Citation/Atıf: Manouchehri A, Pirhadi M, Shokri S, Khaniki GJ, Shamaei S, Miranzadeh MH.2021. The Possible Effects of Heavy Metals in Honey as Toxic and Carcinogenic Substances on Human Health: A Systematic Review (Toksik ve Kanserojen bir Madde Olarak Baldaki Ağır Metallerin İnsan Sağlığına Olası Etkileri; Sistematik bir Inceleme). *Arı D./U. Bee J.* 21(2):238-248, DOI: 10.31467/uluaricilik.973053

DERLEME / REVIEW

THE POSSIBLE EFFECTS OF HEAVY METALS IN HONEY AS TOXIC AND CARCINOGENIC SUBSTANCES ON HUMAN HEALTH: A SYSTEMATIC REVIEW

Toksik ve Kanserojen bir Madde Olarak Baldaki Ağır Metallerin İnsan Sağlığına Olası Etkileri: Sistematik bir Inceleme

Aliasghar MANOUCHEHRI[1], Mohadeseh PIRHADI[2], Samira SHOKRI[3], Gholamreza Jahed KHANIKI[4], Shabnam SHAMAEI[5], Mohammad Hasan MIRANZADEH[6*]

[1]Department of Internal Medicine, Shahid Beheshti Hospital, Babol University of Medical Sciences, Babol, IRAN. E-mail: drmanouchehri@yahoo.com, ORCID No: 0000-0003-1741-9791

[2]Department of Environmental Health, Food Safety Division, Faculty of Public Health, Tehran University of Medical Sciences, Tehran, IRAN E-Mail: m.pirdahi371@gmail.com ORCID No.: 0000-0003-2576-7374

[3]Department of Environmental Health, Food Safety Division, Faculty of Public Health, Tehran University of Medical Sciences, Tehran, IRAN E-Mail: shokrisamira22@yahoo.com ORCID No. 0000-0002-4532-1129

[4]Department of Environmental Health Engineering, Division of Food Safety & Hygiene, School of Public Health, Tehran University of Medical Sciences, Tehran, IRAN. E-mail: ghjahedkh@yahoo.com. ORCID No: 0000 0001-9983-4838.

[5]Department of Chemistry, Khorramabad Branch, Islamic Azad University, Khorramabad, IRAN; E-mail: shabnamshamaie@gmail.com, ORCID No: 0000-0003-4640-3799

[6]Department of Veterinary Medicine, Shahrekord Branch, Islamic Azad University, Shahrekord, IRAN. Yazışma Yazarı/Corresponding author E-mail: miranzadeh.mh@yahoo.com, ORCID No: 0000-0002-8547-2837.

Geliş Tarihi / Received: 19.07.2021 Kabul Tarihi / Accepted:23.09.2021 DOI: 10.31467/uluaricilik.973053

ABSTRACT

Heavy metals are widely known through natural resources, natural resources such as soil, dust in the atmosphere, snow and rain. Soil contaminants, especially heavy metals, can be absorbed by plants and enter the food cycle. Heavy metal contamination causes environmental concerns, such as entering the food chain and contaminating food, which can be harmful to human health. Consumption of food contaminated with heavy metals can cause several disorders including genetic toxicity, carcinogenicity, mutagenicity, teratogenicity, neurotoxicity, endocrine disorders, immune problems and impaired psychosocial function. Bees also absorb heavy metals through the consumption of contaminated water, pollen, and nectar, inhalation of particles during flight, and adhesion of particles to their hairy body as they move on plant and soil surfaces while searching for food. For this review study, keywords such as heavy metals and honey were used. The databases searched in those articles were Google Scholar, SID, Scopus, PubMed, Science Direct, and ISI. The searched articles were reviewed. Given that honey is a valuable and widely consumed food in the diet of most people in different nations, so the study of the quality of honey in the consumer market in order to maintain the health of consumers seems necessary.

Keywords: Bee, Honey, Heavy metals, Toxic, Carcinogenic agent, Carcinogen

ÖZ

Toprak kirleticileri, özellikle ağır metaller, bitkiler tarafından emilebilir ve besin döngüsüne girebilir. Arılar ayrıca yiyecek ararken bitki ve toprak yüzeylerinde hareket ederken kirli su, polen ve nektar tüketimi, uçuş sırasında partiküllerin solunması ve partiküllerin tüylü vücutlarına yapışması yoluyla

ağır metalleri emer. Bu derleme çalışması için ağır metaller ve bal gibi anahtar kelimeler kullanılmıştır. Bu makalelerde aranan veri tabanları Google scholar, SID, Scopus, PubMed, Science direct ve ISI idi. Aranan makaleler incelendi. Balın, farklı uluslardaki çoğu insanın diyetinde değerli ve yaygın olarak tüketilen bir gıda olduğu göz önüne alındığında, tüketicilerin sağlığını korumak için tüketici pazarında bal kalitesinin araştırılması gerekli görünmektedir. Bu konuda kamuoyunu bilgilendirmemiz gerekiyor, bu yüzden bu derleme balda ağır metallerin varlığını açıklıyor.

Anahtar Kelimeler: Arı, Bal, Ağır metaller, Toksik, Kanserojen madde, Kanserojenler

Abbreviations

Fe Iron, Zn Zinc, Cu Copper, As Arsenic, Pb Lead, Cd Cadmium, Ni Nickel, Cr Chromium, Al Aluminium, Mn Manganese, ICP-OES Inductively coupled plasma-optical emission spectrometry, EU European Union, FDA Food and Drug Administration, WHO World Health Organization

GENIŞLETILMIŞ ÖZET

Giriş: Bal, arılar tarafından üretilen çiçek ve bitkilerin nektarıdır. Bal, fruktoz, glikoz, maltoz, sakaroz, protein, mineraller ve su içeren değerli bir besindir. Toprak kirleticileri, özellikle ağır metaller, bitkiler tarafından emilebilir ve besin döngüsüne girebilir. Arılar ayrıca yiyecek ararken bitki ve toprak yüzeylerinde hareket ederken kirli su, polen ve nektar tüketimi, uçuş sırasında partiküllerin solunması ve partiküllerin tüylü vücutlarına yapışması yoluyla ağır metalleri emer. Genel olarak ağır metaller nörolojik bozukluklara, kanserlere, besin eksikliklerine, obeziteye, solunum ve kardiyovasküler bozukluklara, karaciğer, böbrek ve beyin hasarına, alerji ve astıma, endokrin bozukluklara, kronik viral enfeksiyonlara neden olabilir. Enzim disfonksiyonu, kansızlık, yorgunluk, baş ağrısı ve baş dönmesi, zayıflamış bağışıklık sistemi, gen hasarı, erken yaşlanma, cilt bozuklukları, hafıza ve iştah kaybı, artrit, osteoporoz ve akut durumlarda ölüme neden olur.

Amaç: Balın ağır metaller açısından kirlenmesinin araştırılması

Yöntemler: Bu derleme çalışması için ağır metaller ve bal gibi anahtar kelimeler kullanılmıştır. Bu makalelerde aranan veri tabanları Google bilim, SID, Scopus, PubMed, Science direct ve ISI idi. Aranan makaleler incelendi. Bal uzun zamandır sadece gıda olarak değil, aynı zamanda birçok hastalık ve sağlıkla ilgili sorunları tedavi etmek için de yaygın olarak kullanılmaktadır.

Tartışma ve Sonuç: Türkiye'de yapılan bir çalışmanın sonuçları da balın ağır metallerle kirlenme oranı ile sanayi merkezlerinin sayısı ile bölgedeki kirlilik oranı arasında doğrudan bir ilişki olduğunu göstermiştir (Al-Khalifa ve Al-Arify, 1999). Bu rapor, ülkede incelenen bal örneklerinde (özellikle kadmiyum ve cıva) ağır metal miktarlarının izin verilen oranın üzerinde olduğunu göstermiştir. Saveh City'de (Markazi Eyaleti, İran) balın kadmiyum ve arsenik ağır metalleri tarafından kontaminasyonunun ölçülmesine ilişkin sonuçlar, Türkiye, Arjantin, Nijerya ve Pakistan gibi ülkelerde yapılan ve Türkiye'deki bal örneklerinde çok yüksek kontaminasyon gösteren araştırmalara benzerdi (Samimi ve ark., 2001). Bu, bu bölgede sanayi alanlarının varlığına bağlanabilir.

Hırvatistan ve Kosova'da yapılan çalışmaların sonuçları, bal örneklerindeki kurşun içeriğinin diğer Avrupa ülkelerinin rapor edilen miktarından daha yüksek olduğunu gösterdi ki bu endişe vericidir. Bu bulgular, karayolları ve demiryollarından uzak alanlarda bal üretim kovanlarının bulunması ihtiyacını vurgulamaktadır (Bilandžić ve diğerleri, 2011; Fadil ve diğerleri, 2020).

Toma et al. Nijerya'da yapılan bir çalışmada, bal örneklerindeki demir, bakır, manganez ve çinko miktarının dünya sağlık örgütü (WHO) ve gıda ve tarım örgütü (FAO) tarafından belirlenen izin verilen maksimum konsantrasyondan ve ortalama konsantrasyondan daha yüksek olduğu ortaya konmuştur. Endüstriyel şehirlerdeki ağır metallerin oranı kırsal alanlara göre daha yüksektir (Toma et al., 2020).

Altekin ve ark., Piven ve ark. Cs137 ve K40 aktivitelerinin arılar tarafından çevreden bala taşındığını belirtmiştir. Ayrıca bal örneklerinde tespit edilen Cr, Zn, Fe, Ni, Mn, Pb, Cu, Cd ve Co konsantrasyonları FAO/WHO tarafından insan sağlığının korunması için belirlenen limitlerin altındaydı ve herhangi bir risk oluşturmadı (Altekin ve diğerleri, 2015; Piven ve diğerleri, 2020). Bal kontaminasyonunun diğer bir kaynağı, kirletici

maddeler, aletler, arıcılık uygulamaları, çiçek kaynakları, mutfak eşyaları, böcekler, hayvanlar ve su ile teması içerir (Mahmoudi ve diğerleri, 2014). Balın ortalama asidik pH'ı (pH = 3,9) olduğundan metal kaplar ve ağır metal bileşikleri içeren paketler yoluyla bal bulaşabilir, bu nedenle zamanla kutunun metalini aşındırabilir. Bu nedenle, lehimsiz kutular kullanılarak baldaki kurşun ve kalay gibi ağır metallerin miktarını azaltmak için saklama kutularında uygun kaplamalar kullanılabilir (Bonyadian vd., 2011). Bonyadian ve diğerleri, mumlu balın diğer numunelerden daha fazla kurşun içerdiğini bulmuşlardır, bu da balın metal kaplarda depolanmasına ve mumun kimyasal bileşimine atfedilebilir (Bonyadian ve diğerleri, 2011).

Çoğu çalışmada İran balının ağır metallerle kontaminasyonu düşük bulunmuş ve yetişkin arıların vücutlarının polen ve baldan daha fazla kontamine olduğu bildirilmiştir. Görünüşe göre arılar bal üretirken bulaşmalarını azaltıyor. Balın farklı ülkelerdeki çoğu insanın diyetinde değerli ve yaygın olarak tüketilen bir gıda olduğu göz önüne alındığında, tüketicilerin sağlığını korumak için tüketici pazarında balın kalitesinin araştırılması gerekli görünmektedir. Bu konuda kamuoyunu bilgilendirmemiz gerekmektedir. bu yüzden bu derleme yazı balda ağır metallerin varlığını açıklamaktadır.

INTRODUCTION

Honey is the nectar of flowers and plants produced by bees. Honey is a nutrient that has valuable healing properties (Bilandžić et al., 2011). It contains fructose, glucose, maltose, sucrose, protein, minerals, and water (Ioannidou et al., 2005). The composition of honey varies according to plant species, climate, geographical conditions, environmental conditions as well as the method of beekeepers in honey production (Azeredo et al., 2003). Each year, about 30 percent of people in developed countries develop foodborne illnesses. It has been proven that the main way heavy metals enter the body is through food chains (Sobhanardakani & Kianpour, 2016). Heavy metals are the most important sources of contaminants in water, soil, and food (Duruibe et al., 2007; Pirhadi et al., 2021). Heavy metals are toxic and cause various diseases such as cancer, disorders of hemoglobin biosynthesis and anemia, gastrointestinal bleeding, inflammation and renal, pulmonary, gastrointestinal and heart failure. Heavy metals are carcinogenic and endanger a person's health (Duruibe et al., 2007). Today, the role of heavy metals in environmental pollution and their adverse effects on human health have been identified (Malakootian et al., 2011; Pirhadi et al., 2021). Soil contaminants, especially heavy metals, can be absorbed by plants and enter the food cycle. Because heavy metals have a long half-life, they are likely to accumulate in the tissues of living organisms (Hegazi & El-Kay; Rezaei Raja et al., 2016).

Bees can also absorb heavy metals through the consumption of contaminated water, pollen, and nectar, inhalation of particles during flight, and the adhesion of particles to their hairy bodies as they move on plant and soil surfaces while searching for food (Hegazi & El-Kay., 2010). In general, heavy metals can cause neurological disorders, cancers, nutrient deficiencies, obesity, respiratory and cardiovascular disorders, liver, kidney, and brain damage, allergies and asthma, endocrine disorders, chronic viral infections. Enzyme dysfunction, anemia, fatigue, headache and dizziness, weakened immune system, gene damage, premature aging, skin disorders, loss of memory and appetites, arthritis, osteoporosis, and in acute cases cause death (Khaneghah et al., 2020; Negahdari et al., 2021; Singh et al., 2010).

Honey is used as an indicator for measuring environmental pollution such as heavy metal pollution (Celli & Maccagnani, 2003). Heavy metals in honey can be worrisome and dangerous, toxic and carcinogenic for consumers (Leblebici & Aksoy, 2008). Excessive and permanent discharge of pollutants into the environment increases the contamination of honey as one of the important food products with heavy metals. Therefore, in this review study, honey contamination with heavy metals has been investigated.

METHOD FOR REVIEW

For this review study, keywords such as heavy metals and honey were used. The databases searched for in those articles were Google Scholar, SID, Scopus, PubMed, Science Direct, and ISI.

RESULTS

The results of reviewing articles on heavy metals in honey are shown in Table 1.

Table 1. Prevalence of Heavy metals in Honey samples from various countries during 2011–2021 (mg/Kg).

Country	Year	Sample	Cadmium	Chrome	Copper	Manganese	Zinc	Lead	Arsenic	Nickle	Aluminium	Iron	Unit	Method	Ref.
Iran	2015	15	63.18± 43.39	58.05± 30.32			684.43± 190.43			56.15± 54.32			µg/kg	ICP-OES	(Sobhanard akani & Kianpour, 2016)
Iran	2013-2014	72					4.4±3.40	0.08±0.04	0.11± 0.04				ppm	Atomic absorption spectrometry	(Mahmoudi et al., 2018)
Iran	2010	89		7.09±9.4			9.99±26.5	0.04±0.1	0.0008± 0.0011	0.003± 0.005		0.6±0.9	ppm	Atomic absorption spectrometry	(Saghaei et al., 2012)
Iran	2013	27							0.005± 0.002				ppm	Graphite Furnace Atomic Absorption	(Piran et al., 2015)
Iran	2010	10	0.39 ± 0.08		0.13 ± 0.08	0.42 ± 0.16	2.53 ± 2.93	0.11 ± 0.05	0.16 ± 0.13		9.62 ± 6.7	5.31 ± 2.29	mg/kg	ICP-AES	(Akbari et al., 2012)
Iran	2013	25	27.62±32	899.75± 184.03	243± 559.3		1481.64 ± 1709.81	507.58± 402.14	<11.87	651.78± 173.29			µg/kg	ICP-OES	(Aghamirlou et al., 2015)
Turkey	2013	20	0.011±0.0002	0.007±0.0004	0.064± 0.0086	0.603±0.0084	3.976±0.0416	0.078±0.0036		0.041± 0.0014		0.424± 0.0026	µg/l	ICP-OES	(Altekin et al., 2015)
Turkey	2018	3	0.64±0.08	1.05±0.00	0.87± 0.01	21.58±0.07	2.59±0.00	0		0.10± 0.01	10.41 0.00	20.52± 0.09	mg/kg	ICP-OES	(Temizer et al., 2018)
Bangladesh	2015		0.01 ± 0.00	0.39 ± 0.32	0.15 ± 0.06	2.69 ± 1.66		0.16 ± 0.04					mg/kg	Atomic Absorption Spectroscopy	(Sarker et al., 2015)
Turkey	2015	180				4,636 ± 3.943					124.863 ± 313.44	67.352 ± 34.636	ppb	ICP-OES	(EKİCİ, 2018)
Iraq	2015		0.108-0.8200			0.0392±0.0481		0.100-0.730	0.0104-0.035	0.210-0.894		0.117-0.440	mg/kg	FAAS and GFAAS	(Dhahir & Hemed, 2015)
Turkey	2015	100	0.343±0.205		0.06± 0.028		6.76±3.88	1101±1.277			1.490	41.13	mg/kg, wet weight	atomic absorption spectrometry	(UT)
Ghana	1017	20	0.625 ± 1.667	2.655 ± 4.773	13.855 ± 10.213	8.215 ± 4.452	0.615 ± 1.996	79.815 ± 16.796	0.665 ± 0.108	15.785 ± 10.968			mg/Kg	atomic absorption spectrometry	(Magna et al., 2018)
Italia	2016	72	0.61±0.66	12.8±10.7	220±134	664	1072±1315	32.8±47.9	1.27±2.88		1400±2300	2080± 1060	µg/kg	ICP-MS	(Quinto et al., 2016)
Ukraine	2019	60	0.02±0.01					0.185±0.01					mg/Kg	atomic absorption spectrometry	(Piven et al., 2020)
Kosovo	2018-2019	80	0.05	0.04	0.36		1.150	0.88				1.670	mg/Kg	atomic absorption spectrometry	(Fadil et al.)
Poland	2019	50	0.02±0.01			3.39±2.89		0.05±0.10		0.45±0.54	11.64±19.88		mg/kg d.w	ICP-OES	(Tomczyk et al., 2020)
Turkey	2020	146	0.09±0.07	0.01±0.01	0.37±0.37	11.05±1.21	1.58±1.11	0.18±0.05		0.11±0.06	2.55±2.55	4.21± 1.15	mg/Kg	ICP-OES	(Kanbur et al., 2021)
Ethiopia	2018	12	0.46±0.04	3.16±0.25	0.250±0.03	0.46±0.03	2.85±0.24	ND		2.61±0.16		9.65± 0.75	µg/g	flame atomic absorption spectrometry	(Yohannes et al., 2018)
Nigeria	2020	5	0.041±0.01	0.037±0.01	0.368±0.126	9.79±0.37	2.88±0.15	0.013±0.01				1.55± 0.27	µg/kg	Atomic Absorption Spectrophotometer	(Toma et al.)

Nigeria	2015 - 2017	40	0.109±0.046	6.03±0.78	51.84±6.7		38.98±8.46	0.26±0.055					µg/g	inductively coupled plasma mass spectrometer	(Ernest et al., 2018)
Romania	2015	52	2.19	41.57	228.26				7.82			22708.25	µg/kg	ICP-MS	(Oroian et al., 2016)
Brazil	2014		<2 -8	83-94				141 -228					ng/g	atomic absorption spectrometry	(de Andrade et al., 2014)
India	2012	70	0.008±0.005	0.0561±0.008	0.008±0.004		0.3725±0.615	0.002±0.001	0.319±0.20	0.011±0.003		10109±0.74	mg/Kg	Flame Atomic absorption spectrometer	(Bhalchandra & Baviskar)
Saudi Arabia	2017		0	0	0.001	0	0	0		0.001		0.003	mg/L	y Hydride generation atomic absorption spectroscopy (HGAAS)	(Aljedani, 2017)
Tadla-Azilal	2017	10	<0.015					<0.07					mg/Kg	atomic absorption spectrophotometry	(Moujanni et al., 2017)
Poland	2020	49	0.025±0.023					0.19±0.179					mg/Kg	ICP-OES	(Winiarska-Mieczan et al.)
Croatia	2019	244	0.013	0.29	5.81	53.1	12.6	0.458	0.037	0.88	288.5	82.5	mg/Kg	ICP-MS	(Bilandžić et al., 2011)
Hungary	2014	187				3.32±3.11		0.51±0.2			2.53±4.67		mg/Kg	ICP-OES	(Sajtos et al., 2019)

DISCUSSION

Honey has long been used not only as a food but also it has been widely applied to treat many diseases and health-related problems (Ediriweera & Premarathna, 2012). Honey can be contaminated by various sources. These sources can be classified into two important categories: contaminants of environmental origin and those related to beekeeping and maintenance (Mahmoudi et al., 2014). According to rules and regulations of the institute of standards and industrial research of Iran (ISIRI), provisional tolerable daily intake (PTDI) for lead, cadmium, mercury, and arsenic is equal to 0.0036, 0.001, 0.007, and 0.0021 in milligrams per kilogram of temporary bodyweight, respectively (Mahmoudi & Emami, 2015). Studies have shown that there is a direct relationship between contamination of honey with heavy metals in honey samples and industry-related environmental pollution in the area (Demirezen & Aksoy, 2005).

The results of a study conducted in Turkey also demonstrated a direct relationship between rate of honey contamination with heavy metals and number of industrial centers and rate of contamination in the area (Al-Khalifa & Al-Arify, 1999). This report indicated that amounts of heavy metals in honey samples studied in the country (especially cadmium and mercury) were higher than permissible rate. The results regarding measuring contamination of honey by heavy metals of cadmium and arsenic in Saveh City (Markazi Province, Iran) were similar to studies done in countries, such as Turkey, Argentina, Nigeria, and Pakistan, showing very high contamination of honey samples in this region (Samimi et al., 2001). This can be attributed to the presence of industrial areas in this region. The results of studies conducted in Croatia and Kosovo showed that content of lead in honey samples was higher than the reported amount of other European countries, which is worrying. These findings highlight the need for locating honey production hives in areas far from highways and railways (Bilandžić et al., 2011; Fadil et al., 2020).

Toma et al. in a study conducted in Nigeria demonstrated that the amount of iron, copper, manganese, and zinc in honey samples was higher than the maximum allowable concentration set by the world health organization (WHO) and food and

agriculture organization (FAO), and average concentration of heavy metals in industrial cities was higher than rural areas (Toma et al., 2020). Berinde and Michnea reported a positive relationship between metal content in honey samples, respiration of the contaminated particles in the air, and contaminated surface water (Berinde & Michnea, 2013). Cimino et al., showed the effects of volcanic activity on honey (Cimino et al., 1984). In this regard, the results of a study done in Chile showed that aluminum at the concentration of 6.15 ± 4.53 mg/kg and cadmium with the concentration between 0.01 - 0.05 mg/kg were the highest and lowest amounts of heavy metals in honey, respectively (Fredes & Montenegro, 2006). High levels of aluminum were attributed to the presence of colonies in the lands with volcanic soils. Radioactivity is naturally present in the environment and contaminates leaves and flowers and also has negative effects on human health.

The results of studies performed by Altekin et al., and Piven et al. indicated that Cs137 and K40 activities were transported by bees from the environment into honey. In addition, concentrations of Cr, Zn, Fe, Ni, Mn, Pb, Cu, Cd, and Co detected in the honey samples were lower than the limits established by FAO/WHO for protection of human health, and they had no risk to public health (Altekin et al., 2015; Piven et al., 2020). Another source of honey contamination includes having contact with contaminants, tools, beekeeping practices, floral sources, utensils, insects, animals, and water (Mahmoudi et al., 2014).

Honey can be contaminated through metal containers and heavy metal compounds-containing packages because honey has an average acidic pH (pH = 3.9), so over time, it can corrode metal of the can. Therefore, suitable coatings can be used in storage cans to reduce the amount of heavy metals, such as lead and tin in honey using solderless cans (Bonyadian et al., 2011). Bonyadian et al., found that the waxed honey contained more lead than other samples, which could be attributed to storage of honey in metal containers and chemical composition of wax (Bonyadian et al., 2011).

In most studies, contamination of the Iranian honey with heavy metals was low, and it has been reported that adult bees' bodies are more contaminated than pollen and honey. It seems that bees reduce their contamination while producing honey (Samimi et al., 2001).

In general, low amount of heavy metals in honey is not considered a problem and the amount of heavy metals in honey is significantly lower than in bees due to filtering done by bees (Bogdanov, 2006). Akbari et al., and Saghaei et al., in their studies conducted in Iran demonstrated that lead levels in honey measured in samples obtained from the markets in Iran, Ardabil, and Urmia cities were equal to 0/11, 0/935, and 0/04 mg/kg, respectively. The honey samples obtained from the market of Urmia City showed good quality in terms of the amount of heavy metals (Saghaei et al., 2012). Also, it has been indicated that average consumption of honey in Poland, Romania, and Ethiopia is nutritionally safe for health of children and adults (Winiarska-Mieczan et al., 2021). Bhalchandra in a study showed the presence of toxic metals including As, Cd, Pb, Hg, and Ni in all honey samples. Average concentration of heavy metals in honey samples was lower than the standard Indian limit (Bhalchandra & Baviskar, 2015).

The results of a study conducted in Saudi Arabia indicated the highest amount of potassium and cadmium in only one of the samples (0.008 ±0.008) (Saghaei et al., 2012). The results of a study done in China showed that the amounts of cadmium, lead, arsenic, and mercury were equal to 1.34, 33.98, 13.44, and 1.65 µg/kg, respectively (Tuzen et al., 2007).

There are various techniques to determine chemical elements, such as heavy metals and minerals in honey samples. Various studies have been performed on determination of heavy metals in honey samples. The most commonly used techniques are inductively coupled plasma optical emission spectrometry (ICP-OES), flame emission spectrometry (FES), flame atomic absorption spectrometry (FAAS), inductively coupled plasma mass spectrometry (ICP-MS), high-performance liquid chromatography (HPLC), Atomic absorption spectroscopy (AAS), total reflection x-ray fluorescence spectroscopy (TXRF), Graphite furnace atomic absorption spectroscopy (GFAAS), and hydride generation atomic absorption spectroscopy (HGAAS). ICP-OES that are used as analytical techniques for detection of chemical elements with excellent sensitivity (Fakhri et al., 2019). This method has been applied in most studies to determine heavy metals in various samples. In

any case, food contamination with heavy metals and other environmental chemicals may occur (Manouchehri et al., 2021; Pirhadi et al., 2021) and any medicinal plants used by bees may contain active compounds or heavy metals (Manouchehri et al., 2021; Abbasi et al., 2020; Aidy et al., 2020; Karimi et al., 2019; Abbasi et al., 2016; Abbaszadeh et al., 2018; Sedighi et al., 2019; Nouri et al., 2019; Abbasi et al., 2021) and be transmitted to bees.

Conclusion

Honey has long been used not only as a food but also it has been widely applied to treat many diseases and health-related problems. In most studies, contamination of the Iranian honey with heavy metals was low, and it has been reported that adult bees' bodies are more contaminated than pollen and honey. It seems that bees reduce their contamination while producing honey. Given that honey is a valuable and widely consumed food in the diet of most people in different nations, so the study of the quality of honey in the consumer market to maintain the health of consumers seems necessary. We need to inform the public about this, so this review article explains the presence of heavy metals in honey.

Authors' contribution: All authors contributed equally to the manuscript.

Conflicts of interest: The authors declared no competing interests.

Ethical considerations: Ethical issues (including plagiarism, data fabrication, double publication etc.) have been completely observed by author.

Funding/Support: None.

REFERENCES

Abbasi, N,, Khalighi, Z,, Eftekhari, Z,, Bahmani, M. Extraction and phytoanalysis of chemical compounds of Eucalyptus globulus leaf native to Dehloran, Ilam province, Iran by HS-SPME and GC-MS. Advances in Animal and Veterinary Sciences 2020; 8(6): 647-652.

Abbasi, N., Ghaneialvar, H., Saneei, S., Zangeneh, M.M., Zangeneh, A. (2021). Assessment of the wound healing property of aqueous extract of Stevia rebaudiana: An ethno medicinal plant. Plant Biotechnol Persa, 3 (1), http://pbp.medilam.ac.ir/article-1-61-en.html

Abbasi, N., Khosravi, A., Aidy, A., Shafiei, M. (2016). Biphasic response to luteolin in MG-63 osteoblast-like cells under high glucose-induced oxidative stress. Iranian Journal of Medical Sciences, 41(2), 118-125.

Abbaszadeh, S., Andevari, A.N., Koohpayeh, A., Naghdi, N., Alizadeh, M., Beyranvand, F., Harsej, Z. (2018). Folklore medicinal plants used in liver disease: A review. Int J Green Pharmacy, 12(3), 463-472.

Aghamirlou, H. M., Khadem, M., Rahmani, A., Sadeghian, M., Mahvi, A. H., Akbarzadeh, A., & Nazmara, S. (2015). Heavy Metals Determination In Honey Samples Using Inductively Coupled Plasma-Optical Emission Spectrometry. Journal of Environmental Health Science and Engineering, 13(1), 1-8.

Aidy, A,, Karimi, E,, Ghaneialvar, H,, Mohammadpour, S,, Abbasi, N. (2020). Protective effect of Nectaroscordum tripedale extract and its bioactive component tetramethylpyrazine against acetaminophen-induced hepatotoxicity in rats. Advances in Traditional Medicine, 20(3), 471-477.

Akbari, B., Gharanfoli, F., Khayyat, M. H., Khashyarmanesh, Z., Rezaee, R., & Karimi, G. (2012). Determination Of Heavy Metals In Different Honey Brands From Iranian Markets. Food Additives And Contaminants: Part B, 5(2), 105-111.

Aljedani, D. M. (2017). Determination Of Some Heavy Metals And Elements In Honeybee And Honey Samples From Saudi Arabia. Entomol Appl Sci Lett, 4(3), 1-11.

Al-Khalifa, A., & Al-Arify, I. (1999). Physicochemical Characteristics and Pollen Spectrum of Some Saudi Honeys. Food Chemistry, 67(1), 21-25.

Altekin, E., Dizman, S., & Keser, R. (2015). Radioactivity And Heavy Metal Concentrations In Various Honey Samples. Journal of Environmental Protection and Ecology, 16(2), 716-722.

Berinde, Z. M., & Michnea, A. M. (2013). A Comparative Study On The Evolution Of Environmental And Honey Pollution With Heavy Metals. Journal of Science and Arts, 13(2), 173.

Bhalchandra, W., & Baviskar, R (2015). Essential And Toxic Trace Metals In Raw Honey Of Apis Dorsata Harvested From Different Locations Of Paithan Taluka Of Aurangabad District.

Essential And Toxic Trace Metals In Raw Honey, Special issue, Vol. VII: 00-00: 2015.

Bilandžić, N., Đokić, M., Sedak, M., Kolanović, B. S., Varenina, I., Končurat, A., & Rudan, N. (2011). Determination Of Trace Elements In Croatian Floral Honey Originating From Different Regions. Food chemistry, 128(4), 1160-1164.

Bogdanov, S. (2006). Contaminants Of Bee Products. Apidologie, 37(1), 1-18.

Bonyadian, M., Moshtaghi, H., Nematallahi, A., & Naghavi, Z. (2011). Determination Of Lead, Tin, Cupper And Cadmium In Iranian Caned Fish. Iranian Journal Of Food Science And Technology, 29(8), 27-32

Celli, G., & Maccagnani, B. (2003). Honey Bees As Bioindicators Of Environmental Pollution. Bulletin Of Insectology, 56(1), 137-139.

Cimino, G., Ziino, M., & Panuccio, M. R. (1984). Heavy Metal Pollution. Part X: Impact Of Volcanic Activity On Etnean Honey. Environmental Technology, 5(1-11), 453-456.

da C Azeredo, L., Azeredo, M., De Souza, S., & Dutra, V. (2003). Protein Contents And Physicochemical Properties In Honey Samples Of Apis Mellifera Of Different Floral Origins. Food Chemistry, 80(2), 249-254.

de Andrade, C. K., dos Anjos, V. E., Felsner, M. L., Torres, Y. R., & Quináia, S. P. (2014). Direct Determination Of Cd, Pb And Cr In Honey By Slurry Sampling Electrothermal Atomic Absorption Spectrometry. Food Chemistry, 146, 166-173.

Demirezen, D., & Aksoy, A. (2005). Determination Of Heavy Metals In Bee Honey Using By Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Gazi University Journal of Science, 18(4), 569-575.

Dhahir, S. A., & Hemed, A. H. (2015). Determination Of Heavy Metals And Trace Element Levels In Honey Samples From Different Regions Of Iraq And Compared With Other Kind. American Journal of Applied Chemistry, 3(3), 83-92.

Duruibe, J. O., Ogwuegbu, M., & Egwurugwu, J. (2007). Heavy Metal Pollution And Human Biotoxic Effects. International Journal of physical sciences, 2(5), 112-118.

Ediriweera, E., & Premarathna, N. (2012). Medicinal And Cosmetic Uses Of Bee's Honey–A Review. Ayu, 33(2), 178.

Ekici, H. (2018). Determination Of Heavy Metal Pollution In Honey Samples Collected From Ardahan And Counties. Journal of Advances in VetBio Science and Techniques VetBio, 3(2), 1-7.

Ernest, E., Onyeka, O., Ozuah, A., & Benard, N. (2018). Comparative Assessment Of The Heavy And Trace Metal Levels In Honey Produced Within Nsukka And Enugu Metropolis. Food Public Health, 8(2), 42-46.

Fadil, M., Krasniqi, D., & Ahmet, M (2020). Heavy Metals In Honey Produced In Some Localities In Kosovo. Rasāyan J Chem, 4(13), 2013-2036.

Fakhri, Y., Abtahi, M., Atamaleki, A., Raoofi, A., Atabati, H., Asadi, A., Miri, A., Shamloo, E., Alinejad, A., & Keramati, H. (2019). The Concentration Of Potentially Toxic Elements (Ptes) In Honey: A Global Systematic Review And Meta-Analysis And Risk Assessment. Trends in food science & technology, 91, 498-506.

Fredes, C., & Montenegro, G. (2006). Heavy Metal And Other Trace Elements Contents In Honey Bee In Chile. Cien. Inv. Agr.(in English) 33 (1): 50-58. International Journal of Agriculture and Natural Resources, 33(1), 50-58.

Hegazi, A., & El-Kay, A. Y. (2010). Effect Of Road Dust On Vegetative Characters And Leaves Heavy Metal Contents Of Zizyphus Spina-Christi (L.) Wild, Syzygium Cumini (L.) Skeels And Olea Europaea L. Seedlings. Journal of Horticultural Science and Ornamental Plants, 2(3), 98-107.

Ioannidou, M., Zachariadis, G., Anthemidis, A., & Stratis, J. (2005). Direct Determination Of Toxic Trace Metals In Honey And Sugars Using Inductively Coupled Plasma Atomic Emission Spectrometry. Talanta, 65(1), 92-97.

Kanbur, E. D., Yuksek, T., Atamov, V., & Ozcelik, A. E. (2021). A Comparison Of The Physicochemical Properties Of Chestnut And Highland Honey: The Case Of Senoz Valley

In The Rize Province Of Turkey. Food Chemistry, 345, 128864.

Karimi, E,, Abbasi, S,, Abbasi, N. (2019). Thymol polymeric nanoparticle synthesis and its effects on the toxicity of high glucose on OEC cells: Involvement of growth factors and integrin-linked kinase. Drug Design, Development and Therapy, 13, 2513-2532.

Khaneghah, A. M., Fakhri, Y., Nematollahi, A., & Pirhadi, M. (2020). Potentially Toxic Elements (Ptes) In Cereal-Based Foods: A Systematic Review And Meta-Analysis. Trends in Food Science & Technology, 96, 30-44.

Leblebici, Z., & Aksoy, A. (2008). Determination Of Heavy Metals In Honey Samples From Central Anatolia Using Plasma Optical Emission Spectrofotometry (ICP-OES). Polish Journal of Environmental Studies, 17(4).

Magna, E. K., Dabi, M., Badu, E., & Owusu, P. (2018). Determination Of Heavy Metals And Potential Health Risk Assessment Of Honey Harvested From The Tamale Metropolis Of Ghana Using Atomic Absorption Spectrophotometer (AAS). Elixir Pollut, 121, 51522-51525.

Mahmoudi, R., & Emami, S. (2015). Honey Contamination With Heavy Metals In Iran. Journal of Inflammatory Disease, 18(6), 67-70.

Mahmoudi, R., Mardani, K., & Rahimi, B. (2018). Analysis Of Heavy Metals In Honey From North-Western Regions Of Iran. Journal of Chemical Health Risks, 5(4).

Mahmoudi, R., Moosavy, M., Norian, R., Kazemi, S., ASADI, N. M. R., & Mardani, K. (2014). Detection Of Oxytetracycline Residues In Honey Samples Using ELISA And HPLC Methods. Pharmaceutical sciences, 2014, 19(4), 145-150.

Malakootian, M., Yaghmaeian, K., Meserghani, M., & Mahvi, A. (2011). Determination Of Pb, Cd, Cr And Ni Concentration In Imported Indian Rice To Iran. Iranian Journal Of Health And Environment, 4(1), 77-84.

Manouchehri, A,, Shakib, P,, Biglaryan, F,, Nazer, M,, Darvishi, M. (2021). The most important medicinal plants affecting bee stings: A systematic review study. Uludag Aricilik Dergisi, 21(1), 91-103.

Manouchehri, A,A,, Pirhadi, M,, Parsaei, P,, Alikord, M,, Safian Boldaji, H. (2021). A review of aflatoxin M1 in milk and dairy products and new procedure for evaluating aflatoxin M1. J Chem Health Risks, 11(0), 0-0.

Moujanni, A., Terrab, A., Eddoha, R., Nasser, B., Benbachir, M., Tannaoui, M., Zouaoui, A., & Essamadi, A. (2017). Quantification Of Heavy Metals And Pesticides Residues In Labeled Moroccan Euphorbia Resinifera Honey From Tadla-Azilal. Journal of Materials and Environmental Sciences, 2, 1826-1836.

Negahdari, S., Sabaghan, M., Pirhadi, M., Alikord, M., Sadighara, P., Darvishi, M., & Nazer, M (2021). Potential Harmful Effects Of Heavy Metals As A Toxic And Carcinogenic Agent In Marine Food-An Overview. Egyptian Journal of Veterinary Sciences, 52(3), 379-385.

Nouri, A., Heidarian, E., Amini-Khoei, H., Abbaszadeh, S., Basati, G. (2019). Quercetin through mitigation of inflammatory response and oxidative stress exerts protective effects in rat model of diclofenac-induced liver toxicity. J Pharmacy Pharmacog Res, 7(3), 200-212.

Oroian, M., Prisacaru, A., Hretcanu, E. C., Stroe, S.-G., Leahu, A., & Buculei, A. (2016). Heavy Metals Profile In Honey As A Potential Indicator Of Botanical And Geographical Origin. International journal of food properties, 19(8), 1825-1836.

Piran, F., Emamifar, A., & Delalat, H. (2015). Investigation Of Heavy Metal (Arsenic) Of Honey Samples From Sanandaj, Ghorveand Saghez In Kurdistan, Iran. Int. J. Farm Alli. Sci, 4(6), 522-525.

Pirhadi, M., Shariatifar, N., Bahmani, M., & Manouchehri, A. (2021). Heavy Metals In Wheat Grain And Its Impact On Human Health: A Mini-Review. Journal of Chemical Health Risks. doi: 10.22034/jchr.2021.1924307.1269.

Pirhadi, M., Shariatifar, N., Bahmani, M., Manouchehri, A.A. (2021). Heavy metals in wheat grain and its impact on human health: A review. J Chem Health Risks, 10.22034/jchr.2021.1924307.1269

Piven, O., Khimych, M., Salata, V., Gutyj, B., Naidich, O., Skrypka, H., Koreneva, Z., Dvylyuk, I., Gorobey, O., & Rud, V. (2020).

Contmination Of Heavy Metals And Radionuclides In The Honey With Different Production Origin. Ukrainian Journal of Ecology, 10(2), 405-409.

Quinto, M., Miedico, O., Spadaccino, G., Paglia, G., Mangiacotti, M., Li, D., Centonze, D., & Chiaravalle, A. E. (2016). Characterization, Chemometric Evaluation, And Human Health-Related Aspects Of Essential And Toxic Elements In Italian Honey Samples By Inductively Coupled Plasma Mass Spectrometry. Environmental Science and Pollution Research, 23(24), 25374-25384.

Rezaei Raja, O., Sobhanardakani, S., & Cheraghi, M (2016). Health Risk Assessment Of Citrus Contaminated With Heavy Metals In Hamedan City, Potential Risk Of Al And Cu. Environmental Health Engineering and Management Journal, 3(3), 131-135.

Saghaei, S., Ekici, H., Demirbas, M., Yarsan, E., & Tumer, I. (2012). Determination Of The Metal Contents Of Honey Samples From Orumieh In Iran. Kafkas Univ Vet Fak Derg, 18(2), 281-284.

Sajtos, Z., Herman, P., Harangi, S., & Baranyai, E. (2019). Elemental Analysis Of Hungarian Honey Samples And Bee Products By MP-AES Method. Microchemical Journal, 149, 103968.

Samimi, A., Maymand, O. E., & Mehrtabatabaei, M. (2001). Determination Of Cadmium And Arsenic Pollution By Bee Honey Based On The Study On Ja'far Abad Area From Saveh City From Iran. Water and Geoscience, 199-192.

Sarker, N., Chowdhury, M. A. Z., Fakhruddin, A. N. M., Fardous, Z., Moniruzzaman, M., & Gan, S. H. (2015). Heavy Metal Contents And Physical Parameters Of Aegiceras Corniculatum, Brassica Juncea, And Litchi Chinensis Honeys From Bangladesh. BioMed research international, https://doi.org/10.1155/2015/720341.

Sedighi, M., Sewell, R.D.E, Nazari, A., Abbaszadeh, S., Cheraghi, M., Amini, A., Heydari, Z., Rafieian-Kopaei, M. (2019). A review on the most important medicinal plants effective in cardiac ischemia-reperfusion injury. Current Pharmaceutical Design, 25(3), 352-358.

Singh, A., Sharma, R. K., Agrawal, M., & Marshall, F. M. (2010). Health Risk Assessment Of Heavy Metals Via Dietary Intake Of Foodstuffs From The Wastewater Irrigated Site Of A Dry Tropical Area Of India. Food and chemical toxicology, 48(2), 611-619.

Sobhanardakani, S., & Kianpour, M. (2016). Heavy Metal Levels And Potential Health Risk Assessment In Honey Consumed In Thewest Of Iran. Avicenna J Environ Health Eng, 3(2): e7795

Temizer, İ., Güder, A., Temel, F., & Cüce, H. (2018). Antioxidant Activities And Heavy Metal Contents Of Castanea Sativa Honey. Global Nest Journal, 20(3), 541-550.

Toma, I., Jefferson, J., Clifford, L., & Mofio, B (2020). Assessment Of Heavy Metals And Pesticide Residues In Honey Samples Collected From Selected Villages In Five Local Government Areas Of Adamawa State, Nigeria. International Journal of Scientific and Research Publications (IJSRP), 10(9): 383-392.

Tomczyk, M., Zaguła, G., Puchalski, C., & Dżugan, M. (2020). Transfer Of Some Toxic Metals From Soil To Honey Depending On Bee Habitat Conditions. Acta Universitatis Cibiniensis. Series E: Food Technology, 24(1), 49-59.

Tuzen, M., Silici, S., Mendil, D., & Soylak, M. (2007). Trace Element Levels In Honeys From Different Regions Of Turkey. Food Chemistry, 103(2), 325-330.

UT, Ş (2015). Detection Of Metals In Different Honey Brands. Kafkas Universitesi Veteriner Fakultesi Dergis, 21 (6): 915-918.

Winiarska-Mieczan, A., Wargocka, B., Jachimowicz, K., Baranowska-Wójcik, E., Kwiatkowska, K., & Kwiecień, M (2021). Evaluation Of Consumer Safety Of Polish Honey—The Content Of Cd And Pb In Multifloral, Monofloral And Honeydew Honeys. Biological Trace Element Research, 1-14.

Yohannes, W., Chandravanshi, B. S., & Moges, G. (2018). Assessment Of Trace Metals And Physicochemical Parametres Of Commercially Available Honey In Ethiopia. Chemistry International, 4(2), 91-101.