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Assessment of Honey Quality with a Special Emphasis on Health Risks in Haryana, India

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Abstract

Heavy metal contamination in water and various food resources has raised concerns about the human health and well-being. Therefore, the purpose of the present study was to determine the physicochemical parameters and the levels of minerals and heavy metals in honey along with special implication of health risk assessment in Haryana, India. All the physic-chemical parameters were estimated by standard methods. All the minerals and heavy metals were analysed by Inductively Coupled Plasma-Optic Emission Spectrophotometer (ICP-OES). Results showed that the pH, moisture content, electrical conductivity, optical density, total protein content and acidity were 5.78, 20.89%, 0.81 mS/cm, 0.25, 0.00, and 0.21%, respectively. The mean values of minerals were 13.21 mg/100 g for sodium; 177.52 mg/100 g for potassium; 20.26 mg/100 g for calcium and 71.10 mg/100 g for magnesium. Among heavy metals, iron was most abundant with an average of 1.69 mg/100 g. The mean concentrations of selenium and copper in investigated honey samples were 0.68 mg/100g and 1.50 mg/100 g, respectively. Non-carcinogenic risk related parameters like estimated daily intake (EDI) and hazard quotient (HQ) were also analysed. HQ level indicated that there is a potential threat to children and adult population due to honey consumption in future. Our findings could lead to the need for future research, emphasizing the importance of exploring sources of heavy metals and implementing strategies to mitigate heavy metal contamination in honey.

***Key words*:** Hazard quotient, Heavy metal, ICP-OES, Non-carcinogenic risk, Physicochemical parameters

Honey is a sweet substance produced by honeybees through the collection of nectar from flowers and plants. It is composed of fructose, glucose, sucrose, maltose, water, minerals and protein. Its composition varies with respect to climate, species of plant, extraction techniques used by beekeepers and geographical and environmental factors. Honey, a functional food has many biological properties such as antioxidant, antibacterial, antimicrobial, radical scavenging, anti-inflammatory and antidiabetic properties [1]. Honey's antioxidant properties develop due to the presence of flavanoids, ascorbic acid, carotenoids, phenolic acids, enzymes such as catalase and glucose oxidase, and proteins [2].

However, in recent decades, several studies have indicated the presence of heavy metals in honey. This can be attributed to industrial emissions, the use of pesticides and fertilizers in crop fields, irrigation with polluted water, transport and tin storage. Every year, almost 30% of individuals in developed countries are diagnosed with food borne infections or diseases. Heavy metals are basically metallic elements that possess relatively higher density than water [3].

According to the theory that toxicity and heaviness are interlinked, heavy metals also comprise metalloids such as arsenic, which can induce toxicity even at lower exposure levels [4]. In the recent period, people have become more concerned about the ecological and global human health risks linked with heavy metal contamination of the environment. Additionally, human exposure has increased rapidly due to the exponential increase in the of use of heavy metals in industry [5], agriculture [6], and technology and for domestic purposes [7]. The sources reported to be responsible for heavy metals in environment are agricultural, geogenic, pharmaceutical, industrial and atmospheric sources [8]. Environment pollution is greater in point source areas such as foundries, smelters, metal-based industrial activities and mining [9]. Studies have reported that some metals like copper, iron, cobalt, magnesium, chromium, selenium, manganese, nickel, zinc and molybdenum are essential nutrients that are needed for different physiological and biochemical functions in the body. An inadequate supply of these micronutrients can lead to various diseases and syndromes [10-11].

Heavy metals enter the human body through food chain. These heavy metals are very harmful and can lead to various diseases such as anaemia [12], cancer [13] and heart failure [14], disorders in the synthesis of haemoglobin, inflammation, gastrointestinal bleeding, and renal and pulmonary infections [15]. Therefore there is an increased demand for safe honey free of heavy metals such as lead, cadmium and arsenic [16-18].

The presence of heavy metals in honey is now an issue of concern as it is a threat to the health of consumers. They can affect quality of life by accumulating to a level that could be toxic [19]. Therefore, a health risk assessment was performed to analyze the risks associated with the consumption of honey. Risk assessment is a process of risk analysis that yields as qualitative and quantitative explanations of the probability of hazards being associated with exposure to a harmful chemical. This process involves identifying and collecting data regarding

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health risks due to exposure to toxic chemicals, integrating the collected data and analyzing the relationships between the duration of exposure to a particular toxin, its dose, dose-response analysis and the associated adverse health risks [20].

Since toxic heavy metal pollution can affect the health and well-being of the human population via accumulation in the food chain, the health risks associated with heavy metals needed to be studied. To date, few studies have been conducted on heavy metals in honey from Haryana. Hence, this study was conducted to analyze the potential health risks of to heavy metals presented in honey collected from several districts of Haryana to promote safe consumption of honey and general awareness among consumers.

MATERIALS AND METHODS

Study area

This study was carried out in four districts of Haryana, namely, Rohtak, Gurgaon, Hisar and Panipat. Haryana is a state that lies in the northern part of India. It is located between latitude 29.0588° N and longitude 76.0856° E and lies at an altitude varying from 700 to 3600 ft above sea level. The study area lies between: Rohtak- 28.8955° N and 76.6066° E; Gurgaon- 28.4595° N and 77.0266° E; Hisar- 29.1492° N and 75.7217° E; and Panipat- 29.3909° N and 76.9635° E (Fig 1).

Sample collection

All the honey samples were collected from local apiaries and bee hives. A total of twenty samples were collected from the Rohtak, Gurgaon, Hisar and Panipat districts of Haryana. From each site, five samples were collected. These honey samples were collected in pre-treated and pre-labelled 50 mL falcon tubes and were ensured to be free from contamination. All the samples collected from different locations were heated at 400°C for 30 min and then cooled for 24 hours. The samples were then filtered through a cotton filter mesh and stored in Falcon tubes at room temperature (25 to 35°C) for further analysis.

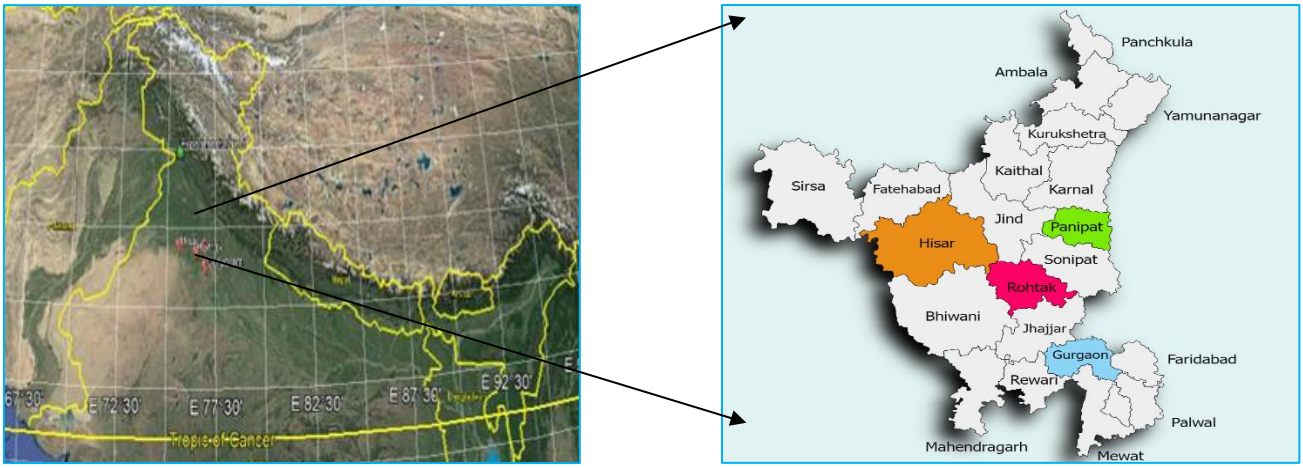

Fig 1 All honey samples were collected from four 4 districts of Haryana *viz.* Rohtak, Hisar, Gurgaon and Panipat

Methods used for physicochemical and mineral analysis

The color of the honey was analyzed using a spectrophotometer and the absorbance was recorded at 635 nm [21]. A refractometer was used to measure the moisture content. The pH of the samples was measured with a pH meter [22]. For the determination of electrical conductivity 20% (w/v) solution was prepared in Milli-Q water and EC was measured through a conductivity meter [23]. The optical density of the honey samples was measured using a spectrophotometer. For this purpose, 1 g honey samples were diluted with 9 mL of distilled water and then centrifuged at 3000 g for 10 min. The absorbance was measured at 530 nm against distilled water which was used as a blank [24]. The total protein content of honey samples was determined by the Kjeldahl method as described previously by converting organic nitrogen into $(NH_4)_2SO_4$. One gram of sample was dried and then subjected to digestion and distillation. A selenium catalyst and sulfuric acid (15 mL, 95-98%) were then mixed. This solution was distilled after the addition of NaOH and this distillate was taken in a flask with H_3BO_3 (4%) and a mixed indicator. This mixture was further titrated with 0.1 N HCl. The percentage of quantified nitrogen was converted to protein content by multiplying it by a conversion factor of 6.25 [24]. The acidity of the honey was measured using the volumetric method. Ten grams of honey was mixed with 75 mL of distilled water and this solution was titrated to a pH of 8.30 with 0.1 M NaOH [22].

An inductively coupled plasma-optic emission spectrophotometer (ICP-OES) was used for heavy metal detection. All the honey samples were first digested using a microwave oven. The microwave settings for sample digestion were 15 min/600 W at 120°C, 20 min/600 W at 180°C and 20 min of venting. Double-deionized water was used for all dilutions. Concentrated nitric acid (65%) and hydrogen peroxide (30%) were used for digestion of the honey samples. To determine the heavy metal concentrations, 1 g of honey sample was weighed and dissolved in 10 mL of concentrated nitric acid. Then, sample digestion was performed using a microwave oven. Blank solutions were made with the help of nitric acid. Since the ICP-OES method yields highly accurate and precise results, this technique was used for elemental analysis. The precision of this technique was evaluated in terms of the repeatability of the results and was represented as the standard deviation (S.D). For verification of accuracy, calibration was performed [19]. The ions in the honey samples were analysed using ion chromatography. For this purpose, the samples were dissolved in deionized water and vortexed for 5 minutes. The solution was then filtered through a 0.45 mm filter membrane. These sample solutions were then analysed for different ions. Working standard solutions were made by diluting them with stock solutions [25].

Quality control and assurance for controlled methods

Quality control during analysis was the primary concern. The environmental conditions of the experimental areas were maintained according to the ISO standards. The glassware used during the experiments was kept in 20% HNO_3 (6 M) for one day and then washed carefully with deionized water. All the samples were analyzed in triplicate. In every analysis, quality

control (QC) was carried out at regular intervals. A control chart was constructed at the time of analysis to check for deviations from the QC standard. Limit of detection was examined using formulas presented in Kicinska [26] and the method followed by [27-28].

Health risk assessment

Estimated daily intake

The EDI was calculated using the following equation:

$$EDI = \frac{C \times F}{D \times W}$$

Here, C is the concentration of the metal in honey (mg/100 g), F is the total dietary intake (0.07 kg), D is the total number of days in a year (350 days/year), and W refers to the body weight (60 kg for adults and 15 kg for children) [27], [29].

Non-carcinogenic risk

The non-carcinogenic risk assessment due to the consumption of trace elements was calculated by the following equation:

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

Here, THQ refers to the total hazard quotient, EDI is the estimated daily intake and RfD (mg/100 g-d) is the oral reference dose [30-32]. The oral RfD for Se is 0.005 mg/kg, that for Cu- is 0.04 mg/kg/d, and that for Fe is 0.7209 mg/kg/d [33-34].

Statistical analysis

The data presented in this study were analyzed for the mean and standard error (SE). The significance level among different districts (Rohtak, Gurgaon, Panipat and Hisar) was calculated by one-way ANOVA using SPSS statistical software.

RESULTS AND DISCUSSION

Physicochemical parameters of honey in various districts of Haryana

pH

pH is associated with the storage of honey and the growth of microorganisms that can alter the texture and stability of honey [35]. According to the Iranian National Standards Organization (INSO), the lowest tolerable pH value for honey is 3.5 [36]. Food safety organizations have not described the pH limits of honey; however, our results indicate that honey is acidic [37]. The pH values obtained from the honey samples ranged from 5.31 to 6.13. All the samples had acidic pH values, and the lowest value was recorded in the Panipat district (5.31±0.01) while the highest was recorded in the Hisar district (6.13±0.09) (Table 1). The results of the analysis of variance suggested that there was no significant difference ($p < 0.05$) in the pH of the honey collected from the different locations. Our values for pH are higher than those obtained from other parts of India [38-41]. Honey is usually acidic and the variations in its values can be attributed to its source, enzymatic process, or conversion of raw material by fermentation and salivary secretions from honey bees [42].

Table 1 Mean values of physicochemical parameters of honey samples collected from various districts of Haryana

	Rohtak	Gurugram	Hisar	Panipat
pH	5.70±0.01^{b}	5.90±0.03^{b}	6.13±0.09^{c}	5.31±0.01^{a}
Range	5.68-5.72	5.85-5.94	6.00-6.30	5.30-5.32
MC	20.40±0.02^{a}	21.14±0.02^{b}	21.32±0.03^{b}	20.73±0.15^{a}
Range	20.37-20.43	21.10-21.17	21.29-21.37	20.43-20.90^{a}
EC	0.80±0.01^{b}	0.91±0.01^{c}	0.71±0.01^{a}	0.83±0.03^{b}
Range	0.77-0.82	0.90-0.93	0.70-0.73	0.80-0.88
OD	0.26±0.02^{a}	0.25±0.01^{a}	0.26±0.01^{a}	0.26±0.02^{a}
Range	0.23-0.29	0.23-0.27	0.24-0.27	0.23-0.29
Acidity	0.21±0.02^{a}	0.23±0.02^{a}	0.23±0.01^{a}	0.20±0.01^{a}
Range	0.17-0.24	0.21-0.27	0.21-0.25	0.19-0.22

MC: moisture content; EC: electrical conductivity; OD: optical density

Moisture content

Moisture is a major factor that determines the potential of honey to stay fresh and prevent fermentation [22]. The moisture content of the analyzed honey samples ranged between 20.37 and 21.37% and was under the maximum acceptable limit set by the FSSAI (< 25%). In 2011, BISs were grouped with honey based on their moisture content. According to these criteria, honey samples with moisture levels less than 20% were categorized as “Special Grade”, those with < 22% moisture as “Grade A” and those with moisture < 25% as “Standard Grade”. In our study all the samples were found to have moisture level < 22% hence, they can be categorized as Grade A honeys. No significant difference was observed in the moisture content of honey samples collected from different locations [29]. Our results were consistent with those of a study conducted by Gairola *et al.* [43] in which the values were also greater than those of other studies [40]. The higher values can be attributed to the removal of unripe honey from the bee hives. This variation can also be attributed to the source of origin, climatic conditions, grade of maturity in hives, processing, season in which harvesting is performed, and storage conditions thus, the variation can differ from time to time. A high amount of water can cause unwanted fermentation of honey at the time of storage, eventually resulting in a bitter taste. A greater humidity during the removal of honey from hives is more likely to elevate the moisture content [44].

Electrical conductivity

The EC of honey is directly associated with the concentration of organic acids and minerals present in honey [45]. The distribution of honeydew is highly variable depending upon the source of nectar; hence, nectar intake is considered to be a major factor for the classification of honey [29], [46]. The EC values obtained from the honey samples collected from different districts ranged between 0.70 and 0.93 mS/cm. The mean EC values of honey from Rohtak and Hisar (0.80±0.01 and 0.71±0.01, respectively) (Table 1) were below the permitted limits of 0.800 mS/cm, whereas, their values exceeded those of samples from Gurgaon and Panipat *i.e.* 0.91±0.01 and 0.83±0.03, respectively. Our results were comparable to those of Kamal *et al.* [47] and were higher than the values reported by other researchers [41], [48] (Table 2).

Optical density

The optical density varied from 0.23-0.29 and was lowest (0.25) in honey samples from Gurgaon. All the samples were light dark in colour. Optical density is a key factor in determining the color and freshness of honey. In this study, the mean optical density was similar in samples collected from Rohtak, Hisar and Panipat (0.26). Among the samples collected from the Rohtak district, the OD ranged from 0.23-0.29, 0.23-0.27 in Gurgaon, 0.24-0.27 in Hisar and 0.23-0.29 in Panipat (Table 1). The OD values of Rohtak and Panipat were statistically similar. Overall, OD values can provide useful information about the color and freshness of honey samples [49]. Our study produced quite similar results to those reported by and the values were lower than those in the studies of Thomas and Kharnaior [50] (Table 2).

Total protein content

The total protein content of honey strongly depends upon floral source and may be promoted by enzymes produced either by bees or derived from nectar [51]. The total protein content of the studied honey samples was not significantly different. Usually, the protein content of honey is less than 5.00 g/kg [2]. The amount of pollen and nectar in honey likely determines its protein content. However, in some other studies proteins were found to be present in honey [2], [45] (Table 2).

Acidity

The acidity of the samples from different locations ranged from 0.17-0.27%. The mean values for acidity were recorded to be highest in the Gurgaon and Hisar honey samples (0.23% each) honey samples and lowest (0.20%) in samples from Panipat (Table 1). Therefore, none of the samples exceeded the permitted value of 50 meq/kg. All the samples were consistent with the established standards, which suggest that the honey was fresh and not fermented. Acidity plays an important role in contributing to the flavour of honey, increasing chemical reactions, antioxidant and antibacterial activity and stability against microbes [52]. The acidity of honey is due to the presence of different gluconic acids, particularly gluconic acid, lactones and inorganic ions such as chlorides, sulfates and phosphates. A high amount of acidity indicates sugar fermentation which is transformed into organic acids as mentioned by Gomes *et al*. [53] and Habib *et al.* [45] whereas low acidity is an indicator of the freshness of honey [41] (Table 2).

Table 2 Reported values of physicochemical parameters of honey in various studies

Parameters	Reported levels	References
pH	5.30-6.30	In present study
	4.85-3.81	[38]
	3.52-3.78	[39]
	3.01–4.35	[40]
	3.7-3.9	[41]
Moisture content	20.37-21.37%	In present study
	19-25%	[43]
	17.5-19.1%	[40]
	18-24.5%	[54]
Electrical conductivity	0.70-0.93 mS/cm	In present study
	0.45-0.55 mS/cm	[41]
	0.351-1.447 mS/cm	[48]
	631.95-804.54 µS/cm	[47]
Optical density	0.23-0.29	In present study
	0.29 -1.24	[55]
	0.786- 0.062	[50]
	0.513 - 2.977	[49]
Total protein content	Nil	In present study
	0.27–0.64%	[45]
	0.048-0.229%	[2]
Acidity	0.17-0.27%	In present study
	29.8-38.62 meq/kg	[55]
	14.83-40.17 meq/kg	[38]
	9.2-41.4 meq/kg	[41]

Variation in the ion and mineral contents of honey in various districts of Haryana

The mean contents of minerals found in the analyzed honey samples from all four districts are shown in (Table 3). The minerals found in the samples were sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg), which ranged from 12.15-13.92 mg/100 g, 176.20-178.51 mg/100 g, 19.25-21.92 mg/100 g and 6.23-7.85 mg/100 g, respectively. K was the most abundant mineral found in honey and Ca was the second most abundant mineral, with the highest amount in samples collected from Panipat and the lowest in those collected from Gurgaon. Our results for Na and Ca were lower than the values reported in other studies [56] (Ikegbunam & Okwu, 2021).The mineral that was least abundant was magnesium (6.23-7.85%). Among the trace minerals analysed in the honey, Cu was found to be most abundant in Panipat honey (1.25-1.87) and least abundant in Rohtak honey (1.08-1.54). The selenium (Se) content was highest in Panipat ranging between 1.02 and 1.46, and lowest in Gurgaon (0.21-0.46). Similarly, iron (Fe) was most abundant in honey samples from Gurgaon (1.65-1.88) and least abundant in those from Panipat (1.28-1.77). Lead (Pb) and arsenic (As) concentrations were below the limit of quantification (0.05). Several other studies depicting the content of heavy metals in honey have been mentioned in (Table 4).

Copper

The obtained values for Cu ranged from 1.08-2.11 mg/100 g and were below the permitted value of Cu (30 mg/kg). However, the average values were much greater than those reported in previous studies in New Zealand (0.25 mg/kg; [57], Solvenia (3.22 mg/kg; [58], Croatia (1074 µg/kg ; [59], Turkey (0.23–2.41 and 0.25–1.10 mg/kg; [60-61], Italy (890 and 960 µg/kg; [62-63], and the Black Sea area of Turkey (9.75–35.8 µg/kg; [64] (Table 4).

Selenium

The Se values ranged between 0.21 and 1.46 mg/100 g. These values were much greater than those reported in other studies. Pehlivan and Gul [65] reported that the Se concentration was 0.0003 mg/kg. Similarly, in another study conducted by Dhahir and Hemed [66], the Se concentration ranged from 0.232- 0.8100 mg/kg (Table 4).

Iron

In the present study, the concentration of Fe ranged between 1.28 and1.88 mg/100 g. Thus, the obtained values are much lower than the permissible limit, *i.e.*, 800 mg/kg. These values were higher than those reported in previous studies. In Turkey, Fe concentrations were reported to be in the range of 268-1036 µg/kg [67]. Saghaei *et al*. [68] reported an Fe value between 0.70 ± 0.20 mg/kg, ranging from 0.37 - 1.98 mg/kg in honey samples; study conducted in Kahramanmaraş Province, Turkey reported an Fe level in honey of 0.36 mg/kg [69]and that in the Lazio region in Italy reported an Fe level of 4.51 ± 0.39 mg/kg [70] (Table 4).

Table 3 Mineral and heavy metal contents in honey samples collected from different districts of Haryana

Attributes	Rohtak	Gurgaon	Hisar	Panipat
Sodium	13.20±0.01^{ab}	12.60±0.23^{a}	13.60±0.17^{b}	13.47±0.25^{b}
Range	13.19-13.22	12.15±12.91	13.27±13.83	13.05-13.92
Potassium	176.38±0.12^{a}	177.26±0.26^{b}	177.13±0.19^{ab}	178.31±0.12^{c}
Range	176.20-176.61	176.78±177.69	176.81-177.48	178.09-178.51
Calcium	20.74±0.17^{b}	19.29±0.02^{a}	21.19±0.36^{bc}	21.83±0.05^{c}
Range	20.41-20.97	19.25-19.33	20.56-21.79	19.25-21.92
Magnesium	6.58±0.21^{a}	7.33±0.07^{a}	7.18±0.41^{a}	7.34±0.10^{a}
Range	6.23-6.96	7.21-7.44	6.43-7.85	7.18-7.53
Copper	1.30±0.13^{a}	1.78±0.25^{a}	1.34±0.05^{a}	1.59±0.18^{a}
Range	1.08-1.54	1.29-2.11	1.27-1.44	1.25-1.87
Selenium	0.52±0.08^{a}	0.33±0.07^{a}	0.67±0.23^{ab}	1.20±0.13^{b}
Range	0.37-0.62	0.21-0.46	0.22-0.93	1.02-1.46
Iron	1.78±0.06^{a}	1.78±0.07^{a}	1.70±0.08^{a}	1.49±0.15^{a}
Range	1.66-1.85	1.65-1.88	1.59-1.86	1.28-1.77

Table 4 Reported ion and mineral contents in honey samples from different studies conducted worldwide

Parameters	Reported levels	References
Sodium	12.15-13.92 mg/100 g	In present study
	0.30 mg/100 g	[56]
	153.0 ppm	[71]
Potassium	176.20-178.51 mg/100 g	In present study
	2.97 mg/100 g	[56]
	2018.0 ppm	[71]
Calcium	19.25-21.92 mg/100 g	In present study
	68.50 mg/100 g	[56]
	287.0 ppm	[71]
Magnesium	6.23-7.85 mg/100 g	In present study
	9.0-11.8 mg/kg	[72]
	5.50 mg/100 g	[56]
	327.0 ppm	[71]
Copper	1.08-2.11 mg/100 g	In present study
	1.49 ppm	[71]
	0.01–0.23 mg/kg	[73]
	0.01–0.09 µg/g	[1]
Lead	BLQ	In present study
	BLQ	[74]
	BLQ	[73]
	BLQ	[56]
Iron	1.28-1.88 mg/100g	In present study
	3.29-4.56 µg/g	[16]
	22.4 ppm	[71]
Arsenic	BLQ	In present study
	<0.01 mg/kg	[72]
	BLQ	[75]
Selenium	0.21-1.46 mg/100g	In present study
	0.0003 mg/kg	[65]
	0.232- 0.810 mg/kg	[66]

BLQ: Below limit of quantification

Health risk assessment

Estimated daily intake

The calculated values of the estimated daily intake (EDI) of each metal for both human adults and children are shown in (Table 5). The obtained EDIs of Cu, Se and Fe for adults were 0.15, 0.06 and 0.20 mg/kg/day, respectively (adults) and 0.04, 0.02 and 0.05 mg/kg/day, respectively (children) in Rohtak; 0.20, 0.04 and 0.20 mg/kg/day, respectively (adults) and 0.05, 0.01, and 0.05 mg/kg/day, respectively (children) in Gurgaon; 0.15, 0.08 and 0.20 mg/kg/day, respectively (adults); and 0.04, 0.02 and 0.05 mg/kg/day, respectively (children) in Hisar; 0.18, 0.14 and 0.17 mg/kg/day, respectively (adults); and 0.05, 0.04 and 0.04 mg/kg/day, respectively (children) in Panipat. The decreasing pattern of the EDI values of the metals was Fe > Cu > Se.

Hazard quotient

The HQ data are presented in Table 5. The HQs for Cu, Se and Fe in adults were 3.75, 12.00 and 0.28, respectively, in Rohtak; 5.00, 8.00 and 0.28, respectively, in Gurgaon; and 3.75, 16.00, and 0.28, respectively, in Hisar; and 4.50, 28.00, and 0.24, respectively, in Panipat. The HQs for Cu, Se and Fe in children were 1.00, 4.00, and 0.07, respectively, in Rohtak; 1.25, 2.00, and 0.07, respectively, in Gurgaon; 1.00, 4.00, and 0.07, respectively, in Hisar; and 1.25, 8.00, and 0.06, respectively, in Panipat. A HQ < 1 indicates no probable adverse health effects; however, a HQ > 1 indicates probable adverse effects on health [30], [76]. All the values for Fe were less than 1 for both adults and children, which indicate that Fe is not a potential threat to human health. However, a HQ > 1 for Cu and Se suggested potential health risks in humans.

CONCLUSION

In conclusion, our investigation into the quality of honey in Haryana has revealed important insights with implications for both health and sustainability. The presence of elevated levels of copper and selenium in honey raises concerns about potential health risks for consumers, underscoring the need for ongoing monitoring and awareness. This study addresses a critical gap in understanding the impact of industrialization on honey quality in Haryana. As we navigate the complexities of modern development, it is imperative to consider not only the immediate health risks posed by heavy metal contamination but also the long-term sustainability of food sources. Our findings could lead to the need for future research, emphasizing the importance of exploring sources of heavy metals and implementing strategies to mitigate heavy metal contamination in honey. Sustainable practices should be at the fore front of these efforts, ensuring that the honey industry continues to thrive without compromising the health of consumers or the environment. Moving ahead, the integration of regular monitoring programs has become crucial, aligning with the principles of human sustainability. By fostering awareness among consumers and implementing strategies to reduce pollutant levels in floral sources, we can contribute to a healthier future for both individuals and the ecosystem. Therefore, this study not only highlights the immediate need for vigilance in honey quality but also underscores the broader goal of fostering human sustainability through responsible practices and a commitment to the well-being of both consumers and the environment.

Table 5 Calculated EDI and HQ for metals in both adults and children in Haryana

Location	Element	EDI (Adult)	HQ (Adult)	EDI (Children)	HQ (Children)
Rohtak	Copper	0.15	3.75	0.04	1.00
	Selenium	0.06	12.00	0.02	4.00
	Iron	0.20	0.28	0.05	0.07
Gurgaon	Copper	0.20	5.00	0.05	1.25
	Selenium	0.04	8.00	0.01	2.00
	Iron	0.20	0.28	0.05	0.07
Hisar	Copper	0.15	3.75	0.04	1.00
	Selenium	0.08	16.00	0.02	4.00
	Iron	0.20	0.28	0.05	0.07
Panipat	Copper	0.18	4.50	0.05	1.25
	Selenium	0.14	28.00	0.04	8.00
	Iron	0.17	0.24	0.04	0.06

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Author(s) contributions
First author collected all the samples, performed all the analysis, and prepared the primary draft. AG was responsible for conceptualization, methodology, writing - review AND editing, and supervision. All the authors have read and approved the final version of the manuscript.

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