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Original Article

Contamination levels of toxic metals in selected traditional plants incense (gum)

Níveis de contaminação de metais tóxicos em plantas tradicionais selecionadas incenso (goma)

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Abstract

Gums are polysaccharides, proteins, and minerals that occur naturally in seed coverings and as exudative resinous substance from woody plants. It is reported to have antibacterial, anticancer, blood sugar regulation, and immune system boosting properties. However, the presence of toxic metals in gum is caused for caution as these metals can be harmful if taken in high quantities. The purpose of this study was to determine the amounts of toxic metals in gums collected from the local market, as many consumers tend to use them daily for incense or food ingredients. Gum samples were extracted from several parts of 10 selected medicinal plants (bark, sap, root, latex, leaf glue, and gum). Two fractions of each sample were produced using nitric acid (NHO_3), followed by hydrochloric acid (HCl) at first and then hydrogen peroxide (H_2O_2). The presence of toxic metals in the solutions was determined using an Inductively Coupled Plasma Atomic Emission Spectrometer (ICP OES). The results showed that most of the elements were detected in high concentrations in *Commiphora myrrha* (Cd, Cu, Fe, K, Mn, Ni, Pb, and Zn) followed by Benzoin resin (Jawi Oud) and *Paeonia officinalis*. The most prevalent elements detected in all of the herbal gums were potassium (K) and iron (Fe). Fortunately, the sampled herbal gums were found to be within the WHO/FAO permitted range. This study may provide insights about the safety of the selected gums to be used for food applications. Further *in vitro* and *in vivo* toxicity studies should be performed to identify the safe dose.

Keywords: arabic gum, herbal plants, ICP OES, toxic metals.

Resumo

As gomas são polissacarídeos, proteínas e minerais que ocorrem naturalmente nas cascas de sementes e como substância resinosa exsudativa de plantas lenhosas. Possuem propriedades antibacterianas, anticancerígenas, reguladoras de açúcar no sangue e do reforço do sistema imunológico. No entanto, a presença de metais tóxicos na goma é motivo de cautela, pois esses metais podem ser prejudiciais se ingeridos em grandes quantidades. O objetivo deste estudo foi determinar as quantidades de metais tóxicos nas gomas coletadas no mercado local, já que muitos consumidores tendem a utilizá-las diariamente para incenso ou ingredientes alimentares. Amostras de goma foram extraídas de diversas partes de 10 plantas medicinais selecionadas (casca, seiva, raiz, látex, cola de folhas e goma). Duas frações de cada amostra foram produzidas utilizando ácido nítrico (NHO_3), seguido primeiro de ácido clorídrico (HCl) e depois de peróxido de hidrogênio (H_2O_2). A presença de metais tóxicos nas soluções foi determinada utilizando um Espectrômetro de Emissão Atômica com Plasma Acoplado Indutivamente (ICP OES). Os resultados mostraram que a maioria dos elementos foi detectada em altas concentrações em *Commiphora myrrha* (Cd, Cu, Fe, K, Mn, Ni, Pb e Zn) seguida pela resina de benjoim (Jawi Oud) e *Paeonia officinalis*. Os elementos mais prevalentes detectados em todas as gomas vegetais foram o potássio (K) e o ferro (Fe). Felizmente, descobriu-se que as gomas herbáceas amostradas estavam dentro da faixa permitida pela OMS/FAO. Este estudo pode fornecer *insights* sobre a segurança das gomas selecionadas para uso em aplicações alimentícias. Devem ser realizados mais estudos de toxicidade *in vitro* e *in vivo* para identificar a dose segura.

Palavras-chave: goma arábica, plantas fitoterápicas, ICP OES, metais tóxicos.

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1. Introduction

The medicinal benefits in plants have been linked to phytochemical elements associated with various plant species (Yogi et al., 2021; Hamdani et al., 2019; Ashour et al., 2022; Lelon et al., 2010; Mariod, 2018). Since ancient times, humans have used plant parts for therapeutic purposes (Yogi et al., 2021). Gum is used for a range of things, including emulsifiers, foaming agents, and stabilizers (Hamdani et al., 2019). It can improve the texture and stability of numerous products (Ashour et al., 2022; Lelon et al., 2010; Mariod, 2018), and some gums are reported to have antibacterial, anticancer, blood sugar regulation, and immune system boosting properties. Therefore, humans have employed plant parts for therapeutic purposes (Yogi et al., 2021; Ashour et al., 2022) Due to the great diversity of floral species in Saudi Arabia, it is valuable to select the medicinal plants rich in gums for the purpose of analyzing the toxic metals in their gums. The ten studied medicinal plants include *Commiphora myrrha*, *Ferula assa-foetida*, *Styrax benzoide* (Jawi Oud, White Musk Jawi, Black Musk Jawi, and Jawi Anbar), *Boswellia sacra*, *Acacia seyal*, *Aloe perryi*, and *Paeonia officinalis*.

Commiphora myrrha is a species from the family Burseraceae, which is distributed in arid, tropical and sub-tropical climates, such as southern Arabia, northern Somalia and other parts of the world (Abukhader and Al Tawaha, 2021; Germano et al., 2017). *Commiphora* produce Myrrh, an exudate from its bark that has been used as a traditional medicine for many years by Chinese, Indians, Africans as well as Arabs to cure various conditions, such as inflammation and teeth infections (Orabi et al., 2020). Asafoetida is an oleo-resin gum derived from the roots of several *Ferula* species that belong to the family *Apiaceae* (Iranshahi et al., 2018). The plant grows from the Mediterranean region to Central Asia, including Turkey, Iran, Afghanistan, China, India and Iraq, as well as Europe and North Africa (Amalraj and Gopi, 2017). Its medicinal effects have been applied in the treatment of respiratory disorders such as whooping cough, asthma, bronchitis and even tuberculosis (Iranshahi et al., 2018; Ghasemi et al., 2021). Acacia is a genus of the Fabaceae family (Ashour et al., 2022). The Acacia plant has been used to treat several ailments due to phytoconstituents from its bark, roots, fruits, and gum (Ashour et al., 2022; Ahmed, 2018; Alajmi et al., 2017; Batiha et al., 2022; Kaddam et al., 2018). It showed antibacterial, antimalarial, anticancer, antioxidant, anti-mycobacterial, and immune system modulating properties (Ashour et al., 2022; Ahmed, 2018; Alajmi et al., 2017; Kaddam et al., 2018; Al-Baadani et al., 2022; Baien et al., 2020).

Benzoin is a complex balsamic resin that occurs naturally in the sap of Styrax plant. It is found throughout eastern and southeastern Asia, including Thailand, Laos, Indonesia, and Vietnam (Li et al., 2021). Benzoin resin has traditionally been used to treat erythema, coughs, and wounds in Asia (Li et al., 2021). *Boswellia sacra* is a genus from the Burseraceae family and is indigenous to Yemen and Oman. Its medicinal properties include anti-inflammatory, antibacterial and anti-cancer (Parsonidis et al., 2021). *B. sacra* has been used to treat pain, as an analgesic, antioxidant and cardio-protective agent (Di Stefano et al., 2020; Asad and Alhomoud, 2016). *Aloe perryi* is a member of the Aloe genus, which is the largest genus in the Asphodelaceae family. the Aloe genus contains about 500 species and the majority of which are indigenous to Africa, with other species found in the Arabian Peninsula and Madagascar (Cock, 2015). *Aloe perryi* is also known as Socotrine Aloe due to its location on the Yemeni island of Socotra in the Arabian Peninsula (Cock, 2015). It is often used in the treatment of burns, wounds and, as antidiabetic, as well as for the treatment of skin conditions (Aldayel et al., 2020). *Paeonia officinalis* is a member of the *Paeonia* genus peony. Volatile oil, benzoic acid, tannic acid, paeonol, asparagine, flavonoids, paeoniflorin, protoanemonin, and paeonin are among the active chemicals found in *P.officinalis* root (Li et al., 2021). *P. officinalis* has been used as a traditional medicine. The root of the plant is used for its spasmolytic and astringent properties (Demirboğa et al., 2021). All these medicinal plants produce gums, attracting toxic metals that can be a source of toxicity.

Toxic metals are naturally occurring elements with atomic weights greater than those of other elements. Metals such as lead, mercury, cadmium, and chromium are often found in the environment (Rawi et al., 2021; Jarrar et al., 2021). When consumed in significant amounts, toxic metals can be hazardous to humans, animals, and plants (Azzaoui et al., 2015). The presence of toxic metals in food and beverage products, such as medicinal plants and Gum, can be a cause for concern, as these metals can accumulate in the body and cause health concerns (Philp, 2018; Korfali et al., 2013a). Toxic metal concentrations in gum samples from various sources have been found to vary Ernst, 2002; Mahurpawar, 2015; Korfali et al., 2013b). The most abundant toxic metals discovered in gums samples from various sources were lead and cadmium followed by chromium and mercury (Ernst, 2002; Korfali et al., 2013a; Harris et al., 2011) Moreover, processing methods, such as drying, milling, and packaging as well as contamination from the environment can increase the concentration of toxic metals in gum (Abou-Arab and Abou Donia, 2000; Singh et al., 2011). Trace elements play vital roles in the regular functioning of bodily organs and are essential in life. Toxic metals can build up in the body and harm organs, neurons, and the endocrine system (Alwakeel, 2008; Rahimi et al., 2012; Balali-Mood et al., 2021). Lead is especially hazardous to children, as it can cause brain damage, learning impairments, and behavioral issues (Mensah et al., 2009). Cadmium can harm the kidneys and liver, as well as create reproductive issues (Mensah et al., 2009). Chromium can irritate the skin, while mercury can induce neurological damage (Mensah et al., 2009). Existing studies and reviews have assessed the physical properties and the constituents of gums e.g. (Ashour et al., 2022; Lelon et al., 2010) from different parts of the world however, and one study assessed metal contamination in herbal plants used among citizens (Almahasheer, 2020). Thus, this study aims to evaluate the toxic metals in the gum extracted from 10 selected plants. To the best of our knowledge, this is the first study that has assessed metal contamination in gum samples taken from local Saudi market. The research issue addressed by this study was, “What level of toxic metals contained in gums Saudi Arabia is above the permissible level set by the World Health Organization?” (WHO, 2016)

2. Methodology

2.1. Materials and reagent

All reagents were of an analytical grade. Throughout the studies, the solutions and vessels were prepared with double-deionized water produced by the Milli Q water purification system (Millipore), which was used in all dilutions. Trace analysis reagents included H_2O_2 (30%), HNO_3 (69%), and HCl (37%), all of which were obtained from Sigma Aldrich. These reagents are often used to digest environmental materials. All element stock solutions (1000 mg/l, ICP standard CertiPUR) were obtained from Merck (Germany), and the elements' standard solutions were prepared by diluting them.

2.2. Sample preparation

Ten samples of medicinal plants were acquired from the local market in Saudi Arabia. The samples were obtained from municipality-approved authorized stores. The scientific and popular names of the selected herbal plants are presented in (Table 1, Figure 1). For metal analysis, all samples were pulverized, sieved, photographed, and stored in plastic bags. Three replicated samples (n = 3) were taken from each medicinal plant and placed on the electronic analytical balance (Mettler Toledo ME204). The weight of each sample was measured. A total of 30 samples were weighed and labelled as primary weight and secondary weight. Using distilled water, the Teflon vessels were washed and dried well. Then, the samples were immersed in 2 ml of hydrogen peroxide 30% w/v (100 vol.) stabilised pure (H_2O_2) for the primary weight and 2 ml of hydrochloric acid (HCl) for the secondary weight. After that, 6 ml of pure pharma grade 69% nitric acid (HNO_3) (USP-NF, BP, Ph. Eur.), was added for all samples. The Teflon vessel was tightly closed to be inserted into the microwave. The volume of H_2O_2, HCl, and HNO_3 was determined according to the weight of the samples.

2.3. Microwave digestion system

Acid digestion with a high-performance microwave digestion system was used to digest the samples conveniently. The Teflon vessels run in a microwave-assisted acid-digestion system was set, and the total weight was approximately 500 mg + 3 ml (HNO_3) + 2 ml (H_2O_2). The whole process was performed in 8 h. The sample microwave digestion settings were 600 W at 120°C for 15 min followed by 600 W at 180°C for 20 min, and 20 min of venting. The Teflon vessels were ventilated for 50 min. After cooling at 40 °C for 30 min, ultra pure water was added to the pre-processed solution, and the volumes were diluted to 10 ml. The resulting solutions were filtered through 110 µm polytetrafluoroethylene membrane filters (Whatman) for Inductively Coupled Plasma Atomic Emission Spectrometer (ICP OES) analysis.

2.4. Inductively Coupled Plasma Atomic Emission Spectrometer (ICP OES)

The ICP OES (Agilent 7500ce with ORS) method provides great precision and accuracy for multi-elemental analysis

Table 1. The names, family, and part assayed of medicinal plants producing gum.

S/no.	Names		Family	Analyzed Part
	Scientific	**Common**		
1	*Commiphora myrrha*	Myraah	Burseraceae	The bark of plants
2	*Ferula assa-foetida*	Hing, Devil's dung	Apiaceae	Roots and stems
3	*Styrax benzoin dryander, Styrax benzoide*	Benzoin resin (Jawi Oud)	Styracaceae	The sap of the tree
4	*Styrax benzoin dryander, Styrax benzoide*	Benzoin resin (White Musk Jawi)	Styracaceae	The sap of the tree
5	*Styrax benzoin dryander, Styrax benzoide*	Benzoin resin (Black Musk Jawi)	Styracaceae	The sap of the tree
6	*Styrax benzoin dryander, Styrax benzoide*	Benzoin resin (Jawi Anbar)	Styracaceae	The sap of the tree
7	*Boswellia sacra*	Frankincense, olibanum, al-luban	Burseraceae	The bark of plants
8	*Acacia seyal, A.senegal*	Gum Arabic	Fabaceae, Leguminosae	Trunk, branches, stem or stalks
9	*Aloe perryi*	Socotra aloe	Asphodelaceae	Leaves glue
10	*Paeonia officinalis*	Common Paeony, Garden Paeony	Paeoniaceae	Latex

Figure 1. The herbal gums used in this study. *Commiphora myrrha* (01); *Ferula asafoetida* (02); Benzoin resin (Black Musk Jawi) (03); Benzoin resin (Jawi Oud) (04); Benzoin resin (White Musk Jawi) (05); Benzoin resin (Jawi Anbar) (06); Frankincense, olibanum, al-Luban (07); *Acacia seyal*, *A. senegal* (08); *Aloe perryi* (09); *Paeonia officinalis* (10).

due to its sensitivity and ability to use large sample size. Hence, it was used to evaluate the toxic metals in the gum samples. The ICP OES analysis was performed after the samples were filtered entirely. The diluted water samples, standard models, and filtered samples were initially injected. Concentrations of seventeen elements including cadmium (Cd), copper (Cu), iron (Fe), potassium (K), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) were analysed using ICP OES. During the measurements, the ICP-OES spectrometer operated under the following conditions: RF power; 1400 W, auxiliary argon flow rate; 2.00 L/min, plasma argon flow rate; 13 L/min, and nebuliser argon flow rate; 0.95 L/min. According to the operating conditions mentioned, the most notable analytical lines were selected. The analytical method's precision was measured by the repeatability of real-sample results, given as standard deviation (SD) and the calibration was used to ensure accuracy. Calibration verification was carried out after each set of all samples by analysing a midpoint concentration standard (check standard) at regular intervals throughout the run. Quality assurance was maintained throughout the analytical procedure by including a reference material in between sample analyses. To adjust for matrix effects, the internal standards (^{45}Sc, ^{89}Y, and ^{159}Tb) were used in conjunction with the ICP-OES technique. Additional information of accuracy of the results are presented in the Supplementary Material S1.

2.5. Statistical analysis

The data were presented as the mean ± SD of three replicates. The examination of significant differences was carried out using ANOVA. Statistical calculations were performed using Microsoft Excel and SPSS software version 18 (SPSS Inc., Chicago, IL, USA). The Pearson correlation test was also run using SPSS software to determine the relationships among variables. The significance level was set as $p < 0.05$.

3. Results and Discussion

Table 2 shows the results of toxic metals analysis in the herbal gum samples. The analysis of gums from the medicinal plants showed that *C. myrrha* gum contained the highest levels of most elements (Cd, Cu, Fe, K, Mn, Ni, Pb, and Zn) followed by Benzoin resin (Jawi Oud) and *P. officinalis.* Potassium (K) and iron (Fe) were the most typical elements found in all of the herbal gums (Figure 2, Table 2). Many of the assessed features are essential nutrients that help to maintain normal human physiological functions.

Table 2. Average concentrations of toxic metals (mg/kg ± SD) of the 10 selected medicinal gums from the Eastern Region of Saudi Arabia.

Herbal gums	Code	Average concentrations of toxic metals in mg/kg ± SD							
		Cd	Cu	Fe	K	Mn	Ni	Pb	Zn
Myraah	MR	0.18 ± 0.11	0.325 ± 0.01	6.51 ± 5.78	39.275 ± 2.16	1.075 ± 0.81	1.285± 0.12	1.64 ± 0.65	0.755 ± 0.28
Hing, Devil's dung	HI	0.045 ± 0.01	0.13 ± 0.03	1.42 ± 0.37	1.2 ± 0.13	0.12 ± 0.06	0.045 ± 0.01	0.55 ± 0.11	0.35 ± 0.13
Jawi Oud	GW	0.17 ± 0.03	0.6 ± 0.14	2.745 ± 0.64	1.975 ± 0.19	0.215 ± 0.02	0.55 ± 0.51	3.615 ± 0.67	1.195 ± 0.22
White Musk Jawi	WMG	0.015 ± 0.01	0.065 ± 0.04	0.185 ± 0.02	0.17 ± 0.03	0.01 ± 0	0.025 ± 0.01	0.335 ± 0.16	0.06 ± 0.01
Black Musk Jawi	BMG	0.01 ± 0	0.03 ± 0	0.55 ± 0.33	0.24 ± 0.11	0.03 ± 0.01	0.11 ± 0.04	0.155 ± 0.02	0.19 ± 0.01
Al-Luban	LDH	0.02 ± 0	0.02 ± 0	0.135 ± 0.02	0.89 ± 0.25	0.01 ± 0	0.05 ± 0.04	0.1 ± 0	0.075 ± 0.02
Gum Arabic	GA	0.03 ± 0	0.015 ± 0.01	0.065 ± 0.01	5.7 ± 0.52	0.005 ± 0.01	0.01 ± 0	0.17 ± 0	0.11 ± 0
Sacotra Aloe	SR	0.01 ± 0	0.015 ± 0.01	0.125 ± 0.02	1.64 ± 0.16	0.01 ± 0	0.01 ± 0	0.035 ± 0.01	0.07 ± 0.03
Jawi Anbar	G ANB	0.02 ± 0	0.08 ± 0.01	0.205 ± 0.09	0.275 ± 0.01	0.025 ± 0.02	0.02 ± 0	0.36 ± 0.04	0.075 ± 0.05
Common Paeony	O MAT	0.035 ± 0.01	0.025 ± 0.01	0.055 ± 0.02	8.02 ± 11.34	0.01 ± 0	0.01 ± 0	0.2 ± 0.04	0.16 ± 0.01
FAO/WHO maximum permissible values (mg/kg)		0.3	10.0	20.0	3,400 (mg/d)	200	1.5	10.0	50.0

The data are presented as the mean ± SD of three replicates.

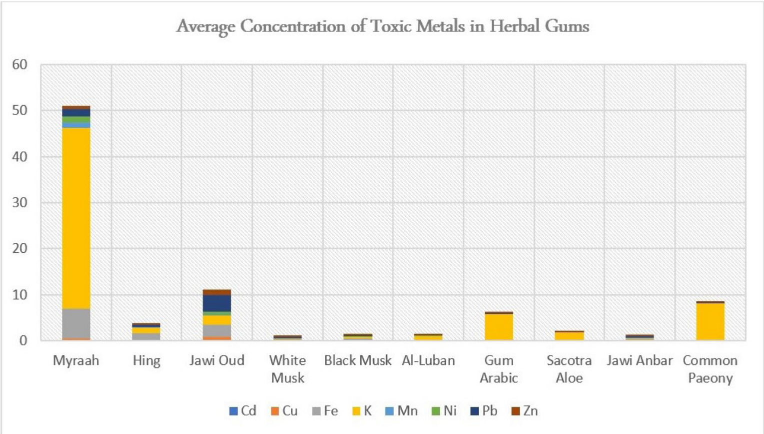

Figure 2. Average concentrations of toxic metals in the selected herbal gums.

For example, iron is a critical component for haemoglobin production and enzyme synthesis.

The average concentration of Cadmium (Cd) in the analysed medicinal herbs ranged from 0.01 to 0.18 mg/kg.

With the highest average concentration of Cd in *C. myrrha* (0.18 ± 0.11 mg/kg). The lowest average concentrations (0.01± 0) were observed in black Musk Jawi and Socotra aloe (Table 2). These concentrations were within the permissible limit set by FAO/WHO, which is 0.3 mg/kg for medicinal plants (Table 3) (Mensah et al., 2009; Abu Bakar and Bhattacherjy, 2012; World Health Organization, 2006). Cadmium overdose leads to adverse health effects in different organ systems in the body and its main toxicity can affect the kidney and may lead to death (Abu Bakar and Bhattacherjy, 2012).

The average concentration of copper (Cu) varied between 0.015 and 0.6 mg/kg. The highest average copper concentration (0.6 ± 0.14 mg/kg) was found in Jawi Oud, and the lowest concentrations were found in Acacia gum and Socotra aloe (0.015 and 0.01 mg/kg, respectively). These concentrations were all within the permissible limit set by the WHO/FAO of 10 mg/kg. It is also within the limits of China and Singapore, which are 20 and 150 mg/kg, respectively. Copper enables enzyme activities as well as skin and musculoskeletal development. However, the consumption of copper above the permissible limit can lead to liver damage and other symptoms related to the affected specific system (Ernst, 2002; Abu Bakar and Bhattacherjy, 2012; Tschinkel et al., 2020).

The average concentration of iron (Fe) in the analysed samples ranged from 0.055 to 6.51 mg/kg. The highest average concentration (6.51 ± 5.78 mg/kg) of Fe was found in *C. myrrha*, and the lowest concentration was found in common peony (0.055 ± 0.02 mg/kg). The FAO/WHO sets the permissible limit for iron in herbal medicines to be 20 mg/kg. This study results showed that all the gum from all the analysed herbs had average iron concentrations within the permissible limit. Iron helps distribute oxygen in body tissues and supports the body's immune system and other vital functions. However, taking iron excessively could lead to toxicity, which may affect the heart and the blood levels and damage the liver (Ernst, 2002; Tschinkel et al., 2020).

The average nickel (Ni) concentration in the analysed medicinal herbs ranged from 0.01 to 1.285 mg/kg. The highest average concentration of Ni in *C. myrrha* was 1.285 ± 0.12 mg/kg. The lowest average concentrations (0.01± 0) were observed in Acacia gum, Socotra aloe, and common peony. These concentrations were within the permissible limit set by FAO/WHO (1.5 mg/kg) for medicinal plants. Nickel toxicity may cause allergic skin reactions as well as irritation of the nose and lungs (Abu Bakar and Bhattacherjy, 2012).

The average concentration of lead (Pb) in the analysed samples ranged from 0.035 to 3.615 mg/kg. The maximum concentration of lead (3.615 ± 0.67 mg/kg) was found in Jawi Oud. The FAO/WHO's permissible limit of lead in consumed medicinal herbs is 10 mg/kg (Table 2). Therefore, the average concentration of lead in the analysed gums of the selected plants was within the permissible limit. Lead is highly toxic and adversely affects the health of individuals who consume it. Lead affects the functions of different vital systems in the body, such as the cardiovascular, nervous, musculoskeletal, renal, and immune systems. It could damage critical function such as vision, hearing, cognitive development, and reproduction) Ernst, 2002; Abu Bakar and Bhattcherjy, 2012; Tschinkel et al., 2020). Lead enters the atmosphere and then mixes with the soil near one of its sources, eventually penetrating the plants. As a result, lead concentrations in certain parts of the plant, such as gum, might rise due to a variety of factors.

Zinc (Zn) in the analysed samples was detected in concentrations that ranged between 0.06 and 1.195 mg/kg. The maximum average Zn concentration (1.195 ± 0.22 mg/kg) was seen in Jawi Oud, while the lowest was in White Musk Jawi (0.06 ± 0.01 mg/kg). The FAO/WHO's permissible limit for Zn in herbal medicines is 50 mg/kg. Therefore, all the herbs analysed in this study have Zn concentrations within the permissible limit. Zinc is essential for adequately functioning the immune system. However, its toxicity could weaken it (Ernst, 2002; Abu Bakar and Bhattacherjy, 2012).

The findings in Table 3 show the correlation between HCl and H_2O_2. The correlation indicates the categories of relationships in these elements. The first group consists of the ingredients (Cd, B, Zn, Na, Pb, Be, Bi, Co, and Cu) with the strongest positive correlations and moderate correlations in Ba, Ni, Li, and B. In contrast, Fe, Mn, and Cd showed the weakest correlation among other elements. Lastly, Sr, Ti, K, Mn, and Cr showed no relationship with most of the elements.

Moreover, Cd, B, and Zn elements were found to be the most correlated elements with more than ten elements. For example, 12 (Al, B, Ba, Be, Bi, Co, Cu, Na, Ni, Pb, Tl, and Zn) out of 19 elements were found to be strongly correlated with Cd, followed by B, which was found to be the second most highly correlated element, with 11 out 20 elements (Ba, Be, Bi, Cd, Co, Cu, Na, Ni, Pb, Tl, Zn) reported a strong positive relationship with B elements, and Zn was also found to be the third most highly correlated element with 11 out of 20 elements (Al, B, Be, Bi, Cd, Co, Cu, Li, Ni, Pb, Tl), showing strong correlation with it. However, Sr showed no relationship with fifteen elements, while Cr, K, and Mn elements reported no correlations with twelve, eleven, and ten elements, respectively. According to the results in Table 4, two groups of relationships can be defined in gums. The first group included B, Ni, Ba, Be, Bi, Cd, Co, Cu, Na, Pb, Ti, and Zn with the highest positive correlation, while Sr, K, Li, Mn, and Fe revealed no correlation with most elements.

Table 5 shows the relationships between the HCL elements factors. The first group includes the elements with the most significant correlations (Cr, Fe, B, Be, Bi, Cd, Mn, Na, Pb, and Zn), whereas Sr, K, Ni, and Li presented no correlation with most of the elements.

After analyzing the samples to compare the difference between HCl and H_2O_2 across each metal, it has been reported that there is no significant difference ($P>0.05$) among samples treated with HCl and H_2O_2 of the herbal gum sample. The closeness to industry, the use of different types of soil, the use of various fertilisers, and the variation in plant cultivation practices may all contribute to plant gum differences. However, in this study there is no toxicity concern and more research on other gums is needed, particularly from various sources and places marketed in the Saudi market.

Table 3. Correlation matrix for metal concentrations in HCl an H_2O_2 samples.

	Al	B	Ba	Be	Bi	Cd	Co	Cr	Cu	Fe	K	Li	Mn	Na	Ni	Pb	Sr	Tl	Zn
Al	1																		
B	0.636**	1																	
Ba	0.359	0.799**	1																
Be	0.946**	0.771**	0.586**	1															
Bi	0.940**	0.812**	0.589**	0.979**	1														
Cd	0.706**	0.885**	0.887**	0.863**	0.843**	1													
Co	0.956**	0.772**	0.530*	0.981**	0.971**	0.837**	1												
Cr	0.209	0.564**	0.328	0.353	0.359	0.408	0.434	1											
Cu	0.941**	0.823**	0.559*	0.975**	0.976**	0.845**	0.992**	0.482*	1										
Fe	0.308	0.652**	0.395	0.450*	0.464*	0.486*	0.520*	0.988**	0.573**	1									
K	-0.007	0.604**	0.673**	0.243	0.212	0.590**	0.265	0.741**	0.302	0.724**	1								
Li	0.627**	0.438	0.258	0.656**	0.697**	0.459*	0.649**	0.183	0.610**	0.234	-0.033	1							
Mn	0.151	0.599**	0.422	0.326	0.331	0.450*	0.394	0.989**	0.448*	0.979**	0.816**	0.130	1						
Na	0.637**	0.910**	0.788**	0.796**	0.845**	0.844**	0.750**	0.437	0.785**	0.544*	0.454	0.636**	0.469*	1					
Ni	0.444*	0.811**	0.727**	0.626**	0.595**	0.797**	0.651**	0.796**	0.697**	0.835**	0.827**	0.112	0.836**	0.652**	1				
Pb	0.962**	0.783**	0.571**	0.988**	0.979**	0.864**	0.993**	0.356	0.986**	0.449*	0.242	0.636**	0.325	0.766**	0.629**	1			
Sr	0.049	0.521*	0.492*	0.143	0.301	0.287	0.111	0.165	0.187	0.246	0.215	0.174	0.217	0.611**	0.210	0.138	1		
Tl	0.961**	0.779**	0.573**	0.986**	0.990**	0.853**	0.986**	0.326	0.978**	0.424	0.203	0.691**	0.295	0.793**	0.587**	0.995**	0.190	1	
Zn	0.836**	0.824**	0.671**	0.919**	0.936**	0.887**	0.925**	0.412	0.912**	0.497*	0.371	0.748**	0.403	0.863**	0.637**	0.929**	0.291	0.945**	1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). N=30.

Table 4. Correlation matrix for metal concentrations in HCl samples.

Salt	Al	B	Ba	Be	Bi	Cd	Co	Cr	Cu	Fe	K	Li	Mn	Na	Ni	Pb	Sr	Tl	Zn
Al	1																		
B	.696*	1																	
Ba	0.584	.764*	1																
Be	.967**	.808**	.744*	1															
Bi	.958**	.836**	.751*	.994**	1														
Cd	.907**	.870**	.788**	.962**	.955**	1													
Co	.957**	.832**	.717*	.976**	.970**	.980**	1												
Cr	0.127	.674*	0.558	0.290	0.306	0.480	0.404	1											
Cu	.940**	.875**	.740*	.975**	.976**	.981**	.995**	0.452	1										
Fe	0.236	.756*	.641*	0.403	0.421	0.574	0.501	.991**	0.550	1									
K	-0.060	0.516	0.452	0.106	0.114	0.334	0.231	.975**	0.274	.944**	1								
Li	0.424	.643*	.716*	0.578	0.627	0.498	0.447	0.203	0.503	0.306	0.055	1							
Mn	0.080	.649*	0.540	0.248	0.267	0.439	0.360	.999**	0.411	.986**	.979**	0.203	1						
Na	0.606	.878**	.841**	.769**	.800**	.763*	.699*	0.484	.747*	0.586	0.331	.906**	0.471	1					
Ni	0.528	.839**	.686*	.645*	.643*	.783**	.746*	.900**	.772**	.935**	.811**	0.276	.877**	0.619	1				
Pb	.983**	.794**	.675*	.985**	.978**	.965**	.993**	0.299	.984**	0.402	0.121	0.454	0.253	.680*	.665*	1			
Sr	0.060	0.492	0.608	0.258	0.316	0.232	0.138	0.285	0.209	0.348	0.208	.920**	0.303	.785**	0.184	0.122	1		
Tl	.986**	.790**	.693*	.992**	.988**	.957**	.987**	0.270	.980**	0.379	0.084	0.506	0.226	.707*	.637*	.997**	0.172	1	
Zn	.896**	.870**	.742*	.954**	.942**	.972**	.972**	0.493	.973**	0.589	0.331	0.487	0.454	.766**	.808**	.952**	0.215	.947**	1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). N=10.

Table 5. Correlation matrix for metal concentrations in H_2O_2 samples.

	Al	**B**	**Ba**	**Be**	**Bi**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Li**	**Mn**	**Na**	**Ni**	**Pb**	**Sr**	**Tl**	**Zn**
Al	1																		
B	0.597	1																	
Ba	0.353	.890**	1																
Be	.922**	.748*	.638*	1															
Bi	.932**	.798**	0.623	.961**	1														
Cd	0.615	.910**	.942**	.850**	.808**	1													
Co	.965**	.726*	0.561	.988**	.974**	.790**	1												
Cr	.843**	.878**	.791**	.970**	.958**	.937**	.946**	1											
Cu	.947**	.802**	0.628	.980**	.986**	.828**	.989**	.968**	1										
Fe	.791**	.912**	.798**	.892**	.931**	.892**	.877**	.954**	.919**	1									
K	0.074	.689*	.860**	0.415	0.327	.792**	0.313	0.551	0.355	0.502	1								
Li	.965**	0.420	0.178	.851**	.870**	0.464	.903**	.734*	.861**	.664*	-0.076	1							
Mn	0.510	.924**	.976**	.766**	.735*	.981**	.695*	.885**	.751*	.884**	.816**	0.338	1						
Na	.731*	.937**	.828**	.853**	.909**	.898**	.834**	.937**	.884**	.988**	0.566	0.610	.895**	1					
Ni	0.287	.828**	.969**	0.599	0.531	.916**	0.504	.739*	0.564	.733*	.887**	0.096	.962**	.748*	1				
Pb	.939**	.785**	.639*	.993**	.982**	.844**	.994**	.974**	.995**	.912**	0.391	.861**	.762*	.878**	0.581	1			
Sr	0.057	0.554	0.463	0.088	0.322	0.303	0.114	0.273	0.214	0.442	0.229	0.005	0.374	0.533	0.287	0.167	1		
Tl	.951**	.773**	0.609	.984**	.993**	.814**	.993**	.964**	.995**	.914**	0.334	.885**	.732*	.881**	0.537	.996**	0.214	1	
Zn	.905**	.809**	.668*	.969**	.992**	.846**	.969**	.970**	.977**	.940**	0.412	.843**	.776**	.928**	0.583	.981**	0.312	.987**	1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). N=10.

4. Conclusions

Generally, this study was aimed to detect toxic metals in the herbal gum samples consumed for medicinal purposes in the eastern region of Saudi Arabia. The average concentration of toxic metals in these herbal gums was found to be within the permissible levels set by the WHO/FAO. However, the consumption of large quantities of these herbs for a long term could lead to the accumulation of toxic metals above the permissible limits within the body, consequently leading to toxicity. Therefore, caution must be taken in consuming some of the analysed herbs. To conclude, according to the literature, some recommendations should be followed to avoid the contamination of gums by toxic metals, such as monitoring the soil in agricultural regions, limiting the consumption of hazardous fertilisers, controlling the quality of food products, taking into account the distance of agricultural lands from industries, monitoring the waters used for agriculture, and providing some accurate standards limits for hazardous compounds in foods. Gums' corrosive impact can cause toxic metals to be released when they come into touch with stainless steel surfaces and galvanised containers. It is advised that the gum to be stored in proper containers with proper handling.

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Supplementary Material

Supplementary material accompanies this paper.

Supplementary Material S1. ICP OES raw data for the calculation of toxic metals (mg/kg ± SD) in the 10 selected medicinal gums.

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