Journal of Consumer Protection and Food Safety (2023) 18:393–402
https://doi.org/10.1007/s00003-023-01460-x

Journal of Consumer Protection and Food Safety
Journal für Verbraucherschutz und Lebensmittelsicherheit

RESEARCH ARTICLE

Contaminants in honey: an analysis of EU RASFF notifications from 2002 to 2022

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Received: 26 March 2023 / Revised: 2 September 2023 / Accepted: 13 September 2023 / Published online: 21 September 2023

Abstract

Honey is regarded as natural and healthy. However, a variety of contaminants could be present in the areas of production. The study aimed to identify the top hazard categories in Rapid Alert System for Food and Feed (RASFF) notifications for honey from 2002 to 2022, taking into account the notification year and type, country of origin, notifying country, risk decision, and actions taken. All RASFF notifications were processed in Pivot tables using Microsoft Excel. Out of 388 notifications for honey in the last 21 years 309 (79.64%) concerned the unauthorized residues of veterinary medicinal products hazard category, followed by adulteration/fraud (5.15%), foreign bodies (2.83%), pesticide residues (2.58%), and poor or insufficient controls (2.58%). China was the most frequently notified country of origin (25.77%), followed by Turkey (6.44%), Ukraine (6.19%), Argentina (6.19%), and Bulgaria (5.67%). Germany was the most frequently notifying country (16.49%), followed by the UK (16.24%), Spain (13.40%), Italy (10.82%), and Belgium (7.99%). Among all notifications, 22.68% were alerted and 12.37% were border rejected. The notification frequency (%) and mean concentration ± standard deviation (SD) (µg/kg) of the most frequently reported contaminants in the honey were as follows: chloramphenicol (25.26%, 172.10 ± 827.92 µg/kg), followed by streptomycin (12.11%, 104.94 ± 209.44 µg/kg), sulfathiazole (9.54%, 52.31 ± 52.62 µg/kg), tylosin (4.90%, 9.03 ± 11.23 µg/kg), and sulfadimidine (4.64%, 254.99 ± 587.00 µg/kg), respectively, due to their application by beekeepers to control infectious diseases of bees. Strict restrictions must be put in place to reduce the risk posed by these contaminants in honey.

Keywords Honey · Veterinary drug residues · RASFF · Pesticide residues · Fraud

1 Introduction

Honey is the main product of the beehive. The honeybee workers collect nectar from various botanical sources and bring it to the hive, where the nurse bees convert it to honey and store it in the wax combs. Honey is a mixture of sugars and minor ingredients, including enzymes, organic acids, amino acids, and macro- and trace elements (Saxena et al. 2010; Kaygusuz et al. 2016; Taha et al. 2021; Otero and Bernolo 2020; Zapata-Vahos et al. 2023). Consumers mainly consume honey for its nutritional and medicinal values, which are due to its physicochemical properties. Honey is recognized for its antioxidant and antimicrobial properties (Alvarez-Suarez et al. 2010; Gül and Pehlivan 2018; Feknous and Boumendjel 2022; Weis et al. 2022; Zapata-Vahos et al. 2023).

Among the environmental contaminants of honey are trace elements, microorganisms, antibiotics, pesticides, per- and polyfluoroalkyl substances (PFAS), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and dioxins (Nowak and Nowak 2023). These contaminants may occur in the air, soil, water, and plants and are transported to the comb wax by worker bees. Additionally, pesticides used to control small hive beetle (*Aethina tumida* Murray), greater wax moth *(Galleria mellonella L.)*, and lesser wax moth *(Achroia grisella Fab.)*, antibiotics used to treat larval diseases, bee repellents used during honey harvest, and

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acaricides used to control *Varroa* mites [*Varroa destructor* (Oud.) Anderson and Trueman] are among the contaminants associated with beekeeping practices (Eissa et al. 2014; Chiesa et al. 2018; Česnik et al. 2019; Oymen et al. 2022).

Both adult bees and larval stages can be infected by fungal diseases, bacterial diseases, viral diseases, and they can also be infested by some pests. The pathogens of American foulbrood diseases [*Paenibacilus larvae* (White)] and European foulbrood disease [*Streptococcus pluton* (White)] have been commonly treated by using chloramphenicol, oxytetra-cycline, tetracycline, and tylosin (Thompson et al. 2005; Alippi et al. 2007; Giersch et al. 2010). In addition, the *Varroa* mite is the main pest of honeybees worldwide and infests larval, pupal, and adult stages. It has been controlled using synthetic chemical treatments such as *tau*-fluvalinate (Cabras et al. 1997), bromopropylate (Ravoet et al. 2015), perizin (Blacquière et al. 2017), amitraz (Haber et al. 2019), and coumaphos (Kast et al. 2020). Currently, honey standards are regulated by various regulations to ensure their authenticity and to eliminate fraud. According to the EU report on pesticide residues in food for 2020, the residues of coumaphos and *tau*-fluvalinate in 5.50% of honey samples exceeded their respective maximum residue levels (MRLs) (EFSA 2022). There is no established MRL for honey for antibacterial compounds classified in Annex I, II, or III of Council Regulation 2377/90. As a result, under Article 14 of the same Regulation, the use of antibiotics in honeybees is prohibited, and they are classified as "unauthorized substances" in the EU (European Commission 2007).

According to Taha and Al-Kahtani (2020), most beekeepers worldwide use combs in the hives for more than 3 years. However, beeswax is mainly composed of hydrocarbons and ester components that easily absorb a wide range of materials (Tulloch 1980). The presence of different honey contaminants has been reported to be affected by several factors, including beekeeping practices, the surrounding environment, the age of the comb, and botanical origin (Taha et al. 2017; Matović et al. 2018; Ćirić et al. 2021; Bayir and Aygun 2022).

The RASFF was established in 1979 to facilitate the transmission of information related to human health concerns and to support the supervision and safety of food and animal feed on the European market. Article 50 of Regulation (EC) No. 178/2002, referred to as the European General Food Law, serves as the present legal basis for the RASFF (Bouzembrak and Marvin 2016). The RASFF system enables rapid information sharing, immediate action in response to risks, and the elimination of items that are harmful to consumer health.

However, there is very little data related to contaminants and the safety of honey on an international level. The current study aims to identify the top hazard categories involved in RASFF notifications on honey from 2002 to 2022, considering the year, notification type, origin country, notifying country, risk decision, and action taken.

2 Materials and methods

2.1 Data collection and processing

From the product field, in the RASFF portal database, and under the product category "honey", all notifications were tracked from January 01, 2002 to December 31, 2022. The following criteria were evaluated: notification reference, notification date, notification type, notifying countries, countries of origin, subject (reason for notification), risk decision (not serious, serious, or undecided), and actions taken. Notifications were classified as alert, border rejection, and information. An alert is issued if a product poses a serious risk on the EU market and prompt action is or may be required in a country other than the notifying country. Border rejection is imposed if a consignment of the product was denied entry into the EU due to a risk to human health. Information notification is used if a product carries a recognized risk that doesn't require immediate action, either because the risk is not considered serious or because the product is not on the market at the time of notification. All data were exported as Excel files, and descriptive statistical methods such as measures of frequency (frequency and percentages), central tendency (mean), and dispersion or variation (SD and range) were applied. The data were sorted, filtered, and processed in Pivot tables using Microsoft Excel spreadsheets and IBM SPSS Statistics 20 software (SPSS, Chicago, Illinois, USA). The notification frequency (%), range, and mean concentration ± SD (μg/kg) of the most frequently reported contaminants in the honey were calculated.

3 Results and discussion

3.1 Number of RASFF notifications on honey from 2002 to 2022

During the period between 2002 and 2008, the number of RASFF notifications ranged between 27 and 59 notifications per year (Fig. 1). The notifications on honey between 2002 and 2008 accounted for 74.48% of the total notifications (2002–2022). The highest number of RASFF notifications on honey was recorded in 2005 (59 notifications), followed by 2003 (50 notifications), and 2002 (47 notifications). In fact, the number of non-compliant results is matched with the total number of analyses, as a large number of samples that have been tested could account for the high number of

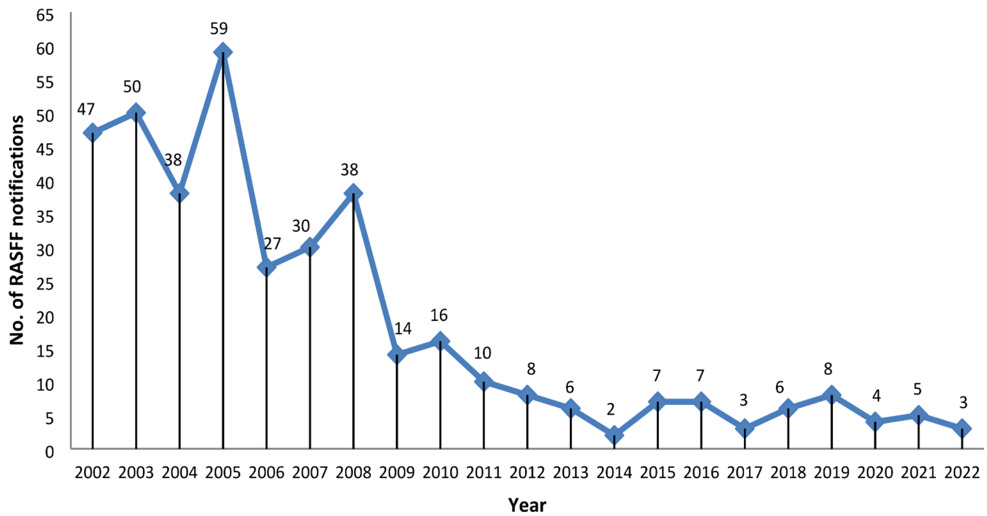


Fig. 1 Number of RASFF notifications per year on honey from 2002 to 2022

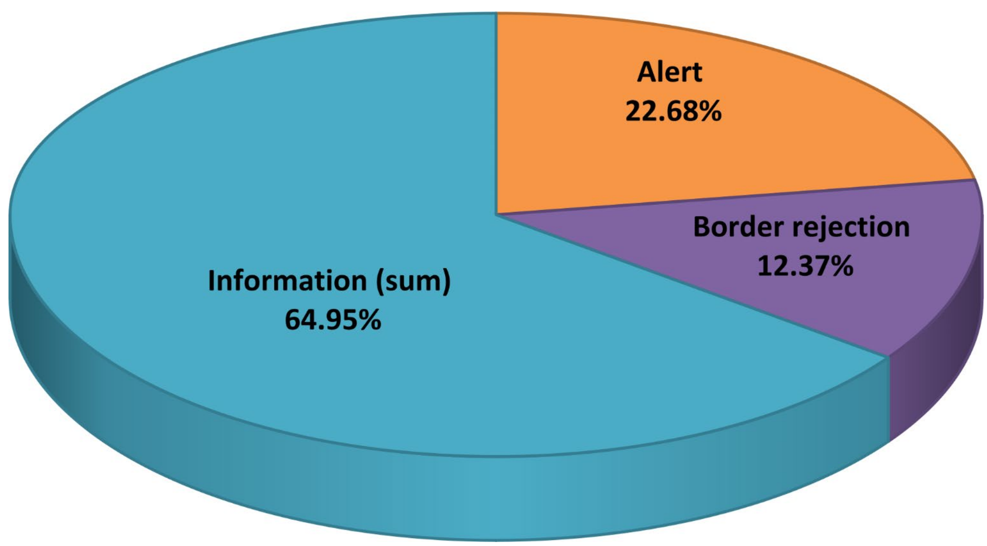


Fig. 2 RASFF notifications percentage on honey from 2002 to 2022 according to notification types

"positive" samples and vice versa. After 2008, there was a considerable decline in the notification rate for honey. During the last 10 years, the number of RASFF notifications ranged between 2 and 8 notifications per year, with only 3 notifications recorded in 2022. The notifications on honey during the last 10 years accounted for 13.14% of the total notifications.

This decline may be due to the restrictions imposed by some countries on honey importation as well as the recent advances in food analysis that allow the detection of very low levels of contaminants, so that the exporters take this issue into consideration.

3.2 Honey notifications type

The RASFF notifications percentage on honey from 2002 to 2022 according to notification types could be arranged in descending order as follows: information (64.95%) > alert (22.68%) > border rejection (12.37%) (Fig. 2). The reasons for alerts for honey were:

1) Tetrahydrocannabinol and unauthorized novel food ingredient cannabidiol (CBD) were found in CBD honey from Spain;
2) Metal fragments (staples) were found in comb honey from Turkey, UK;
3) Glass fragments were found in honey from France;
4) Pyrrolizidine alkaloids were found in honey from Spain and Mexico;
5) Residues of veterinary medicinal products including sulfadimethoxine, nitrofuran (metabolite) nitrofurazone, sulphathiazole, sulfadimidine, streptomycin, chloramphenicol, tylosin, sulfamethazine, metronidazole, enrofloxacin, and oxytetra-cycline were found in honey from Argentina, Australia, Chile, China, Czech Republic, Hungary, India, Israel, Italy, Lithuania,

Poland, Portugal, Romania, Slovakia, Spain, Turkey, and Ukraine;
6) Honey comb segments were found in honey from Turkey;
7) Impurities (brood larvae) from Germany;
8) Adulteration with fructose of mixed flower honey with honeycomb segments was detected in honey from Turkey;
9) High levels of hydroxyl methyl furfural was found in honey from Hungary;
10) Residues of pharmacologically active substances (coumaphos, acrinathrin, and t-fluvalinate) were found above the MRL in comb honey from Hungary;
11) 1,4-dichlorobenzene was detected in honey from Greece;
12) traces of milk were found in acacia honey from China.

The values of hydroxyl methyl furfural in honey samples from Hungary and Portugal were very high, exceeding the accepted limits (≤ 40 mg/kg) of Codex Alimentarius (2001).

Border rejection notifications of honey happened for the following reasons:

1) Organic honey stored in drums that were not suitable to contain food (rusty) from Argentina, Ethiopia, and Ukraine;
2) Health certificate(s) were absent for honey from the United States, Moldova, and Australia;
3) a bad state of preservation, a bad hygienic state, and dead insects were found in honey from Ukraine;
4) Fermentation of multi-flower honey from Uruguay occurred due to defective packaging;
5) *Paenibacillus larvae* were found in honey from Germany;
6) Residues of veterinary medicinal products, including unauthorized erythromycin, unauthorized streptomycin, and unauthorized ciprofloxacin in honeys from China, as well as unauthorized oxytetra-cycline in natural honey from Argentina;
7) Presence of residues of pharmacologically active substances above the MRL (coumaphos and oxymatrine in organic acacia honey) from China, unauthorized oxytetra-cycline in honey from Israel, lincomycin and unauthorized erythromycin in honey from China, unauthorized sulfamethazine in flower comb honey from Turkey, unauthorized sulfadimidine in comb honey from Turkey, unauthorized substance matrine in acacia honey from China, (Oxy)matrine in honey from China, tetracyclines in honey from Turkey, dihydrostreptomycin in acacia honey, and acrinathrin and t-fluvalinate in comb honey from Hungary;
8) Suspicion of fraud (imported as 100% pure polyfloral honey) and improper health certificate(s) for rice fructose syrup from China;
9) Honey from Ethiopia containing debris from improperly sealed steel drums, in addition to plastic and rubber fragments in natural honey from Cameroon;
10) Altered organoleptic characteristics of honey from Chile;
11) Unsuitable transport conditions (rusty and deteriorated barrels) for honey from Moldova;
12) Absent labelling and improper health certificate(s) for honey from Croatia.

These notifications confirm the previous reports of the occurrence of residues of veterinary medicinal products (Chiesa et al. 2018; Richards et al. 2021) and various types of foreign materials in honey (Edwards and Stringer 2007; Djekic et al. 2011, 2017).

3.3 Top notifying countries

The top 10 notifying countries involved in RASFF notifications on honey accounted for 83.25% of the total notifications on honey between 2002 and 2022 (Fig. 3). The top 5 notifying countries could be arranged in descending order as follows: Germany (16.49%) > the United Kingdom (16.24%) > Spain (13.40%) > Italy (10.82%) > Belgium (7.99%) of the total notifying countries. Europe is the world's largest honey consumer, accounting for more than 20% of total global consumption. The greatest market for fair-trade honey in the EU is by far Germany, which also leads the EU in terms of organic food consumption (Ványi et al. 2011).

3.4 Top origin countries

The top 10 origin countries involved in RASFF notifications on honey from 2002 to 2022 accounted for 66.24% of the total notifications (Fig. 4). The top 5 origin countries could be arranged in descending order as follows: China (25.77%) > Turkey (6.44%) > Ukraine (6.19%) > Argentina (6.19%) > Bulgaria (5.67%). The top 10 honey producing countries are China, Turkey, Argentina, Iran, the U.S., Ukraine, the Russian Federation, India, Mexico, and Ethiopia (Bhat et al. 2020). The origin countries are associated with honey production, which is mainly related to the availability of nectar and pollen flora, geographical origin, the race of honeybees, colony population size, etc. (Taha and Al-Kahtani 2019).

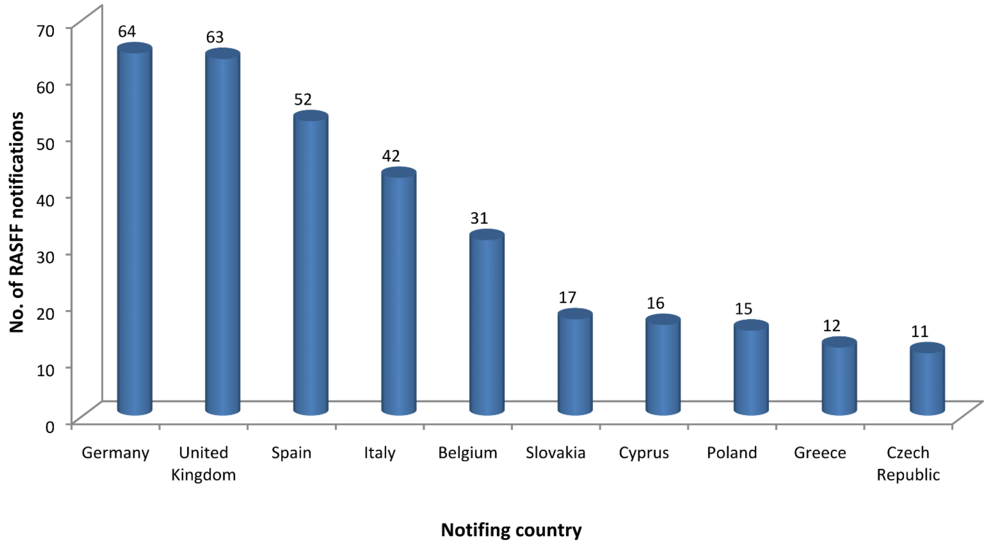


Fig. 3 Top 10 notifying countries involved in RASFF notifications on honey from 2002 to 2022

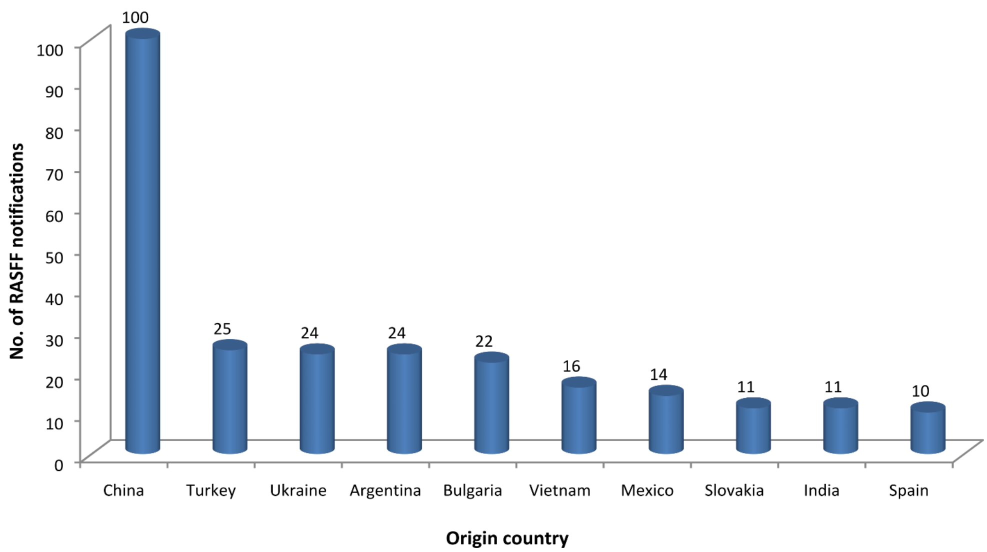


Fig. 4 Top 10 origin countries involved in RASFF notifications on honey from 2002 to 2022

3.5 Top hazard categories

The top 5 hazard categories involved in RASFF notifications on honey from 2002 to 2022 represented 92.78% of the total hazards in honey (Fig. 5). The top 5 hazards could be arranged in descending order as follows: residues of veterinary medicinal products (79.64%) > adulteration/fraud (5.15%) > foreign bodies (2.83%) > pesticide residues (2.58%), and poor or insufficient controls (2.58%). Poor or insufficient controls include an unauthorized operator, a poor hygienic state, unsuitable transport conditions, and a poor state of preservation. For more profit, beekeepers may use antibiotics at relatively high doses to treat larval diseases or at low doses as growth promoters. Residues of oxytetracycline have been detected in honey by McKee et al. (2003) and Thompson et al. (2005). On the other hand, Chiesa et al. (2018) tested 95 organic honeys, and no antibiotics were found in any of them, proving that no apicultural treatments were used.

Pesticide application in agriculture is important for obtaining superior yields. Unfortunately, these practices pollute the air, water, and soil and then reach into the nectar and pollen of flowers (Bogdanov 2006). The veterinary medicinal products are used to prevent and treat brood and adult bee diseases inside the beehives, while pesticides are used to protect crops from insects (insecticides), herbs (herbicides), and fungi (fungicides) outside of the hives, but they are transported into the hive with nectar and/or pollen collected by worker bees and then become residues in honey (Oymen et al. 2022). This confirms a study of Česnik et al. (2019) that detected pesticide residues in Slovenian honey, that, however, did not exceed MRLs.

On the other hand, the presence of various types of foreign materials in honey may be related to the type of hive used for honey production, the extraction method, clearing

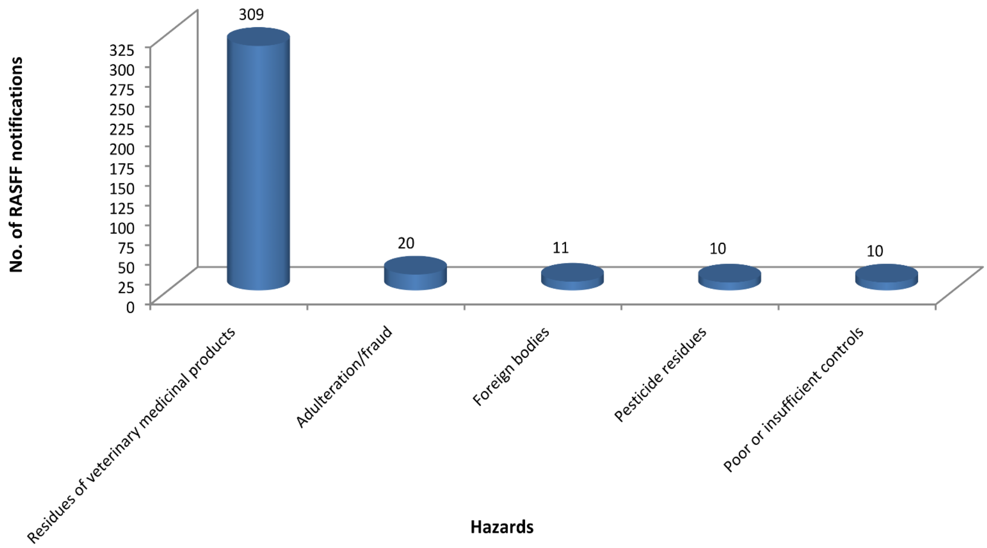


Fig. 5 Top 5 hazard categories involved in RASFF notifications on honey from 2002 to 2022

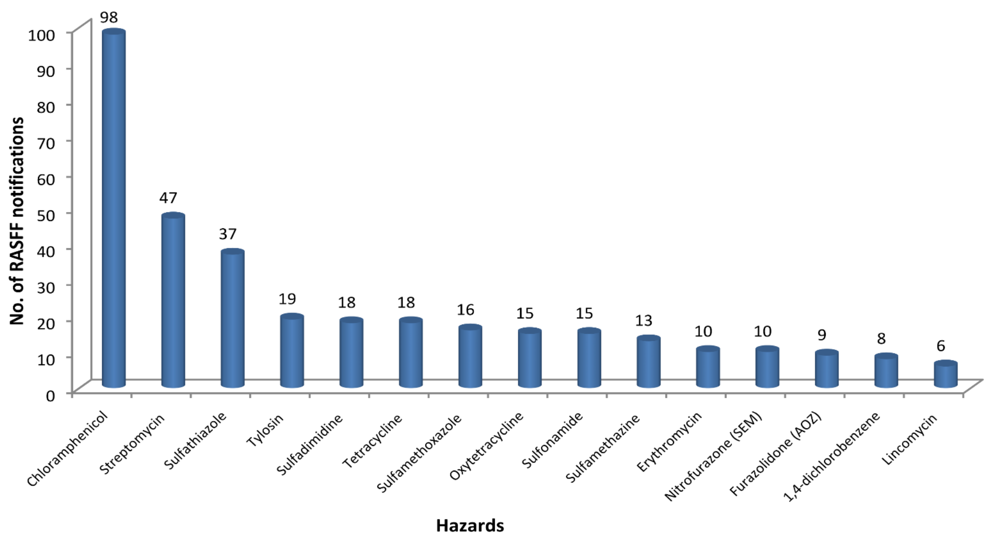


Fig. 6 Top 15 hazards involved in RASFF notifications on honey from 2002 to 2022

after extraction, and packaging. Most of the foreign materials found in honey include parts of the adult bees and/or larvae, hairs, and beeswax. Based on several studies conducted on foreign bodies in food from the UK (Edwards and Stringer 2007), Eastern European countries (Djekic et al. 2011), Italy (Losito et al. 2011), and European countries (Djekic et al. 2017), the detected foreign materials included crystals of salt or sugar, insects, glass pieces, plastic, and metal.

3.6 Top hazards involved in honey RASFF notifications

The top 15 hazards involved in RASFF notifications on honey from 2002 to 2022 represented 87.37% of the total hazards (Fig. 6). The notification frequency (%) and range of the most frequently notified contaminants were as follows: chloramphenicol (25.26%, ranging from 0.01 to 5000 µg/kg), followed by streptomycin (12.11%, 0.3–1300 µg/kg), sulfathiazole (9.54%, 4.1–166 µg/kg), tylosin (4.90% 0.4–36 µg/kg), sulfadimidine (4.64%, 2–2000 µg/kg), tetracycline (4.64%, 12–195 µg/kg), sulfamethoxazole (4.12%, 10.2–92.5 µg/kg), oxytetra-cycline (3.87%, 2.4–67.6 µg/kg), sulfonamide (3.87%, 10–1602 µg/kg), sulfamethazine (3.35%, 20–109 µg/kg), erythromycin (2.58%, 0.2–1.7 µg/kg), nitrofurazone (SEM) (2.58%, 1.1–11 µg/kg), furazolidone (AOZ) (2.32%, 0.1–3 µg/kg), 1,4-dichlorobenzene (2.06%, 11–68 µg/kg), and lincomycin (1.55%, 2.1–10 µg/kg), respectively.

The residues of veterinary medicinal products, especially antibacterial drugs in honey, may result from their application to treat the pathogens of honeybee's larval diseases. Many antibacterial drugs have been used for the treatment and control of American and European foulbrood pathogens, such as chloramphenicol, tetracycline, oxytetracycline, tylosin, and lincomycin (McKee et al. 2003; Rizzo et al. 2020). Bulson et al. (2021) emphasized the necessity of reducing the duration and intensity of antibiotic therapy wherever possible in order to avoid undesired side effects such as host fitness losses caused by dysbiosis and resistance evolution in commensal microbes. As a result, non-antibiotic treatments such as the shook-swarm approach and probiotics should be preferred whenever possible. Furthermore, veterinarians can avoid illegal drug residues in honey and other hive products by combining their expert knowledge of physical examination, diagnostic procedures, and pharmacology with a knowledge of honeybees and honeybee husbandry (Richards et al. 2021).

3.7 Risk decisions and actions taken

The RASFF notifications percentage on honey from 2002 to 2022 based on risk decisions resulted in 4.90% being serious, 6.44% not serious, and 88.66% being undecided (Fig. 7). An "undecided" risk decision concerns an identified risk for which it is not possible at the moment of notification to decide whether it is serious or not. The "undecided" risk decision should only be made in one of the following conditions: (1) the risk evaluation/risk assessment is still ongoing. (2) the nature of the hazard(s) found does not allow taking a decision on the risk as there are too many uncertainties or there is no or insufficient scientific literature to base the decision on. (3) there are differences in the way the risk is evaluated between the network members concerned, leading to different risk decisions in these countries (European Commission 2018). The not-serious decision was taken 4 times for honey from Turkey, 3 times for honey from Ukraine, China, and Moldova, and 2 times for honey from Germany. The serious decision was taken 5 times for honey from China, 3 times for honey from Ukraine, and 2 times for honey from Spain and Mexico. The serious decision contained 5 decisions on residues of veterinary medicinal products, 5 decisions on allergens, 3 decisions on foreign bodies, and 2 decisions on natural toxins.

Several plants produce compounds in response to biotic and abiotic stressors. The pyrrolizidine alkaloids are among them, and they provide protection against insects and herbivorous animals (Croteau et al. 2000). There are several species of plants belonging to the Boraginaceae, Fabaceae, and Asteraceae families that produce pyrrolizidine alkaloids as secondary metabolites (Wiedenfeld 2011). The nectar of flowers may contain pyrrolizidine alkaloids, and honeybees may produce honey contaminated with these compounds when they collect nectar containing these alkaloids (Crews et al. 1997; Griffin et al. 2013; Lucchetti et al. 2016). Unfortunately, foods containing these alkaloids are hazardous to human health (Boppré 2011; Alvarado-Avila et al. 2022) and honeybee health (Reinhard et al. 2009). Commission Regulation (EU) 2020/2040 of December 11, 2020 amended Regulation (EC) No. 1881/2006 as regards maximum levels of pyrrolizidine alkaloids in certain foodstuffs. In the current study, the survey detected 2 samples of honey contaminated with the natural toxin pyrrolizidine alkaloids. In previous studies, pyrrolizidine alkaloids and/or pyrrolizidine alkaloids N-oxides were detected in honey from Australia (Beales et al. 2004), New Zealand (Betteridge et al. 2005), Ireland (Griffin et al. 2013), and Switzerland (Lucchetti et al. 2016).

Concerning the allergens, they include 3 decisions on traces of milk and 2 decisions on the presence of lactoprotein. The foreign bodies include 1 decision on glass fragments, metal pieces, and metal fragments. The occurrence of milk traces in honey may be a leftover from feeding the colonies pollen substitutes or pollen supplements, since beekeepers currently feed their colonies diets containing skimmed powder milk.

The actions taken from 2002 to 2022 were the following: Re-dispatch (97 notifications) was the most frequent

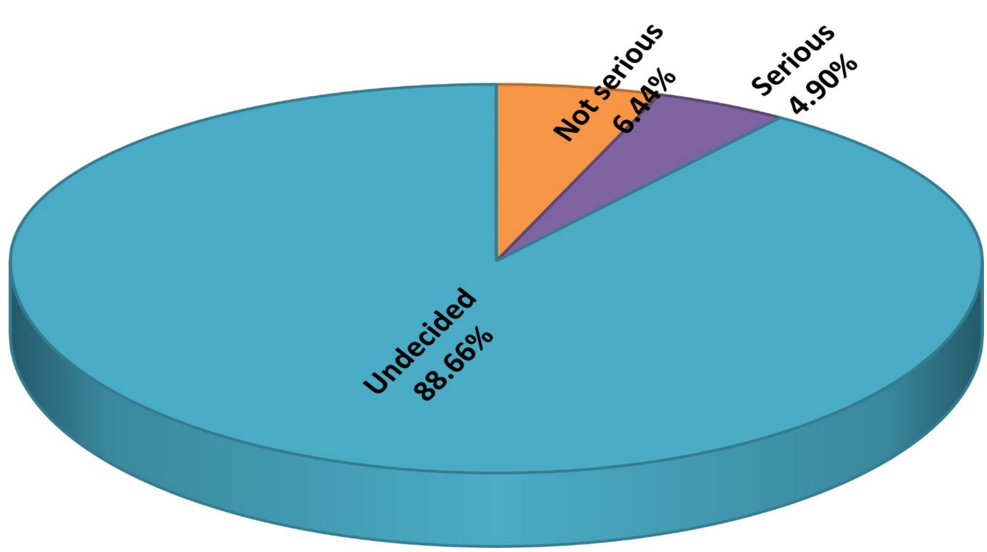
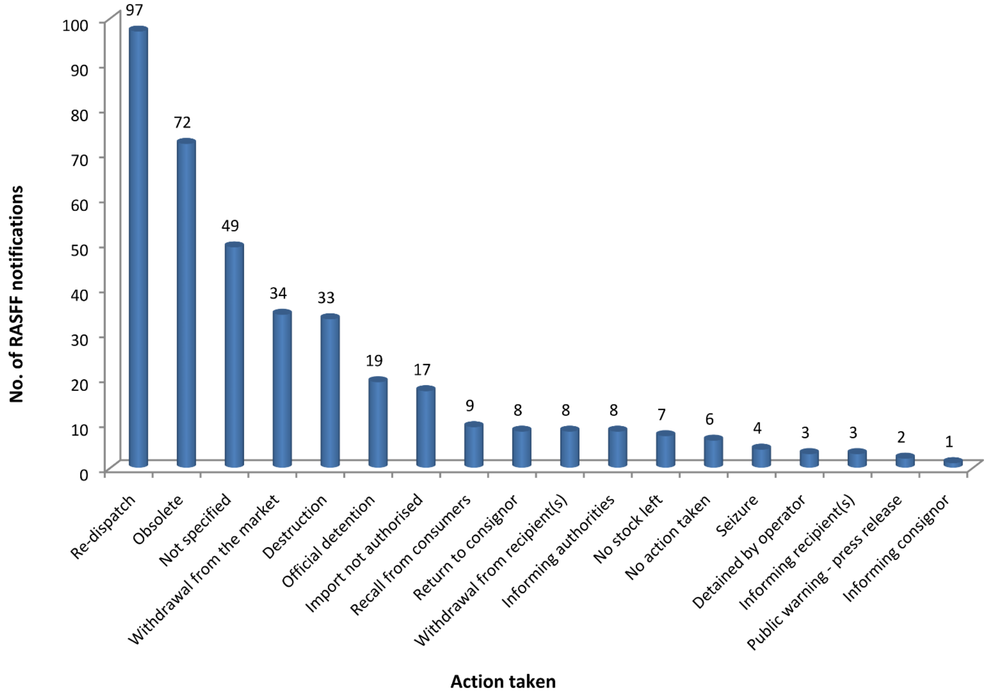


Fig. 7 RASFF notifications percentage on honey from 2002 to 2022 based on risk decisions

Fig. 8 RASFF notifications numbers on honey from 2002 to 2022 based on action taken



action taken, followed by obsolete (72), not specified (49), withdrawal from the market (34), destruction (33), official detention (19), and import not authorized (17) (Fig. 8).

4 Conclusion

This study provides an in-depth analysis of the top hazard categories involved in the EU RASFF notifications on honey from 2002 to 2022. The results showed that residues of veterinary medicinal products accounted for 79.64% of all hazard categories, which are exclusively attributed to beekeeping practices. The antibiotic chloramphenicol was the most notified contaminant in honey, accounting for 25.26% of all notifications and ranging from 0.01 to 5000 µg/kg. 4.90% of all notifications were classified as “serious”, 6.44% as “not serious”, and 88.66% as “undecided”. By properly educating and raising the awareness of beekeepers, it is possible to resolve the negative effects of bad beekeeping management practices on the health of the bees that produce honey. It is essential to continually monitor and update this data to identify new trends and emerging risks in the honey industry. Comprehensive surveillance studies on the occurrence of veterinary drug and pesticide residues in honey inside local markets should be undertaken regularly to find out their origins and take corrective and preventive actions, besides protecting human health in the case of the presence of non-compliant levels.

Author contributions The conceptualization of the paper idea, collection, and processing of the raw data were initiated by Fawzy Eissa, and then the two authors, Fawzy Eissa and El-Kazafy Taha, formulated the research aims, performed the methodology, including statistical treatment, represented the study data with their discussion, and finally wrote the ready-to-be-published manuscript.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
Open access funding provided by The Science, Technology & Innovation Funding Authority (STDF) in cooperation with The Egyptian Knowledge Bank (EKB).

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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