Uttar Pradesh Journal of Zoology

Volume 45, Issue 17, Page 186-199, 2024; Article no.UPJOZ.3907
ISSN: 0256-971X (P)

Contaminants in Honey: Safeguarding Quality and Consumer Health

Khushmeen Kaur [a], Pratham Arora [a] and Garima Gupta [a++*]

[a] University Institute of Agricultural Sciences, Chandigarh University, Punjab, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i174361

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/3907

Review Article

Received: 05/06/2024
Accepted: 09/08/2024
Published: 14/08/2024

ABSTRACT

Honey, produced largely by European Honey Bees, Apis mellifera. It possesses qualities that can be used to cure cancer, wounds, and ailments. The presence of environmental pollutants in honey, poses a significant risk to its therapeutic benefits and the safety of consumers. Antibiotics such as amphenicols, tetracyclines, beta lactams, and others, commonly used to treat multiple diseases in bees, are been found in honey. The presence of antibiotic residue in honey can cause many health issues in humans, such as anemia, enamel hypoplasia, and nephrotoxicity. Residues of pesticides derived from flowers and pollen of treated crops have the potential to induce skin infections, cancer, neurological impairment, and bruising. Pesticides have the ability to harm cells and influence human genetics. Clostridium botulinum spores, known to cause botulism in infants, have been discovered in honey. Zinc, mercury (Hg), copper (Cu), and other heavy metals are toxic and have carcinogenic properties. They can lead to the development of cancer, anemia, heart failure, lung failure, renal failure, and gastrointestinal failure. Heavy metals possess carcinogenic and deleterious properties. This study focuses on the importance of exercising caution while using adulterated honey. Additionally, it highlights the significance of implementing stringent global regulations to ensure honey bee safety and maintain the purity of honey.

[++] Professor;
**Corresponding author: Email: gari_g79@yahoo.com, gaima.e8884@cumail.in;*

Cite as: *Kaur, Khushmeen, Pratham Arora, and Garima Gupta. 2024. "Contaminants in Honey: Safeguarding Quality and Consumer Health". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (17):186-99. https://doi.org/10.56557/upjoz/2024/v45i174361.*

Keywords: Antibiotics; contamination; health impacts; honey; macrolides; neonicotinoids.

1. INTRODUCTION

Apiculture, also known as beekeeping, is the cultivation and management of domesticated honeybee species for the production of honey and its byproducts. It is a prominent agri-horticultural and forest-based approach that is environmentally sustainable, economically profitable and environment friendly. India has an extensive tradition of beekeeping and is currently ranked sixth in the world for honey production, predominantly to its vast bio diverse regions [1]. History shows that bee products have been used by humans from past thousands of years [2]. Coughs and sore throats, gastric ulcers, measles, earaches, and infected leg ulcers all have been treated using honey.

Bee products are rich in simple sugars, minerals, and antioxidants. Honey contains a high concentration of enzymatic and non-enzymatic antioxidants. Honey can also inhibit the growth of pathogens that cause food spoilage, as well as deteriorative oxidation reactions in food, such as lipid oxidation in meat and enzymatic browning in fruits and vegetables [3]. Honey can be used to cure cancer, healing of wounds, and infections. As a result, bee products have regained prominence in recent years as a key natural resource that can be exploited in revolutionary therapies without the negative impacts associated with manufactured chemical drugs. However, market competition imposes extra requirements on these products, which can only be addressed through quality assurance and certification methods [4].

Pollution of bee products, such as honey, occurs from a variety of sources. Radioactive materials, heavy metals, pesticides, and diseases are all examples of environmental contaminants. Pesticide residues have been shown to degrade cells and cause genetic changes. Pesticides degrade the quality of bee products, in addition to posing health risks to the population. A major negative consequence of pesticide use is the poisoning of pollinators, majorly honey bees. Due to which there is a reduction in honeybee population, reduced honey output, degraded plant ecosystems, also the traces of pesticide residues in food, and finally results in a significant loss of revenue for beekeepers. Monitoring pesticide residues in honey, wax, and bees not only provides information on the quantity of pesticide treatments done to the field crops surrounding the hives, but it also aids in determining the potential risk to human health [5]. The main aim of bee product monitoring is to improve product quality, promote worldwide commercial competition, and protect consumer health.

Antibiotics are commonly used by beekeepers, either as "growth promoters" in little dosages or in huge quantities to treat infections. Maximum residue limits (MRLs) have been established for the majority of foods generated from animals treated with sulfonamide and tetracycline. When found in high amounts, these xenobiotics not only decrease the health benefits of honey but, over time, may also put consumers at risk for a number of side effects, such as intestinal disorders, aplastic anaemia from bone marrow toxicity, cellular degradations, hypersensitivity reactions, tooth yellowing, damage to calcium-rich organs (bones, teeth), carcinogenic or teratogenic effects, and, most importantly, develop antibiotic resistance [6]. Antibiotic residues have a rather lengthy half-life and may cause direct harm to consumers.

Bee products, such as honey, do not contain MRLs (Maximum residue limit). International trade in honey is prevalent, with most countries adhering to the Codex Alimentarius Commission (framed in 1981, revised in 1987 and 2001) and EU council directive (2001/110/EC and amended in 2014 as 2014/63/EU) [7] and at national level FSSAI [Food Safety and Standards (Food Product Standards and Food Additive) Amendment Regulations, [8]. In addition, the United States, Canada, Australia, India, and the European Union all have distinct requirements and parameters to define these limits [5]. Unfortunately, overuse of antibiotics causes antibiotic residues to accumulate in honey, lowering its quality and making marketing more complex. An analysis verifying the product's safety and origin is required to enable honey labelling. To maintain the safety of honey, health authorities around the world must pass tight laws and regulations governing its production, handling, and analysis. It is not advisable to use unprocessed or unsterilized raw honey for infants [9]**.** To ensure its safety, raw honey should not be applied directly to wounds or lesions without first being sterilized. It should also be analysed to detect any adulteration that could jeopardize its therapeutic properties. Even when consuming other bee products as nutritional supplements or medical therapies, such as wax, venom, pollen, and royal jelly, follow these rules as well. Adequate monitoring is required since differing production techniques cannot change residual pollution levels. These commodities are subject to additional market competitiveness requirements that can only be met by following to quality assurance and certification standards and laws [2].

2. HONEY COMPOSITION: UNDERSTANDING ITS CHEMICAL MAKEUP

Honey is a natural and organic substance produced by honeybees from plant secretions or nectar. Honeybees collect, transform, and store the honey in combs to mature and ripen. It is sticky and viscous substance and it has a complex chemical makeup that contributes to its unique properties. Glucose and fructose constitute 80-85% of honey's composition. Other components include 15-17% water, 0.1-0.4% protein, and 0.2% ash, as well as trace levels of vitamins, enzymes, amino acids, and phenolic antioxidants (Fig. 1) [10]. Honey can be classified based on its origin (flower, honeydew, monofloral, multifloral), harvesting and processing method (comb, strained, chunk, extracted, pressed, crystallized or granulated, creamed), and intended usage [11]. Honey's distinct properties are attributed to enzymes such as glucose oxidase and amylase, and its acidity and flavour profile are derived from organic acids such as acetic acid, citric acid, and gluconic acids [12]. Honey contains a variety of small components, including alkaloids, flavonoids/isoflavones, glycosides, phenolics, peptides/proteins, specific enzymes (amylase, glucose oxidase, and invertase), compounds similar to carotenoid compounds, organic acids, Maillard reaction products, vitamins, and minerals [13]. Honey's distinct properties are attributed to enzymes such as glucose oxidase and amylase, and its acidity and flavor profile are derived from organic acids such as acetic acid, citric acid, and gluconic acids [14].

Numerous studies have investigated the chemical composition and physical properties of honey derived from various sources. Moisture content, sucrose content, reducing sugar content, pH value, electrical conductivity, ash content, free acidity, diastase activity, and hydroxymethyl furfural (HMF) content are the primary quality characteristics to consider [15]. Honey's composition varies according to various flowers. Although natural honey contains over 300 bioactive compounds, the majority of it is made up of water and sugars, particularly fructose and glucose, which account for 95-99 percent of the dry matter, as well as about 4-5 percent fructo-oligosaccharides (Fig. 2). Other sugars found include maltose, sucrose, maltulose, turanose, isomaltose, laminaribiose, nigerose, kojibiose, gentiobiose, and oligosaccharides. Rapeseed honey differs from chestnut and acacia honey as in that it contains more glucose than fructose [16].

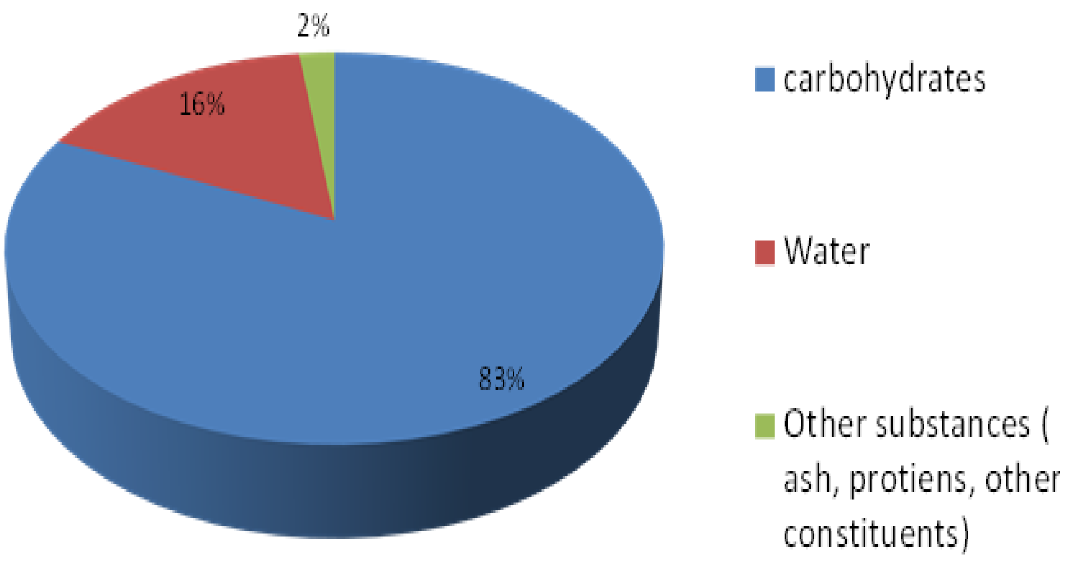

Fig. 1. Composition of honey

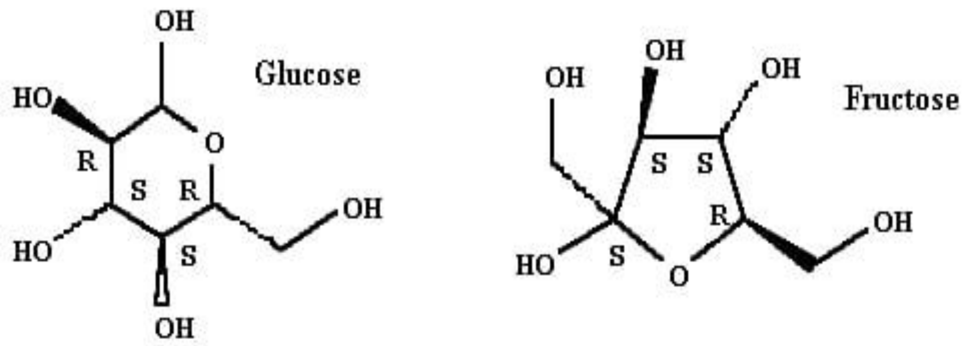

Fig. 2. Molecular structure of sugars found in honey

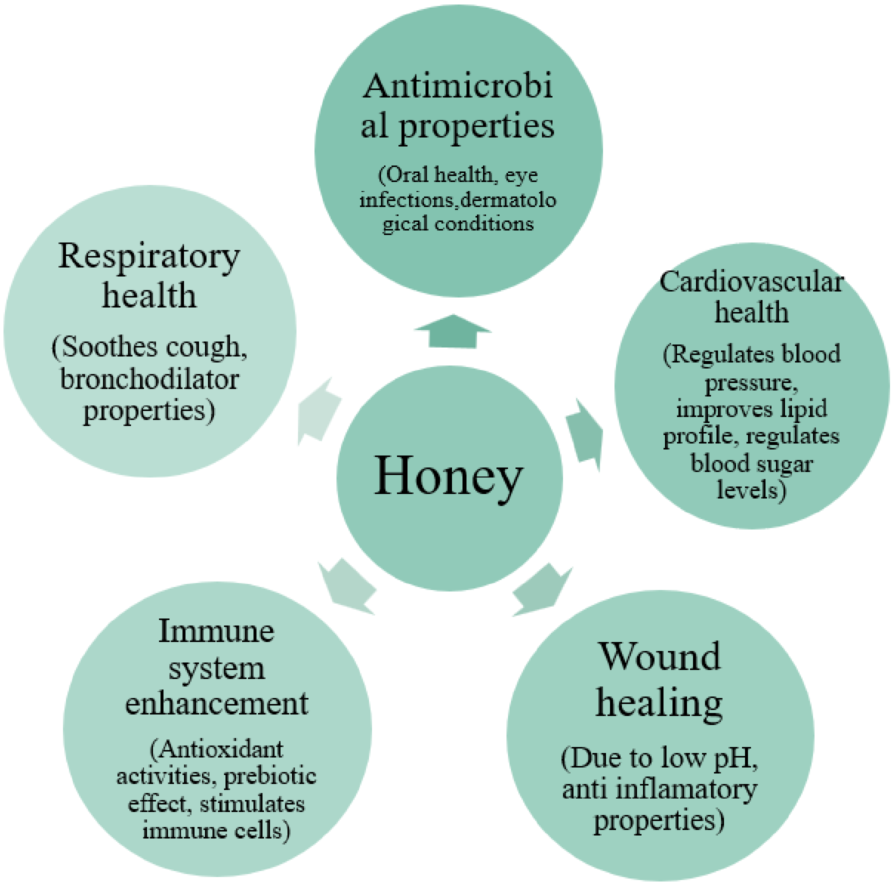

Fig. 3. Health benefits of honey

Additionally, phenolic compounds present in honey are derived from plants and can provide health benefits, including antioxidant properties. The acidity and flavour of honey are mostly attributable to organic acids [13]. Honey's high sugar content may conceal its acidic taste. The average pH of honey is 3.9. The complex combinations of polyphenols contained in honey change depending on several conditions, including soil, climate, location, pollution levels, and storage. These variances can be related to the fact that some polyphenols are unique to specific plants and can only be found in honey collected by bees from those plants [17]. The principal sources of polyphenols in honey include phenolic acids and their derivatives, as well as flavonoids (quercetin, luteolin, kaempferol, apigenin, chrysin, and galangin). These compounds are known to have antioxidant properties. Certain types of honey include trace levels of bitter chemicals. These include terpenoids, polyphenols, alkaloids, and glycosides. Certain plant species, including *Senecio spp*., *Datura spp*., *Euphorbia spp*., and *Agave spp*., give honey an unpleasant flavour [11].

2.1 Health Benefits of Pure Honey

Honey relieves thirst, balances kapha, eliminates hard masses, and improves eyesight. It reduces toxicity, relieves hiccups, blood problems, diabetes, worm infestations, skin troubles, bronchial asthma, cough, diarrhea, nausea, vomiting, wound cleansing, wound healing, and deep wound healing [18]. Honey boosts immunity, wound healing, and contains antioxidant and antibacterial effects [19]. Honey has been shown to improve cardiovascular health, glycemic management, and hypoglycemia [20]. Honey lowers lipids, inflammatory markers, and plasma glucose [21]. Honey has also been demonstrated to regulate weight and enhance lipid profiles in obese rats and humans over time [22]. Honey's antimicrobial, antioxidant, and antiseptic qualities have been shown to cure burns, infected wounds, ophthalmic difficulties, and gastrointestinal concerns. It accelerates wound healing by increasing angiogenesis, fibroblast proliferation, and epithelial cell production. Honey is helpful against drug-resistant bacteria like MRSA and Pseudomonas aeruginosa. Reduces kidney inflammation and improves oral hygiene (Fig.3). Honey is a low-glycemic nutritional source that can replace artificial sweeteners or sucrose in food items and improve sensory quality and shelf life [23]. Honey boosts immunity by releasing cytokines from mono cytes, including TNF-α and interleukins 1 and 6, which elicit immune responses [24]. Honey's ability to strengthen the immune system was demonstrated in studies on young rats fed honey-rich diets, which showed significant increases in phagocytosing neutrophils and lymphocytes [25].

3. CONTAMINATED HONEY

Honey contamination occurs due to addition of unwanted substances in honey such as pesticides, antibiotics, heavy metals, harmful microorganisms etc. Pesticides are hazardous, and several are suspected carcinogens [26]. Pesticides can alter the endocrine system, the reproductive system, and the neurological system [27]. Pesticides used in agriculture and beekeeping activities can contaminate honey since plant protection chemicals persist in the environment [28]. These substances can be transported from the environment to honey via nectar, making it an indirect source of pollution [29] Fig. 4 illustrates the possible negative health impacts of contaminated honey on human when collected from different sources containing different pollutants.

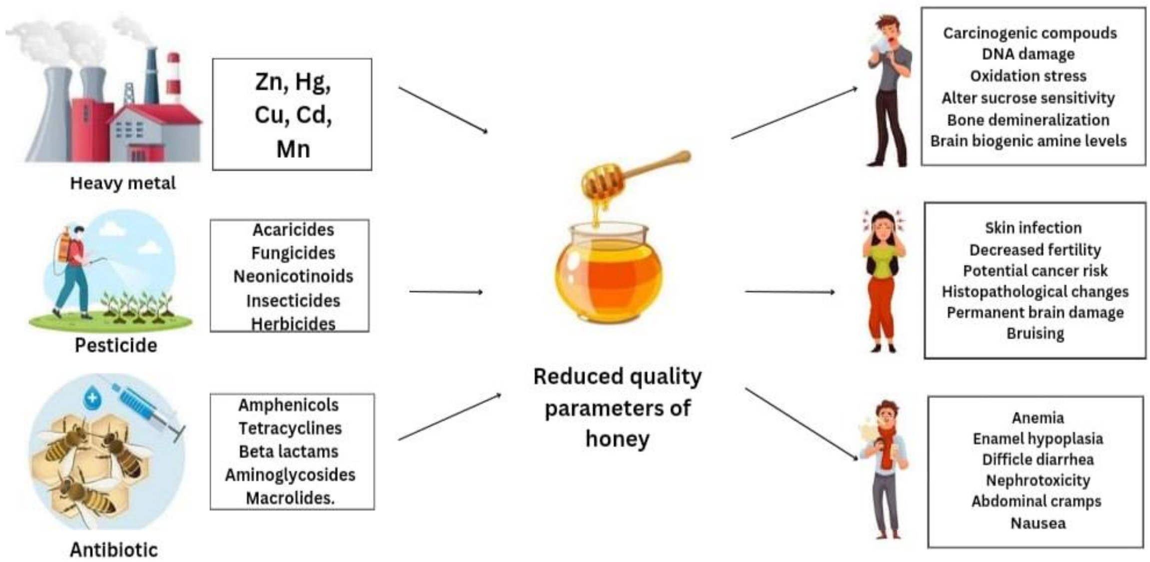

Fig. 4. Health impacts caused by contaminated honey collected from polluted sources

The use of veterinary medications, such as acaricides by beekeepers to manage varroa destructor mite infestation of bee colonies, is the primary source of pesticide contamination in honey [30]. Humans are exposed to pesticides primarily through their diet, which includes vegetables and fruits, but also through honey. It is estimated that humans absorb five times more pesticides through food than other routes of exposure, such as air or drinking water [31]. Consumers may also be at risk for a range of side effects from prolonged exposure of pesticides, such as teratogenic or carcinogenic effects, genetic mutations, hypersensitivity reactions, yellowing of the teeth, damage to calcium-rich organs (bones and teeth), intestinal flora disorders, aplastic anaemia due to toxicity of the bone marrow, and most importantly participation in the development of antibiotic resistance [6].

Neonicotinoids are used prophylactically on a wide range of crops, including sunflower and rapeseed [32]. They are the most often used insecticides for clover, accounting for around one-third of the global insecticide market [33]. Neonicotinoid residues can be identified in honey because they are present in the pollen and nectar of most of the flowering crops [34]. Acetamiprid and Imidacloprid are the group of neonicotinoids, that are the most frequently used insecticides in the world [35].

Antibiotics are another type of contaminants that might affect the quality of honey. Beekeepers employ the chemicals to prevent and treat various bee diseases. The presence of antibiotics in honey is a worldwide problem, as they can develop residues and pose hazards to human health [36]. They can also lead to allergic reactions, antibiotic resistance in humans, toxic consequences, hepatotoxicity, and nephropathy [37].

3.1 Antibiotic Contamination in Honey

Honey has been utilized for millennia as both sustenance and remedy. Similar to other forms of life, honeybees are susceptible to various diseases and parasites, including nosemosis and European and American foulbrood. Antibiotics are effective in treating particular diseases [38]. Beekeepers employ sulphonamides, tetracycline, nitro furans, and macrolides for the prevention and treatment of diseases in honeybees, consequently these chemicals could have left traces in honey. Worried beekeepers may have used antibiotic mixtures randomly and in enormously inadequate doses and at multiple times, because of the risk of these diseases and the rising demand for honey [39]. In addition, several beekeepers enhance their honey output by using low-dose, sub therapeutic antibiotics to stimulate bee development. In order to manage the spread of infectious illnesses in honey bee colonies, it is recommended to provide antibiotics at the correct dosages before the honey flow season begins or during the extended period of dearth [40]. Beekeeping with the use of antibiotics necessitates less labor and results in higher financial gains. The chemicals mentioned consist of antibacterial agents such as sulfonamides, tetracyclines, erythromycin, tylosin, and streptomycin, which are employed for the treatment of bacterial brood diseases. Additionally, acaricides like Folbex VA (brompppropyllate), Perzin (coumafos), Apistan (fluvalinate), and Bayvarl (flumetrine) are utilized to combat mites. Maximum Residue Limits (MRLs) have been established for tetracycline and sulfonamide across all food-producing species. Alone, honey does not have MRLs [41]. The adverse health effects associated with human exposure to these antibiotics are detailed in Table 1.

Table 1. Antibiotic adulterants in honey: components, dose range and adverse effects

Antibiotic	Components	Dose Range	Adverse Effects on Humans	References
Beta lactams	Amoxycilin Piperacillin	25 - 125 mg/kg 150 - 450 mg/kg	Difficile diarrhea Convulsions	[42]
Amphenicols Tetracyclines	chloramphenicol Tetracyclines	50 mg/kg 25-50 mg/kg	Anemia Enamel hypoplasia	[3] [43]
Macrolides	Macrolides	250-500 mg every 12 hours	Abdominal cramps and nausea	[44]
Aminoglycosides	Aminoglycosides	1.5–2.0 mg/kg	Nephrotoxicity	[45]
Fluoroquinolones	levofloxacin	250-750 mg/kg	Irreversible nerve damage	[46]

3.2 Neonicotinoids and Pesticide Contamination in Honey

The growing need for food has led to an increase in the usage of pesticides to control weeds, nematodes, rodents, fungi, and insects [47]. These pesticides must be applied in order to preserve the plants and also to control insects that are harmful to public health, such as mosquitoes and flies. Pesticide application is essential in agriculture to obtain high product yields, but because more than 90% of applied pesticides do not reach their target species, they continue to disrupt ecosystems and contaminate food and water [48, 49]. This application may contaminate honey samples from various countries with pesticides, posing a health risk to the general public. Pesticides applied on crops have the potential to infect bees that collect nectar and pollen from flowers, resulting in an accumulation of harmful compounds in honey. Furthermore, because pesticides are used directly to protect beehives from parasites, chemical residues may pollute the beehives [50].

The neonicotinoids were a novel class of insecticides that hit the market in the 1990s. Systemic, long-lasting neonicotinoids protect crops from mostly sucking insect pests at lower concentrations than other pesticides and replaced carbamates, pyrethrins, pyrethroids, and organophosphates insecticides. However, there is mounting evidence that these pesticides pose a threat to ecosystems, human health, and even beneficial insects like bees [51]. Current research has shown that neonicotinoid can cause neurotoxicity, hepatotoxicity, immunotoxicity, geno-toxicity, reproductive system impairments, neuro developmental immune toxicity, and central nervous system inflammation on human health [52]. Honey bee colony losses have been reported since neonicotinoids were employed in agriculture, raising concerns about their impact on pollinators [53]. Despite numerous other reasons affecting bee survival, neonicotinoids are one of the most extensively linked causes of bee death due to their high toxicity and persistence. Sublethal consequences of neonicotinoids in bees include shorter lifespans, weaker immune systems, poor learning and foraging, and higher virus exposure [54]. The bees' ability to collect nectar and pollinate both domestic and wild plants might be compromised as a result of these consequences, which would be bad for both types of ecosystems [55]. Bees' foraging habits allow them to explore large areas of land, making them environmental sentinels. Nevertheless, this behaviour poses a threat to pollinators due to their continuous exposure to harmful chemicals [56]. The information in Table 2 describes the many kinds of chemicals that may be found in honey, as well as their chemical composition, optimal range, geographic location, and potential health effects on those who consume contaminated honey. The Euphorbia orientalis honey from Laghouat has the highest number of discovered toxicants and the content of cyromazine exceeded the EU maximum residual threshold, making it the most contaminated sample.

Table 2. Honey chemical contaminants: Types, Levels, Regions, and Health Impacts

Type of pesticides	Chemical Compound	Optimum Range (µg/g)	Region	Adverse effects on Human Health	References
Acaricide	Amitraz	0.4	China	Skin infection, Cause poisoning when inhaled	[57]
Insecticide	Cyromazine	0.123	Algeria Laghouat	Skin irritation, Decreased fertility	[58]
Fungicides	Mancozeb	0.003	Russia	Skin irritation, Decreased fertility	[59]
Acaricide	Dicofol	0.08	Pakistan	Potential Cancer risk, Nausea	[60]
Insecticide	Azoxystrovin	0.27	Russia	Histopathological changes, Cyto toxicity	[31]
Nimaticide	Abamectin	2.5	India	Severe nausea, Ptosis	[61]
Insecticide	Actamipirid	0.1	Korea	Indigestion	[62]
Insecticide	Endosulfan	5.5	Vietnam	Endocrine disruption permanent brain damage	[63]
Insecticide	Imidacloprid	0.05	China	Blood clotting bruising	[64]
Insecticide	Fipronil	17	Taiwan	Excessive sweating Stomach pain	[65]
Insecticide	Thiocloprid	0.24	China	Carcinogenic behaviour	[66]

3.3 Microbial Contamination of Honey

Microorganisms can impact the safety and quality of honey. The fungi, yeasts, and bacteria present in honey and honeycomb comes from external sources, such as dust, winds, pollen, honey bee guts, people, equipment, and containers. Pollen is likely the initial reservoir of bacteria in honeybee digestive systems. The composition of bee intestine consists of 2% yeast, 27% Gram-negative bacteria (including *Achromobacter*, *Citrobacter*, *Enterobacter*, *Erwinia*, *Escherichia coli*, *Flavobacterium*, *Klebsiella*, *Proteus*, and *Pseudomonas*), and 20% Gram-positive bacteria (such as *Bacillus*, *Bacteridium*, *Streptococcus*, and *Clostridium spp.*) [67]. The existence of microorganisms in honey may affect its stability and cleanliness. *Bacillus* spores are quite widespread, but non-spore generating bacteria like Flavobacterium and Pseudomonas are less common. Honey can get contaminated by filamentous fungi through the presence of dust or water used during equipment cleaning. This contamination leads to vigorous growth and the development of spores that are resistant to high temperatures [68]. The chemical makeup of honey encourages the development of osmophilic yeast. This can lead to fermentation, breakdown, and crystallization when bees introduce yeast during the process of extracting and processing of honey. Honey has been shown to contain *Clostridium botulinum* spores, which are believed to be responsible for causing botulism in newborns [69]. In addition, honey samples have been discovered to include several microorganisms such as *B. cereus*, yeast, *Mucor*, *Penicillium*, as well as different species of *Aspergillus*, including *A. flavus*, *A.candidus*, *A. fumigatus*, and *A. niger* [68].

3.4 Heavy Metal Contamination

Heavy metals are trace metals that are toxic to humans and have a density at least five times that of water. Heavy metals are consumed, absorbed via the skin, and inhaled after being released into the environment via the air, food, drinkable water, or a variety of other man-made chemicals and products. Heavy metals can enter and collect in bodily tissues faster than the body's detoxification processes can remove them resulting in a gradual build-up of toxins. Exposure to high quantities of heavy metals is not required to produce toxicity in the body because these metals can accumulate in biological tissues over time and reach hazardous concentrations far beyond permitted limits [70]. Approximately 30% of people in developed countries develop foodborne infections each year. According to study, heavy metals enter the body primarily through food chains [71]. Heavy metals are the primary drivers of pollution in water, soil, and food [72]. Heavy metals are toxic and can cause a variety of ailments, including cancer, anaemia, haemoglobin biosynthesis issues, gastrointestinal bleeding, inflammation, and heart, lung, kidney, and gastrointestinal failure. Heavy metals pose a threat to a person's health since they are carcinogenic. Heavy metals have been related to environmental contamination and demonstrated to have negative effects on human health [73]. Plants can absorb heavy metals, which then enter the food chain. Heavy metals accumulate in living tissues due to their long half-lives [74]. Bees can absorb heavy metals through contaminated water, pollen, and nectar; they can also inhale particles in the air and stick to plant and soil surfaces while foraging for food [75]. In addition, honey's strong acidity can cause corrosion in stainless and galvanized steel containers, releasing heavy metals as Pb, Cr, Al, Ni, and Sn during harvesting, processing, and storage [76]. Chronic viral infections, endocrine abnormalities, obesity, respiratory and cardiovascular ailments, liver, kidney, and brain damage, allergies, asthma, and neurological problems have all been related to heavy metal contamination. enzyme malfunction can result in anemia, fatigue, headaches, dizziness, impaired immune system, gene damage, premature aging, skin problems, loss of memory and appetite, arthritis, osteoporosis, and, in severe cases, death [77]. Table 3 provides information about the heavy metal contamination in honey, including region, optimum range and health effects on humans.

Heavy metal, antibiotic, and pesticide contamination have put honey in threat nowadays, despite its historical importance for health benefits. These contaminants endanger customers' health while also reducing honey's medicinal and nutritional value. To overcome this issue, comprehensive standards governing every step of the honey manufacturing process, as well as severe quality control measures, are required. This includes monitoring environmental toxins, adhering to acceptable pesticide and antibiotic dose limits, and conducting extensive testing to ensure the safety of products. Furthermore, it is necessary to address the root causes of contamination through sustainable practices and pollution control activities, such as the use of

Table 3. Metallic impurities in honey: Optimum ranges (µg/g), effects on human health and Regions

Metal	Optimum Range (µg/g)	Effects on Human Health	Region	References
Zinc	16.729	Increase carcinogenic compounds in body	Turkey	[78, 79]
Chromium	6.635	DNA damage, oxidation stress	Arabia	[80, 81]
Manganese	1.129	Brain biogenic amine levels	Iraq	[77, 82]
Mercury	3.035	Problems in developing foetuses	Turkey	[83]
Copper	4.941	Alter sucrose sensitivity Indigestion	Cyprus	[84]
Cadmium	0.282	Cardio toxicity, bone demineralisation	Arabia	[85]

pesticides in agriculture and the reckless use of antibiotics in beekeeping. Furthermore, educating the public and advocating open labelling are critical for giving customers the ability to make their own decisions and push for safer honey. We can protect the health and welfare of current and future generations while preserving honey's purity and cultural significance by combining sustainable practices, consumer education, and government regulation. Working together, we can safeguard not only the honey's symbolic significance of healing and nutrition, but also our common values of environmental conservation and public health.

4. CONCLUSION

Heavy metal, antibiotic, and pesticide contamination have put honey in threat nowadays, despite its historical importance for health benefits. These contaminants endanger customers' health while also reducing honey's medicinal and nutritional value. To overcome this issue, comprehensive standards governing every step of the honey manufacturing process, as well as severe quality control measures, are required. This includes monitoring environmental toxins, adhering to acceptable pesticide and antibiotic dose limits, and conducting extensive testing to ensure the safety of products. Furthermore, it is necessary to address the root causes of contamination through sustainable practices and pollution control activities, such as the use of pesticides in agriculture and the reckless use of antibiotics in beekeeping.

Furthermore, educating the public and advocating open labelling are critical for giving customers the ability to make their own decisions and push for safer honey. We can protect the health and welfare of current and future generations while preserving honey's purity and cultural significance by combining sustainable practices, consumer education, and government regulation. Working together, we can safeguard not only the honey's symbolic significance of healing and nutrition, but also our common values of environmental conservation and public health.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to the Department of Agriculture, Chandigarh University, Mohali, India for providing an environment conducive to research and learning, and for your unwavering commitment to academic excellence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Narang A, Kumar D, Gupta G. Political, economical, social, technological and SWOT analysis of beekeeping as a successful enterprise in India: An overview. Journal of Applied and Natural Science. 2022;14(1):194-202.
2. Al-Waili N, Salom K, Al-Ghamdi A, Ansari MJ. Antibiotic, pesticide, and microbial contaminants of honey: Human health

hazards. The Scientific World Journal; 2012.
Available:https://www.hindawi.com/journals/tswj/2012/930849/

3. Chen H, Rao H, He P, Qiao Y, Wang F, Liu H, Yao J. Potential toxicity of amphenicol antibiotic: Binding of chloramphenicol to human serum albumin. Environmental Science and Pollution Research. 2014;21: 11340-11348.
4. Kelly S, Heaton K, Hoogewerff J. Tracing the geographical origin of food: The application of multi-element and multi-isotope analysis. Trends in Food Science and Technology. 2005;16(12):555-567.
5. Tillotson GS, Doern GV, Blondeau JM. Optimal antimicrobial therapy: The balance of potency and exposure. Expert Opinion on Investigational Drugs. 2006;15(4):335-337.
6. Panseri S, Catalano A, Giorgi A, Arioli F, Procopio A, Britti D, Chiesa LM. Occurrence of pesticide residues in Italian honey from different areas in relation to its potential contamination sources. Food Control. 2014;38:150-156.
7. WHO. World Health Organization. Connecting Global Priorities: Biodiversity and Human Health: A State of Knowledge Review; 2015.
Available:https://www.cbd.int/health/SOK-biodiversity-en.pdf
8. FSSAI. Food safety and standards regulations, 2011; 2022.
Available:https://www.fssai.gov.in/upload/uploadfiles/files/Compendium_Food_Additives_Regulations_20_12_2022.pdf
9. Majtan J. 11 Honey in Pediatrics. Honey in Traditional and Modern Medicine. 2013; 231.
10. Buba F, Gidado A, Shugaba A. Analysis of biochemical composition of honey samples from North-East Nigeria. Biochem Anal Biochem. 2013;2(3):139.
11. Bradbear N. Bees and their role in forest livelihoods: A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. Non-wood Forest Products. 2009;19.
12. Ball DW. The chemical composition of honey. Journal of Chemical Education. 2007;84(10):1643.
13. Aurongzeb M, Azim MK. Antimicrobial properties of natural honey: A review of literature. Pak. J. Biochem. Mol. Biol. 2011; 44(3):118-124.
14. Djebli N, Mustafa MR, Keskin M, Kolayli S. Anti-Ulcerogenic and cytoprotective effects of Saharian (Sidr) honey from Algeria. Combinatorial Chemistrya and High Throughput Screening. 2021;24(10): 1664-1670.
15. Ajibola A. Physico-chemical and physiological values of honey and its importance as a functional food. International Journal of Food Sciences and Nutrition. 2015;2(6):1-9.
16. Vahčić N, Matković D. Kemijske, fizikalneisenzorskeznačajkemeda; 2009.
Available:https://dokumen.tips/download/link/kemijske-fizikalne-i-senzorske-karakteristike-meda
(Accessed on 01.09. 2018*)*.
17. Predescu C, Papuc C, Nicorescu V. Antioxidant activity of sunflower and meadow Honey; 2015.
Available:https://www.semanticscholar.org/paper/ANTIOXIDANT-ACTIVITY-OF-SUNFLOWER-AND-MEADOW-HONEY-Predescu Papuc/e39932233dd69ec5ba8719631e5db9bd29fccc52
18. Murty KR. Ashtangahridayaya Samhita, (Sutrasthana) (English Translation). Varanasi: Krishnadas Academy; 2001.
19. Ranjan A, Pal P, Gupta G. Different flavours of honey, their properties and health benefits. Journal of Eco-Friendly Agriculture. 2022;17(2):338–344.
Available:https://doi.org/10.5958/2582-2683.2022.00066.1
20. Robert SD, Ismail AA. Two varieties of honey that are available in Malaysia gave intermediate glycemic index values when tested among healthy individuals. Biomed Pap Med FacUnivPalacky Olomouc Czech Repub. 2009;153(2):145-147.
21. Al-Waili NS. Natural honey lowers plasma glucose, C-reactive protein, homocysteine, and blood lipids in healthy, diabetic, and hyperlipidemic subjects: Comparison with dextrose and sucrose. Journal of Medicinal Food. 2004; 7(1):100-107.
22. Chepulis L, Starkey N. The long-term effects of feeding honey compared with sucrose and a sugar-free diet on weight gain, lipid profiles, and DEXA measurements in rats. Journal of Food Science. 2008;73(1):H1-H7.
23. Silva RA, Maia GA, Costa JMCD, Rodrigues MDCP, Fonseca AVV, Sousa PHM, Carvalho JM. Honey-sweetened cashew apple juice: Development and

stability. Food Science and Technology. 2008;28:348-354.

24. Jones K, Blair S, Tonks A, Price A, Cooper R. Honey and the stimulation of inflammatory cytokine release from a monocytic cell line. In First world wound healing congress. Melbourne, Australia; 2000.
Available:https://pubmed.ncbi.nlm.nih.gov/12824009/
25. Tonks AJ, Cooper RA, Jones KP, Blair S, Parton J, Tonks A. Honey stimulates inflammatory cytokine production from monocytes. Cytokine. 2003;21(5):242-247.
26. De-Melo MAA, Almeida-Muradian LBD, Sancho MT, Pascual-Maté A. Composition and properties of *Apis mellifera* honey: A review. Journal of Apicultural Research. 2018;57(1):5-37.
27. Agbohessi PT, Toko II, Ouédraogo A, Jauniaux T, Mandiki SNM, Kestemont P. Assessment of the health status of wild fish inhabiting a cotton basin heavily impacted by pesticides in Benin (West Africa). Science of the Total Environment. 2015;506:567-584.
28. Patra B, Pradhan NS. Contamination of honey: A human health perspective. Intech Open; 2023.
DOI: 10.5772/intechopen.109613
29. Morariu ID, Avasilcai L, Vieriu M, Lupu VV, Ioniuc I, Morariu BA, Trandafir L. A Comprehensive narrative review on the hazards of bee honey adulteration and contamination. Journal of Food Quality. 2024(1);3512676.
30. Mancuso T, Croce L, Vercelli M. Total brood removal and other biotechniques for the sustainable control of Varroa mites in honey bee colonies: Economic impact in beekeeping farm case studies in northwestern Italy. Sustainability. 2020;12 (6):2302.
31. Al Naggar Y, Singavarapu B, Paxton RJ, Wubet T. Bees under interactive stressors: The novel insecticides flupyradifurone and sulfoxaflor along with the fungicide azoxystrobin disrupt the gut microbiota of honey bees and increase opportunistic bacterial pathogens. Science of the Total Environment. 2022;849:157941.
32. Woodcock BA, Isaac NJ, Bullock JM, Roy DB, Garthwaite DG, Crowe A, Pywell RF. Impacts of neonicotinoid use on long-term population changes in wild bees in England. Nature Communications. 2016; 7(1):12459.
33. Simon-Delso N, Amaral-Rogers V, Belzunces LP, Bonmatin JM, Chagnon M, Downs C, Wiemers M. Systemic insecticides (neonicotinoids and fipronil): Trends, uses, mode of action and metabolites. Environmental Science and Pollution Research. 2015;22:5-34.
34. Kessler SC, Tiedeken EJ, Simcock KL, Derveau S, Mitchell J, Softley S, Wright GA. Bees prefer foods containing neonicotinoid pesticides. Nature. 2015;521 (7550):74-76.
35. Badawy ME, Ismail AM, Ibrahim AI. Quantitative analysis of acetamiprid and imidacloprid residues in tomato fruits under greenhouse conditions. Journal of Environmental Science and Health, Part B. 2019;54(11):898-905.
36. Kumar A, Gil JPS, Bedi JS, Chhuneja PK. Health risks associated with antibiotics and pesticides in honey: Knowledge, aptitude and practices of beekeepers’ in India. J. Vet. Pub. Hlth. 2018;16(1):1-9.
37. Founou LL, Founou RC, Essack SY. Antibiotic resistance in the food chain: A developing country-perspective. Frontiers in Microbiology. 2016;7:232834.
38. Zhang Y, Li XQ, Li HM, Zhang QH, Gao Y, Li XJ. Antibiotic residues in honey: A review on analytical methods by liquid chromatography tandem mass spectrometry. TRAC Trends in Analytical Chemistry. 2019;110:344-356.
39. Chaudhary OP. Present status of pests and diseases of honey bees *Apis mellifera L*. in India and innovations in their management. In Proceedings of the workshop on promotion of honey bee keeping in Haryana. 2014;97-112.
40. Rana BS, Rana K. Honey bee diseases, their diagnosis and management. In Garg SK, Jakhar MS. (Eds.), Proceedings of the workshop on promotion of honey bee keeping in Haryana. Panchkula: Haryana Kisan Ayog. 2014;85–96.
Available:https://www.tandfonline.com/doi/full/10.1080/00218839.2019.1677000
41. Mutinelli F. Practical application of antibacterial drugs for the control of honey bee diseases, Apiacta. 2003;38:149-155.
42. Legg A, Carmichael S, Chai MG, Roberts JA, Cotta MO. Beta-lactam dose optimisation in the intensive care unit: Targets, therapeutic drug monitoring and toxicity. Antibiotics. 2023;12(5):870.
43. Tkachenko KM, Zupanets IA, Shebeko SK, Otrishko IA, Grintsov YF. The comparative

study of the acute toxicity of Tetracyclines. The Pharma Innovation. 2015;4(3, Part A):8.

44. Quinn KL, Macdonald EM, Gomes T, Mamdani MM, Huang A, Juurlink DN, Canadian Drug Safety and Effectiveness Research Network (CDSERN). Macrolides, digoxin toxicity and the risk of sudden death: A population-based study. Drug Safety. 2017;40:835-840.
45. Eliopoulos GM, Drusano GL, Ambrose PG, Bhavnani SM, Bertino JS, Nafziger AN, Louie A. Back to the future: Using aminoglycosides again and how to dose them optimally. Clinical Infectious Diseases. 2007;45(6):753-760.
46. Estradé O, Vozmediano V, Carral N, Isla A, González M, Poole R, Suarez E. Key factors in effective patient-tailored dosing of fluoroquinolones in urological infections: Interindividual pharmacokinetic and pharmacodynamic variability. Antibiotics. 2022;11(5):641.
47. Jeong IS, Kwak BM, Ahn JH, Jeong SH. Determination of pesticide residues in milk using a QuEChERS-based method developed by response surface methodology. Food Chemistry. 2012;133 (2):473-481.
48. Chaudhary A, Kumari S, Kumari P, Gupta G. Management of pesticides to avoid exposure to bees and other pollinators. Canadian Journal of Agricultural and Applied Sciences. 2021;1(1):9-15. DOI: 10.5281/zenodo.6037714
49. Llorent-Martínez EJ, Ortega-Barrales P, Fernández-de Córdova ML, Ruiz-Medina A. Trends in flow-based analytical methods applied to pesticide detection: A review. Analytica Chimica Acta. 2011;684 (1-2):30-39.
50. El-Nahhal Y. Pesticide residues in honey and their potential reproductive toxicity. Science of the Total Environment. 2020;741:139953.
51. Pisa L, Goulson D, Yang EC, Gibbons D, Sánchez-Bayo F, Mitchell E, Bonmatin JM. An update of the Worldwide Integrated Assessment (WIA) on systemic insecticides. Part 2: Impacts on organisms and ecosystems. Environmental Science and Pollution Research. 2021;28:11749-11797.
52. Han W, Tian Y, Shen X. Human exposure to neonicotinoid insecticides and the evaluation of their potential toxicity: An overview. Chemosphere. 2018;192:59-65.
53. Gupta G. Incorporation of biorational insecticides with neonicotinoids to combat resurgence of *Tetranychus urticae* (Prostigmata: Tetranychidae) on rose. The Florida Entomologist. 2015;98(3):962–966. Available:http://www.jstor.org/stable/24587751
54. Morfin N, Goodwin PH, Guzman-Novoa E. Interaction of field realistic doses of clothianidin and Varroa destructor parasitism on adult honey bee (*Apis mellifera L*.) health and neural gene expression, and antagonistic effects on differentially expressed genes. Plos One. 2020;15(2):e0229030.
55. Chagnon M, Kreutzweiser D, Mitchell EA, Morrissey CA, Noome DA, Van der Sluijs JP. Risks of large-scale use of systemic insecticides to ecosystem functioning and services. Environmental Science and Pollution Research. 2015;22:119-134.
56. Cernansky R. Controversial pesticides found in honey samples from six continents. Nature. 2017;10.
57. Eizadi-Mood N, Sabzghabaee AM, Gheshlaghi F, Yaraghi A. Amitraz poisoning treatment: Still supportive? Iranian Journal of Pharmaceutical Research: IJPR. 2011;10(1):155.
58. Derrar S, Lo Turco V, Albergamo A, Sgrò B, Ayad MA, Litrenta F, Saim MS, Potortì AG, Aggad, H, Rando R, et al. Study of physicochemical quality and organic contamination in Algerian honey. Foods. 2024;13:1413. Available:https://doi.org/10.3390/foods13091413
59. Thiruchelvam M. Mancozeb; 2005. Available:https://www.sciencedirect.com/topics/chemistry/mancozeb
60. Ashraf SA, Mahmood D, AbdElmoneim OE, Siddiqui AJ, Khan MI, Ashfaq F, Adnan M. Exposure to pesticide residues in honey and its potential cancer risk assessment. Food and Chemical Toxicology. 2023;114014
61. Burgarelli JAM, Dos Santos DM, Prado FSR, Rabêlo WF, Sardeli R, Brigante J, Vieira EM. Abamectin and difenoconazole monitoring in strawberry flowers and pollen sampled from *Tetragonisca angustula* (Latreille) (Hymenoptera: Apidae) hives located in crop vicinities. Environmental Science and Pollution Research. 2023;30 (24):65401-65411.
62. Cui D, Cox J, Mejias E, Ng B, Gardinali P, Bagner DM, Quinete N. Evaluating non-

targeted analysis methods for chemical characterization of organic contaminants in different matrices to estimate children's exposure. Journal of Exposure Science and Environmental Epidemiology. 2023; 33(4):589-601.

63. Abay Z, Bezabeh A, Gela A, Tassew A. Evaluating the impact of commonly used pesticides on honeybees (Apismellifera) in North Gonder of Amhara Region, Ethiopia. Journal of Toxicology; 2023. Available:https://pubmed.ncbi.nlm.nih.gov/37034150/
64. Zhu YC, Yao J, Adamczyk J. Long-term risk assessment on noneffective and effective toxic doses of imidacloprid to honeybee workers. Journal of Applied Entomology. 2019;143(1-2):118-128.
65. Vidau C, Diogon M, Aufauvre J, Fontbonne R, Viguès B, Brunet JL, Delbac F. Exposure to sublethal doses of fipronil and thiacloprid highly increases mortality of honeybees previously infected by Nosema ceranae. Plos One. 2011;6(6):e21550.
66. Abdulhussein AQ, Jamil AKM, Bakar NKA. Magnetic molecularly imprinted polymer nanoparticles for the extraction and clean-up of thiamethoxam and thiacloprid in light and dark honey. Food Chemistry. 2021; 359:129936.
67. El-Leithy M, El-Shatoury EH, El-Senousy W, Abou-Zeid M, El-Taweel GE. Detection of six E. coli O157 virulence genes in water samples using multiplex PCR. Egypt. J. Microbiol. 2012;47:171-188.
68. Vica M, Glevitzky M, Dumitrel GA, Popa M, Varvara S. Microbiological role in hazards analysis of natural honey processing. Journal of Agroalimentary Processes and Technologies. 2009;15(3): 353-360.
69. Antonucci L, Locci C, Schettini L, Clemente MG, Antonucci R. Infant botulism: An underestimated threat. Infectious Diseases. 2021;53(9): 647–660. Available:https://doi.org/10.1080/23744235.2021.1919753
70. Suruchi KUMAR, Jilani A. Assessment of heavy metal concentration in washed and unwashed vegetables exposed to different degrees of pollution in Agra, India. Electronic Journal of Environmental, Agricultural and Food Chemistry. 2011; 10(8).
71. Sobhanardakani S, Kianpour M. Heavy Metal Levels and Potential Health Risk Assessment in Honey Consumed In Thewest of Iran; 2016. Available:https://ajehe.umsha.ac.ir/Article/ajehe-2029
72. Duruibe JO, Ogwuegbu MOC, Egwurugwu JN. Heavy metal pollution and human biotoxic effects. International Journal of Physical Sciences. 2007;2(5):112-118.
73. Malakootian M, Yaghmaeian K, Meserghani M, Mahvi AH, Pajouh MD. Determination of Pb, Cd, Cr and Ni concentration in imported Indian rice to Iran; 2011. Available:https://www.researchgate.net/publication/285744454_Determination_of_PbCdCr_and_Ni_concentration_in_Imported_Indian_Rice_to_Iran
74. Rezaei Raja O, Sobhanardakani S, Cheraghi M. Health risk assessment of citrus contaminated with heavy metals in Hamedan city, potential risk of Al and Cu. Environmental Health Engineering and Management Journal. 2016;3(3):131-135.
75. Brifa J, Sinagra E, Blundell R. Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon, vol. 6, no. 9, Article ID e04691; 2020.
76. Hegazi AA, El-Kady A. Effect of road dust on vegetative characters and leaves heavy metal contents of Zizyphus *Spina-christi (L.)*. willd, *Syzygium cuimini* (L.) skeels and Olea europea L. seedlings. Journal of Horticultural Sciences. 2010;2(3):98-107.
77. Khaneghah AM, Fakhri Y, Nematollahi A, Pirhadi M. Potentially toxic elements (PTEs) in cereal-based foods: A systematic review and meta-analysis. Trends in Food Science and Technology. 2020;96:30-44.
78. Altunatmaz SS, Tarhan D, Aksu F, Ozsobaci NP, Or ME, Barutcu UB. Levels of chromium, copper, Iron, magnesium, manganese, selenium, zinc, cadmium, lead and aluminium of honey varieties produced in Turkey. Food Science and Technology. 2018;39:392-397.
79. Manouchehri A, Pirhadi M, Shokri S, Khaniki GJ. The possible effects of heavy metals in honey as toxic and carcinogenic substances on human health: A systematic review. Uludağ Arıcılık Dergisi. 2021;21(2): 237-246.
80. Ali AR, Al-Mufti TM, Taqi CM. Geochemical distribution of some heavy metals in agricultural soil and their environmental impacts in Kirkuk, Northern

Iraq. The Iraqi Geological Journal. 2021;75-92.

81. Georgaki MN, Charalambous M, Kazakis N, Talias MA, Georgakis C, Papamitsou T, Mytiglaki C. Chromium in water and carcinogenic human health risk. Environments. 2023;10(2):33.
82. Søvik E, Perry CJ, LaMora A, Barron AB, Ben-Shahar Y. Negative impact of manganese on honeybee foraging. Biology Letters. 2015;11(3):20140989.
83. Maggid AD, Kimanya ME, Ndakidemi PA. The contamination and exposure of mercury in honey from Singida, Central Tanzania. Am J Res Commun. 2014;2: 127-139.
84. Burden CM, Morgan MO, Hladun KR, Amdam GV, Trumble JJ, Smith BH. Acute sublethal exposure to toxic heavy metals alters honey bee (*Apis mellifera*) feeding behavior. Scientific Reports. 2019;9(1): 4253.
85. Mititelu M, Udeanu DI, Docea AO, Tsatsakis A, Calina D, Arsene AL, Ghica M. New method for risk assessment in environmental health: The paradigm of heavy metals in honey. Environmental Research. 2023;236:115194.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/3907