± 0.09	0.132 ± 0.041	2.08 ± 0.03	4.93 ± 1.99	1.80 ± 0.12	4.04 ± 1.39	0.141 ± 0.021
SC8	Thai Sweet Chili	ND	3.10 ± 0.09	0.164 ± 0.072	2.09 ± 0.06	4.84 ± 1.61	1.83 ± 0.99	3.84 ± 1.35	0.112 ± 0.031
SC9	Mango Chili	ND	3.16 ± 0.05	0.101 ± 0.030	2.08 ± 0.10	4.31 ± 0.92	1.80 ± 0.01	4.04 ± 1.52	0.953 ± 0.041
SC10	Imlee Ginger	ND	3.13 ± 0.14	0.812 ± 0.021	2.14 ± 0.02	4.66 ± 1.53	1.83 ± 0.17	4.04 ± 1.29	0.181 ± 0.051
SC11	Pizza	ND	3.04 ± 0.05	0.121 ± 0.012	2.05 ± 0.00	4.31 ± 0.70	1.81 ± 0.11	3.01 ± 1.52	0.911 ± 0.132
SC12	Tomato Ketchup	ND	3.10 ± 0.09	0.712 ± 0.032	2.06 ± 0.02	4.75 ± 1.68	1.80 ± 0.14	3.73 ± 0.99	0.192 ± 0.041
SC13	Chup Mayo	ND	3.21 ± 0.20	0.711 ± 0.091	2.09 ± 0.08	4.75 ± 0.77	1.77 ± 0.08	4.25 ± 1.46	0.123 ± 0.022
SC14	Pepper	ND	3.36 ± 0.39	0.781 ± 0.102	2.09 ± 0.03	5.28 ± 1.07	1.84 ± 0.14	4.04 ± 1.39	0.784 ± 0.103
SC15	Hot	ND	3.10 ± 0.09	0.781 ± 0.153	2.05 ± 0.02	4.93 ± 1.53	1.82 ± 0.08	2.81 ± 0.78	0.981 ± 0.052
SC16	Mustard	ND	3.19 ± 0.23	0.832 ± 0.141	2.08 ± 0.05	4.13 ± 0.61	1.79 ± 0.11	4.25 ± 1.17	0.932 ± 0.041
SC17	Peri-Peri Hot	ND	3.10 ± 0.09	0.771 ± 0.071	2.12 ± 0.03	4.58 ± 1.38	1.78 ± 0.12	3.53 ± 1.11	0.771 ± 0.072
SC18	Chaat	ND	3.24 ± 0.34	0.772 ± 0.022	2.09 ± 0.04	4.22 ± 0.77	1.79 ± 0.10	4.04 ± 1.59	0.271 ± 0.022
SC19	Imlee	ND	3.10 ± 0.15	0.691 ± 0.152	2.06 ± 0.02	4.40 ± 1.07	1.77 ± 0.07	3.53 ± 1.24	0.191 ± 0.051
SC20	Oyster	ND	3.19 ± 0.15	0.723 ± 0.011	2.18 ± 0.02	4.22 ± 0.77	1.81 ± 0.11	8.01 ± 1.69	0.721 ± 0.014
SC21	Worcestershire	ND	3.10 ± 0.09	0.121 ± 0.032	2.06 ± 0.02	5.11 ± 1.61	1.85 ± 0.11	3.42 ± 0.99	0.691 ± 0.051
SC22	HP Barbecue	ND	3.21 ± 0.14	0.162 ± 0.072	2.08 ± 0.03	4.75 ± 1.46	1.80 ± 0.04	3.84 ± 1.35	0.622 ± 0.012
SC23	Caramel	ND	3.21 ± 0.05	0.162 ± 0.031	2.04 ± 0.02	4.40 ± 1.07	1.79 ± 0.15	4.25 ± 1.25	0.121 ± 0.033
SC24	Chocolate	ND	3.13 ± 0.20	0.101 ± 0.032	2.09 ± 0.07	4.66 ± 1.53	1.87 ± 0.28	3.11 ± 0.18	0.161 ± 0.071
SC25	Strawberry	ND	3.13 ± 0.14	0.122 ± 0.091	2.06 ± 0.03	4.93 ± 1.77	1.87 ± 0.25	3.84 ± 1.35	0.182 ± 0.032
SC26	Spaghetti Pasta	ND	3.07 ± 0.05	0.381 ± 0.031	2.09 ± 0.02	4.66 ± 1.31	1.79 ± 0.10	3.63 ± 1.17	0.105 ± 0.033
SC27	Classic Mayo	ND	3.19 ± 0.18	0.202 ± 0.071	2.07 ± 0.03	4.40 ± 1.07	1.78 ± 0.11	4.35 ± 1.29	0.481 ± 0.102
SC28	Garlic Mayo	ND	3.19 ± 0.23	0.751 ± 0.012	2.12 ± 0.03	4.58 ± 1.38	1.79 ± 0.12	2.81 ± 0.47	0.141 ± 0.021
SC29	Chili Garlic	ND	3.10 ± 0.09	0.292 ± 0.011	2.06 ± 0.02	5.99 ± 0.15	1.77 ± 0.09	3.63 ± 1.17	0.154 ± 0.011
SC30	Green Chili	ND	3.10 ± 0.09	0.711 ± 0.002	2.05 ± 0.00	4.75 ± 1.68	1.80 ± 0.13	2.91 ± 0.62	0.163 ± 0.032

ND = not detected

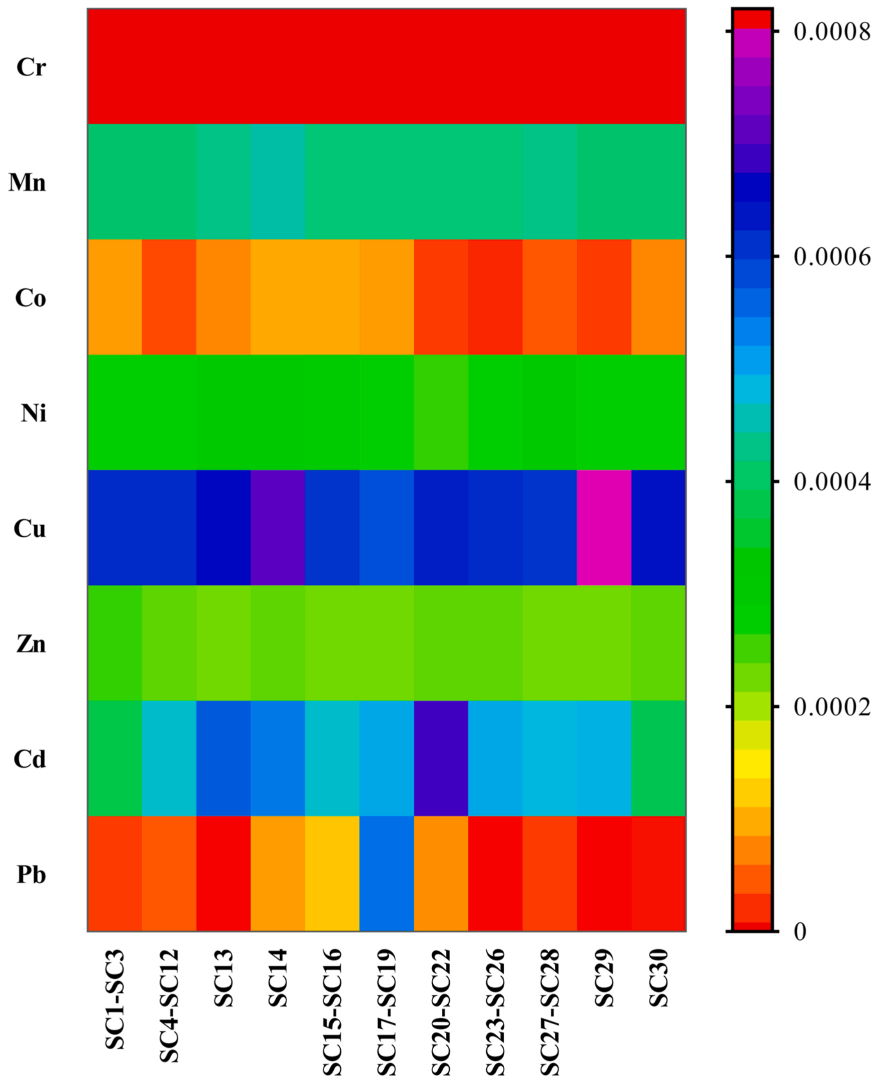

Fig. 1. Estimated daily intake of HMs and TMs from sauce under investigation.

of Cr, Mn, Co, Ni, Cu, Zn, Cd, and Pb in actual samples, NIST, SRM 2384 (baking chocolate) were analyzed and results have been provided in terms of % recovery studies (Table 2). The recovery results that had been acquired ranged from 98.6 % to 101.2 % that determining the top-notch extraction efficiency of respective metals. The repeatability (n = 10) was also evaluated by analyzing the SRM 2384 to assess the precision of the method and the results are presented in % RSD (Table 1S) which were obtained in the range of 0.20–6.40.

0.2–1.0 μg/mL for Mn, Cu, Co, Ni, and Zn, 0.01–500 μg/L for Cr, Cd, and while 0.02–1000 μg/L for Pb concentration range was selected and plotted a curve as concentration vs peak height as a response in form of $y = mx + b$, where slope and intercept are represented by "m" and "b" respectively.

3.2. Application to real samples

Cr is vital in the breakdown of carbohydrates and fats. It also aids in insulin action and the breakdown of glucose. It is also one of the toxic metals which have many industrial applications (Mishra and Bharagava, 2016). But it is not beneficial for human health at high concentrations and causes nasal, lung, and sinus cancers in consumers (Aydin, 2008). The permissible limit of Cr proposed by WHO/FAO is 0.4 mg/kg and in our, study Cr was not detected in any of sauce sample.

Mn is one of the essential trace metals, vital for proper cell functioning and metabolism (Tuschl et al., 2013). In case of high exposure, manganese has proven to be toxic and may result in hepatitis, anemia, cardiac defects, and skin problems (Chen et al., 2016). The concentration of manganese found in our study was within the permissible limit set by WHO/FAO (5 mg/kg) with the maximum concentration (3.36 ± 0.39 mg/kg) in SC14 (Pepper Sauce) as shown in Table 3. In comparison with the previous study from Bangladesh, the concentration of Mn found is higher than our results (Mehrin et al., 2020).

Co is an essential heavy metal used as a co-factor to sustain two vitamin B12-dependent enzymatic reactions in the biochemical pathway (Chou et al., 2009). A high concentration of Co can result in disorders including dermatitis, lung cancer, asthma, cardiomyopathy, and neurological problems (Lauwerys and Lison, 1994). The permissible limit of Co proposed by the European Union is 0.05 mg/kg and its concentration in all our samples was above the permissible limit with the highest average amount (0.83 ± 0.64 mg/kg) found in SC16 (Mustard Sauce). Also, the amount of Co was higher than reported results in Turkey and Bahrain (Musaiger et al., 2008; Tuzen and Soylak, 2007).

Ni content in our study was above the threshold limit with the highest concentration (2.21 ± 0.12 mg/kg) in SC3 (Habanero Sauce) as set by WHO/FAO (0.5 mg/kg). Ni is found everywhere in the environment, but its functionality in vivo essentially has not been recognized so far (Genchi et al., 2020). It is very harmful to human health as its

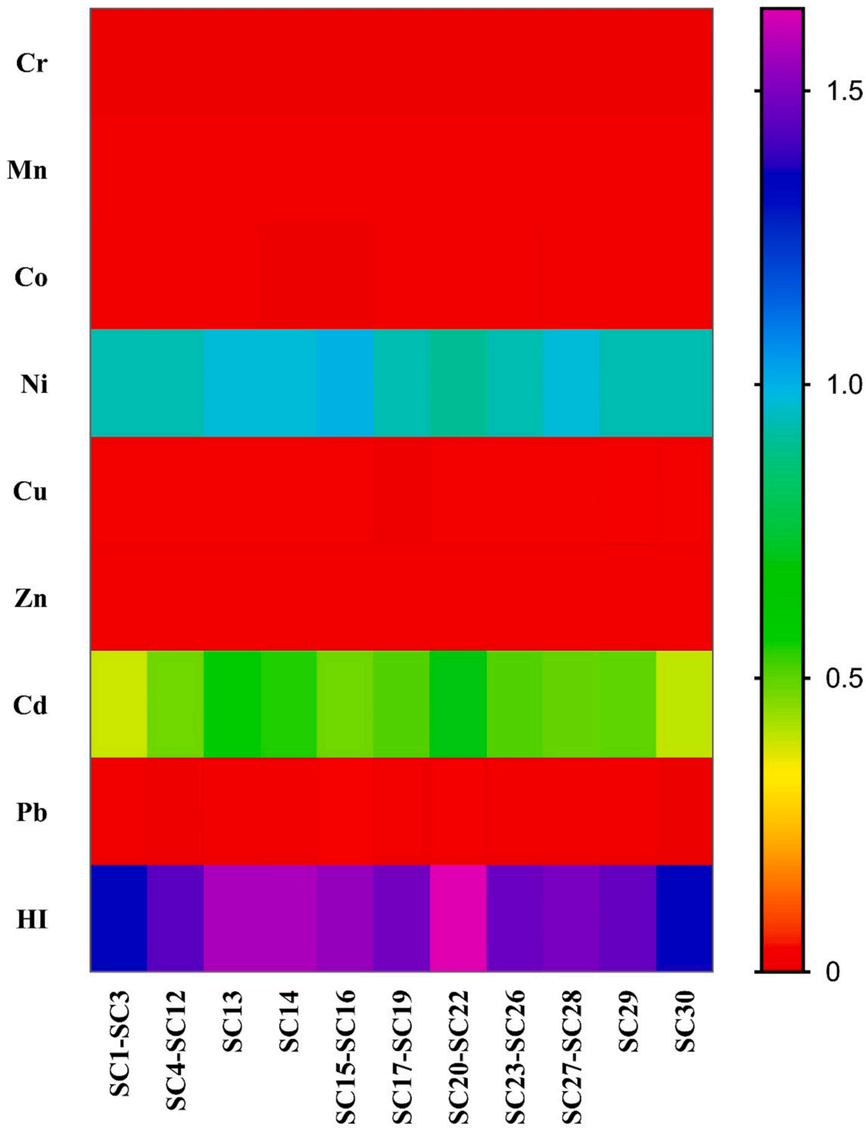

Fig. 2. Target hazard quotient and hazard index values due to consumption of sauce of different brands.

overdose causes vertigo, palpitation, insomnia, bone, blood, and brain cancer (Rehman et al., 2018a). Relatively, measured levels of Ni in our samples were significantly higher than the previous report from Nigeria (Onwuka et al., 2019).

Cu is an essential trace metal that acts as a co-factor of many redox enzymes due to their dependent oxidation activity. Ceruloplasmin is the most abundant Cu-dependent ferroxidase enzyme, involves in biological processes like neuropeptide synthesis, antioxidant defense, immunological functioning, and iron metabolism. Due to copper toxification in the body, different ailments appear like renal failure, acute gastroenteritis, Wilson's disease, and hemolytic anemia (Bost et al., 2016). Cu concentration was under the permissible limit proposed by WHO/FAO (50.0 mg/kg) with the maximum amount in SC23 (Chili Garlic Sauce). In comparison, the concentration of Cu in our samples was higher than in a previous report from Pakistan (Abbasi et al., 2020).

Zn plays an essential role in biological processes as it acts as a catalyst for many enzyme-controlled metabolic activities, physiological and immune functioning, and antioxidant properties (Yuan et al., 2020). On the other hand, the overdose of zinc can cause vomiting, nausea, anemia, abdominal pain, and respiratory disorders (Zahra and Kalim, 2017). The WHO/FAO proposed value (5.0 mg/kg), the concentration of Zn found in our study was within the permissible limit and the maximum value was 1.87 ± 0.28 mg/kg in SC24 (Chocolate Topping) and these values are lower than the reported from Bahrain and Bangladesh (Haque et al., 2019; Musaiger et al., 2008).

Cd is important in different industries for different purposes but it is a carcinogenic metal that causes adverse effects on human health even at a very low level of exposure. Thus, it causes anemia, lung cancer, cardiovascular diseases, and kidney disorders. In general, diet is the main source of Cd exposure (Nordberg et al., 2018). The permissible limit of Cd set by WHO/FAO is 0.5 mg/kg. The results showed the concentration of Cd determined in this study was exceeding the recommended standard value in all samples. SC20 (Oyster Sauce) showed the highest amount (8.01 ± 1.69 mg/kg), and also the concentration of Cd was higher in our study relative to the previous report from Poland, Bahrain, and Bangladesh (Grochowska-Niedworok et al., 2020; Haque et al., 2019; Musaiger et al., 2008).

Pb is a probable carcinogenic metal that causes adverse effects on human health even at a very low level of exposure. Thus, it damages the central nervous system particularly in developing fetuses and children, it also causes Alzheimer's disease, nephropathies, and alterations of the gastrointestinal tract (Fathabad et al., 2018; Hsu et al., 2006; Paz et al., 2019). The data showed the amount of Pb determined in this study was less than the recommended standard value set by WHO/FAO

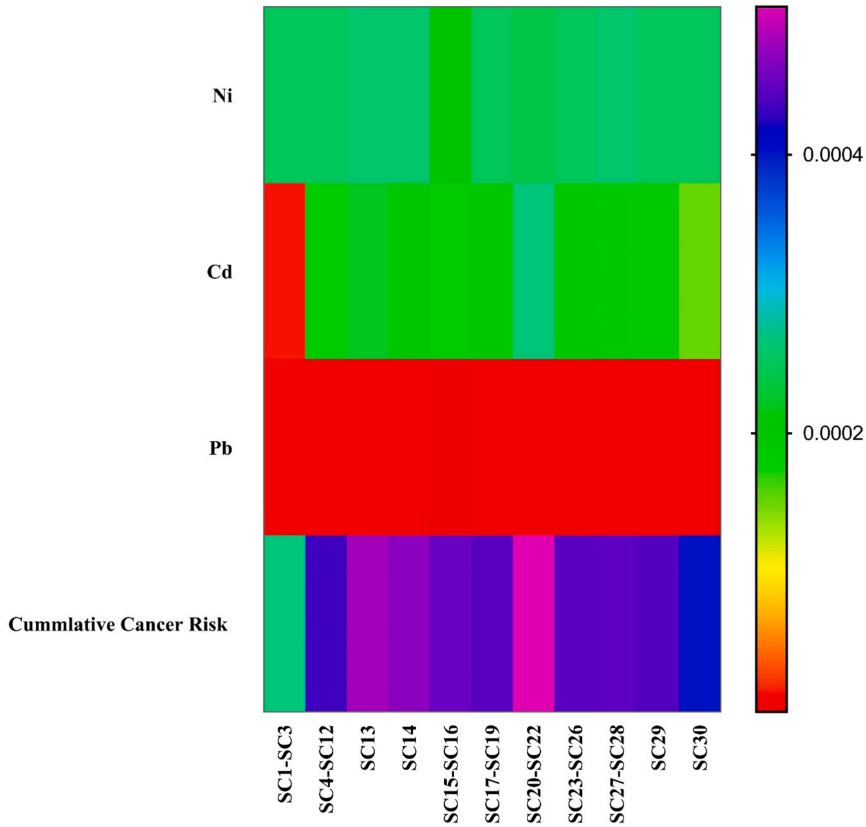

Fig. 3. Cancer risk and cumulative cancer risk due to consumption of sauce of different brands.

(1.0 mg/kg) in all samples. SC15 (Hot Sauce) showed the highest amount (0.981 ± 0.052 mg/kg), and also the concentration of Pb was lower in our study relative to the previous report from Poland, Bahrain, and Bangladesh (Grochowska-Niedworok et al., 2020; Haque et al., 2019; Musaiger et al., 2008).

3.3. Statistical analysis

The different samples' means were compared by using SPSS version 15 software by Pearson's test. The test was performed to specify the viable correlation amongst variable series that have been measured within the present day work as shown in Table 4. The relationship can be recognized from a coefficient (r) value, which indicates the strength degree of association between two variables. To clarify significant differences among mean values at the probability level of ($p < 0.05$), the results of correlation analysis between metal concentrations in sauces are considered a weak correlation ($p < 0.05$). A weak relationship between Mn-Cu and Mn-Cd was found at $r = 0.141$ and $r = 0.145$ respectively. Also, there is a moderate relationship observed among the Ni-Cd and Cu-Zn at $r = 0.308$ and $r = 0.272$ respectively. Here are no definite or established relationships between most of the metal concentrations under observation. Mn-Cu and Cu-Zn suggest their common reasons of contamination in processed ingredients which includes various activities involved in food processing industries where the containers made of steel alloy in which mixing the different ingredients is taken place during the manufacturing of sauce.

3.4. Calculation of impact on human health

3.4.1. Estimated daily intake

Based on 10 g a single serving dose of sauce was considered to calculate the EDI of HMs (Cd and Pb) and TMs (Cr, Mn, Co, Ni, Cu, and Zn). EDI of Cu was observed highest while the lowest for Pb among the metals under investigation (Fig. 1). The highest value of EDI was 8.2×10^{-4} mg/kg/day for Cu whereas 0.2×10^{-4} mg/kg/day for Pb was observed for the sauce code SC29 (Chili Garlic) (Table 2S).

3.4.2. Target hazard quotient and hazard index

THQ for the HMs and THs were determined in the sauce of different brands to evaluate the non-carcinogenic health threats. THQ of Ni was observed highest ranging between 0.90 and 1.0 (Fig. 2a) the THQ value for Ni in sauce (Hot, SC15 and Mustard, SC16) indicating that ingestion of sauce of this brand could posed a borderline non-cancer risk (Table 3S). THQ values were obtained in order of Ni > Cd > Cu > Pb > Co > Mn > Zn (Table 3S). Hazard index value for all the brands under investigation was > 1 (Fig. 2), which indicated the non-carcinogenic health threat to consumers (Table 3S).

3.4.3. Carcinogenic risk

CR was evaluated by employing the carcinogenic slope factor from a lifetime exposure of TMs (Ni) and HMs (Cd and Pb) by consuming the sauce of different brands. 10^{-4} is the threshold value whereas the value $\geq 10^{-3}$ can be considered serious. The CR values for Ni were obtained at the threshold level which is an alarming situation and needs attention to review the process of manufacturing and raw material used for the preparation of the sauce. The lowest CR value was obtained for Pb (Fig. 3). However cumulative cancer risk values (Table 4S) are comparable with threshold value (Fig. 3).

4. Conclusion

Sauces are widely consumed all over the globe and can be a potential source of HMs and TMs which can cause numerous disorders on long-term exposure. Hence, to assess health concerns related to their consumption it was necessary to detect and quantify HMs and TMs in them. The presence of these metals in these sauces' brands was determined by

FAAS and ICP-OES. Cu, Zn, Mn, and Pb were below the permissible limits and Cr was not detected by the method used in all samples while Ni, Co, and Cd were above the permissible limits as defined by WHO/FAO. A statistical test, Pearson's correlation was performed to determine the relationship between the concentrations of HMs and TMs under investigation. There were no definite or established relationships between most of the metal concentrations under observation. The highest value of EDI was 8.2×10^{-4} mg/kg/day for Cu whereas 0.2×10^{-4} mg/kg/day for Pb was observed for the sauce code SC29 (Chili Garlic), THQ value for Ni in sauce (Hot, SC15 and Mustard, SC16) is ≥ 1, whereas HI value of all the brands was obtained in range of 1.35–1.64 which is > 1, indicated that ingestion of sauce of these brands could posed a non-cancer risk. The CR values for Ni ($2.5–2.7 \times 10^{-4}$) were obtained at the threshold level which is an alarming situation and needs attention to review the process of manufacturing and raw material used for the preparation of the sauce.

Funding

There has been no financial support for this work that could have influenced its outcome.

CRediT authorship contribution statement

Anum Khaleeq: Supervision, Writing – review & editing. **Mahmood Ahmed**: Investigation, Methodology, Formal analysis, Writing – review & editing. **Rahila Huma**: Methodology, Formal analysis. **Aiman Mujtaba**: Review, Analysis. **Sara Noor**: Review, **Rimsha Rehman**: Optimization, Writing – original draft. **Tahir Ali Sheikh**: Formal analysis, Review. **Shaista Qamar:** Review, Analysis. **Dure Najaf Iqbal:** Writing – review & editing. **Rima D. Alharthy:** Optimization. **Abdul Hameed:** Review, Analysis.

Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication.

Informed consent

Not applicable.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jfca.2022.104789.

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