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Residues of veterinary medicinal products on the plate: insights from RASFF notifications

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Abstract

Veterinary medicinal products are widely used for disease prevention and treatment, as well as to enhance animal production. However, their inappropriate use may lead to the presence of detectable residue concentrations in food, which is increasingly associated with an important public health concern – antimicrobial resistance. Using the RASFF data over the period 2020–2025, this study evaluates food contamination with residues of veterinary medicinal products. A total of 230 notifications were recorded during the six-year study period, with the five most frequently reported countries of origin being: Vietnam (57; most commonly fish/fish products and crustaceans/crustacean products) > India (26; almost all crustaceans), Poland (24; poultry/meat and products) > the Netherlands (15; almost all meat/meat products) > Ukraine (13; almost all eggs and egg products) > Belgium (12; meat/poultry and products). Across food categories, the most frequently reported veterinary residue classes were: meat and meat products other than poultry (62; 11 nitrofuran derivatives, 7 tetracyclines) > crustaceans/crustacean products (54; 28 nitrofuran derivatives, 16 triphenyl/triaryl methane dye, 8 tetracyclines) > fish/fish products (37; 35 triphenyl/triaryl methane dye) > poultry/poultry products (30; 17 tetracyclines). While most notifications were classified as information (56.0%), nearly half (47.8%) were nonetheless assessed as posing a serious public health risk. These findings highlight the need for strict, risk-based monitoring of veterinary medicinal product residues in food. In this context, the RASFF system plays an important role in protecting consumer health both within the EU and globally.

Keywords: *veterinary drugs; antimicrobial residue; food safety; public health; RASFF database.*

INTRODUCTION

Administered via feed, oral routes, or parenteral injection, veterinary medicinal products are extensively employed for the treatment, prevention, and diagnosis of diseases in animals, including aquatic species. Their application for enhancing production performance should likewise be acknowledged [1,2]. Non-compliance with the prescribed use of veterinary medicinal products may result in the persistence of residues in food, which is most commonly associated with the administration of doses exceeding those authorized, as well as failure to adhere to the required withdrawal period [3]. Nonetheless, both isolated food safety incidents and large-scale market withdrawals or recalls of food products attributable to contaminant presence can impose significant economic burden on the food industry, disrupting supply chains, increasing operational costs, undermining market stability, and eroding consumer trust [4].

A further critical concern associated with the inappropriate use of veterinary medicinal products is the emergence and spread of antimicrobial resistance (AMR), a phenomenon that has garnered increasing attention in the scientific community. AMR is characterized by the ability of microorganisms to survive exposure to antimicrobial agents, thereby reducing the efficacy of therapeutic interventions, complicating disease management, and posing a significant risk to both animal and public health [5].

Within the European Union (EU), the legal framework establishing the general principles for ensuring food safety and safeguarding public health is provided by the General Food Law, namely Regulation (EC) No.

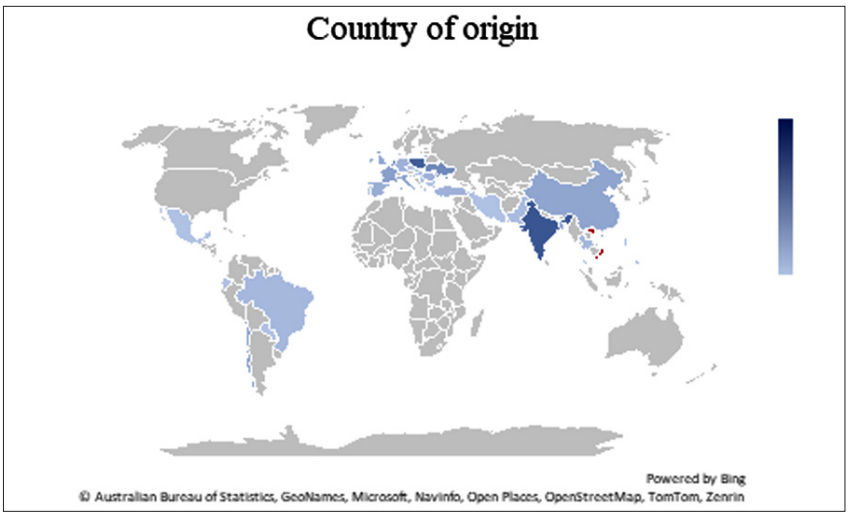


Figure 1. Geographical distribution of RASFF notifications (2020–2025) related to residues of veterinary medicinal products in food, concerning the country of origin.

178/2002 [6], which also constitutes the legislative foundation of the Rapid Alert System for Food and Feed (RASFF). RASFF was established to ensure a high level of consumer protection by providing a structured mechanism for the timely detection, notification, and exchange of information concerning potential health risks associated with food and feed. By facilitating swift communication among member states, RASFF enables rapid risk-management responses, thereby minimizing consumer exposure and contributing substantially to the overall integrity and safety of the food supply chain [7]. Food safety with respect to contamination by residues of pharmacologically active substances is specifically regulated by Regulation (EC) No. 470/2009 [8]. This regulation sets maximum residue limits for pharmacologically active substances in food of animal origin, thereby ensuring that such products placed on the market are safe for human consumption. Another key legislative instrument addressing pharmacologically active substances and their classification with respect to maximum residue limits is Commission Regulation (EU) No. 37/2010 [9].

Therefore, in this study, the RASFF system was utilized as the data source for collecting information on food contamination with residues of veterinary medicinal products, to generate a comprehensive overview of reported incidents, identify prevailing trends and high-risk categories, and provide an evidence-based foundation for further risk assessment and policy development.

METHODS

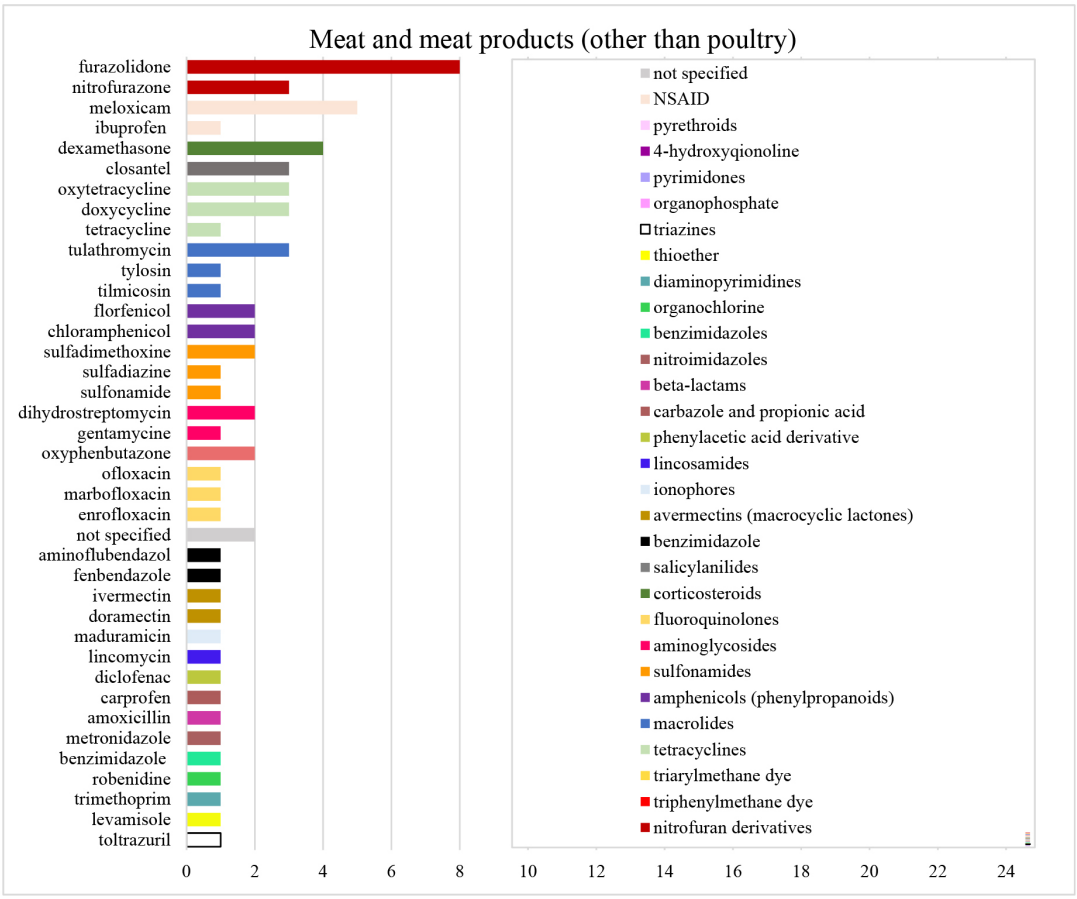
A total of 230 notifications were retrieved from the RASFF database based on a query covering the 6 years – 01/01/2020–13/11/2025, focusing on the Notification type "Food" and the Hazard category "Residues of veterinary medicinal products". The dataset was subsequently exported to Microsoft Excel (Microsoft Corporation, Redmond, DC, USA) for further editing and systematic organization. The analysis included the following variables: Product category, Hazard, Risk decision, Notification classification, and Country of origin. Taking into account these parameters, the data were sorted and examined. In some cases, individual notifications contained more than one hazard and/or more than one country of origin, which resulted in minor discrepancies in the total number of notifications.

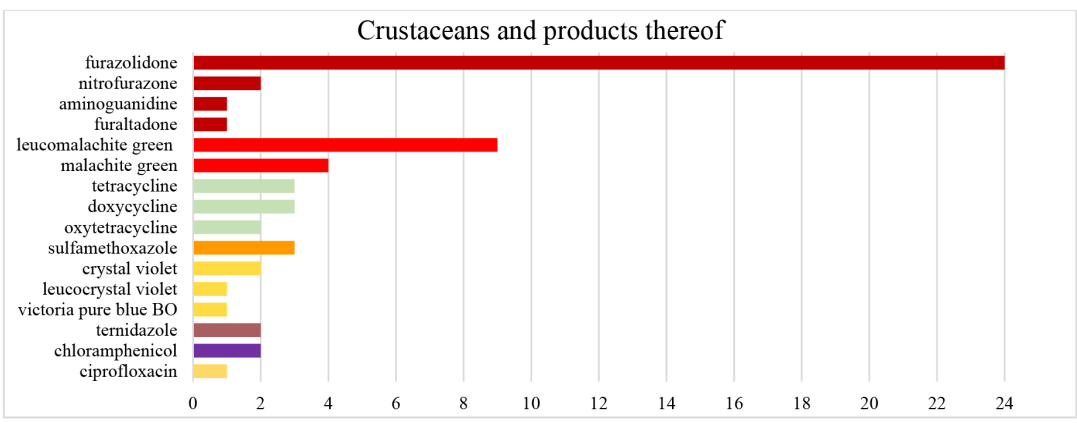
RESULTS

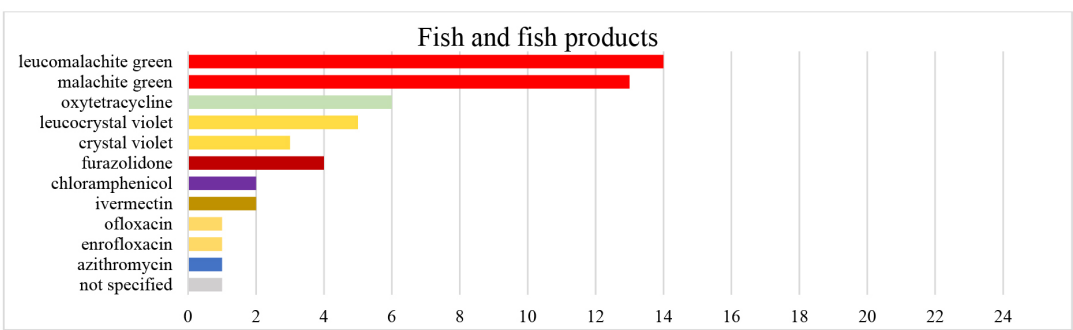
Geographical distribution of RASFF notifications (2020-2025) related to residues of veterinary medicinal products in food by the country of origin is presented in **Figure 1**.

A total of 230 notifications reported the presence of at least one veterinary drug residue in the Notification type „Food". In the majority of cases, the food originated from Vietnam (57; most commonly fish/fish products (28) and crustaceans/crustacean products (20)), followed by India (26; almost all crustaceans (25)), Poland (24; poultry/meat and products thereof (14/7)), the Netherlands (15; 13 related to meat/meat products), Ukraine (13; eggs and egg products (8)), Belgium (12; meat/poultry and products thereof (5/4)), and others (**Figure 1**).

Food categories and the most frequently reported residue classes were meat/meat products (62) – nitrofuran derivatives (11; 8 furazolidone, 3 nitrofurazone), tetracyclines (7; 3 doxycycline, 3 oxytetracycline, 1 tetracycline), crustaceans/crustacean products (54) – nitrofuran derivatives (28; 24 furazolidone; 2 nitrofurazone, 1 aminoguanidine, 1 furaltadone), triphenyl/triaryl methane dye (16; 9 leucomalachite green, 3 malachite green, 2 crystal violet, 1 leucocrystal violet, 1 victoria pure blue BO), tetracyclines (8, 3 doxycycline, 3 tetracycline, 2 oxytetracycline), fish/fish products (37) – triphenyl/triaryl methane dye (35; 14 leucomalachite


Meat and meat products (other than poultry)
furazolidone
nitrofurazone
meloxicam
ibuprofen
dexamethasone
closantel
oxytetracycline
doxycycline
tetracycline
tulathromycin
tylosin
tilmicosin
florfenicol
chloramphenicol
sulfadimethoxine
sulfadiazine
sulfonamide
dihydrostreptomycin
gentamycine
oxyphenbutazone
ofloxacin
marbofloxacin
enrofloxacin
not specified
aminoflubendazol
fenbendazole
ivermectin
doramectin
maduramicin
lincomycin
diclofenac
carprofen
amoxicillin
metronidazole
benzimidazole
robenidine
trimethoprim
levamisole
toltrazuril
not specified
NSAID
pyrethroids
4-hydroxyqionoline
pyrimidones
organophosphate
triazines
thioether
diaminopyrimidines
organochlorine
benzimidazoles
nitroimidazoles
beta-lactams
carbazole and propionic acid
phenylacetic acid derivative
lincosamides
ionophores
avermectins (macrocyclic lactones)
benzimidazole
salicylanilides
corticosteroids
fluoroquinolones
aminoglycosides
sulfonamides
amphenicols (phenylpropanoids)
macrolides
tetracyclines
triarylmethane dye
triphenylmethane dye
nitrofuran derivatives
0 2 4 6 8 10 12 14 16 18 20 22 24


Crustaceans and products thereof
furazolidone
nitrofurazone
aminoguanidine
furaltadone
leucomalachite green
malachite green
tetracycline
doxycycline
oxytetracycline
sulfamethoxazole
crystal violet
leucocrystal violet
victoria pure blue BO
ternidazole
chloramphenicol
ciprofloxacin
0 2 4 6 8 10 12 14 16 18 20 22 24


Fish and fish products
leucomalachite green
malachite green
oxytetracycline
leucocrystal violet
crystal violet
furazolidone
chloramphenicol
ivermectin
ofloxacin
enrofloxacin
azithromycin
not specified
0 2 4 6 8 10 12 14 16 18 20 22 24

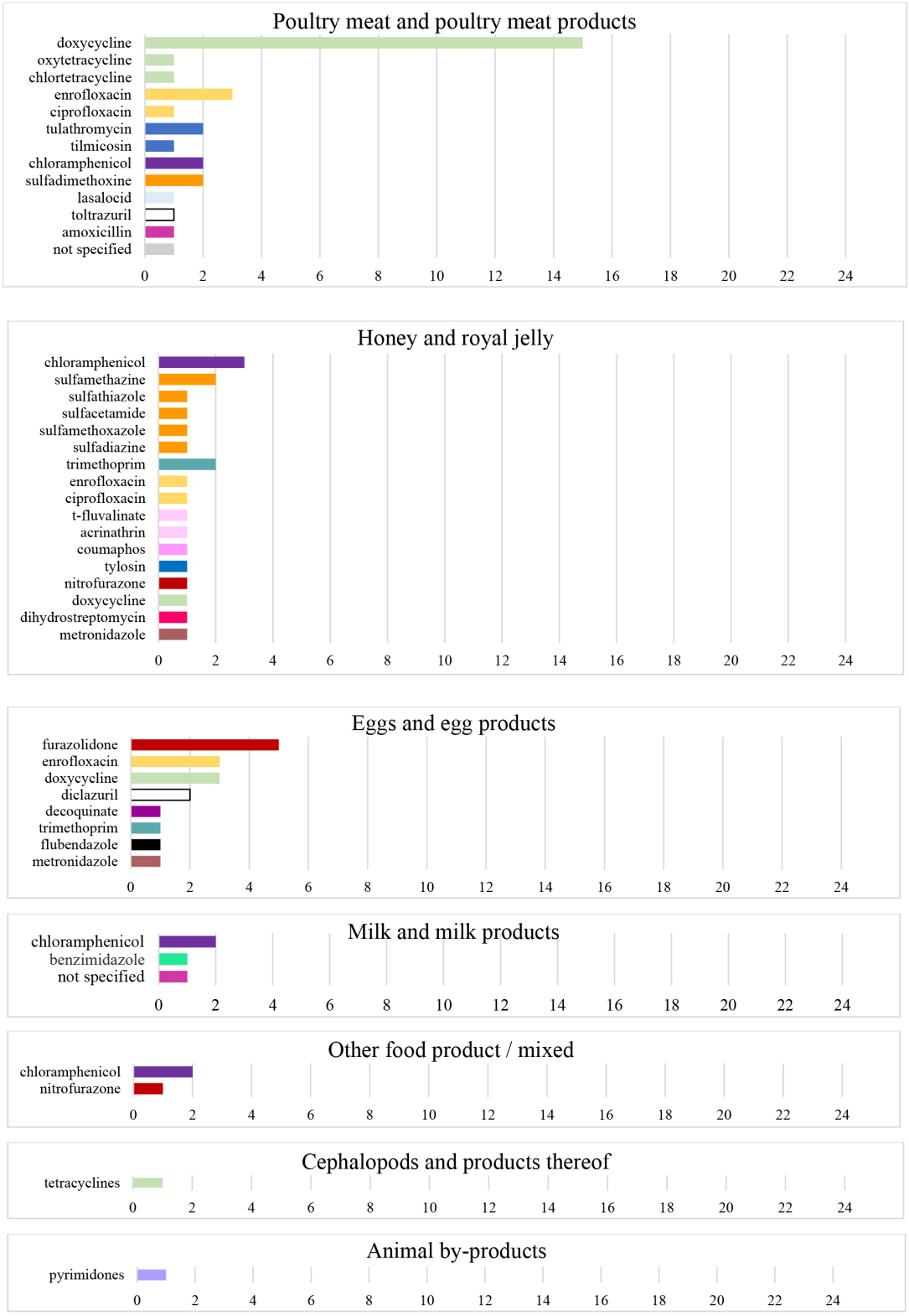
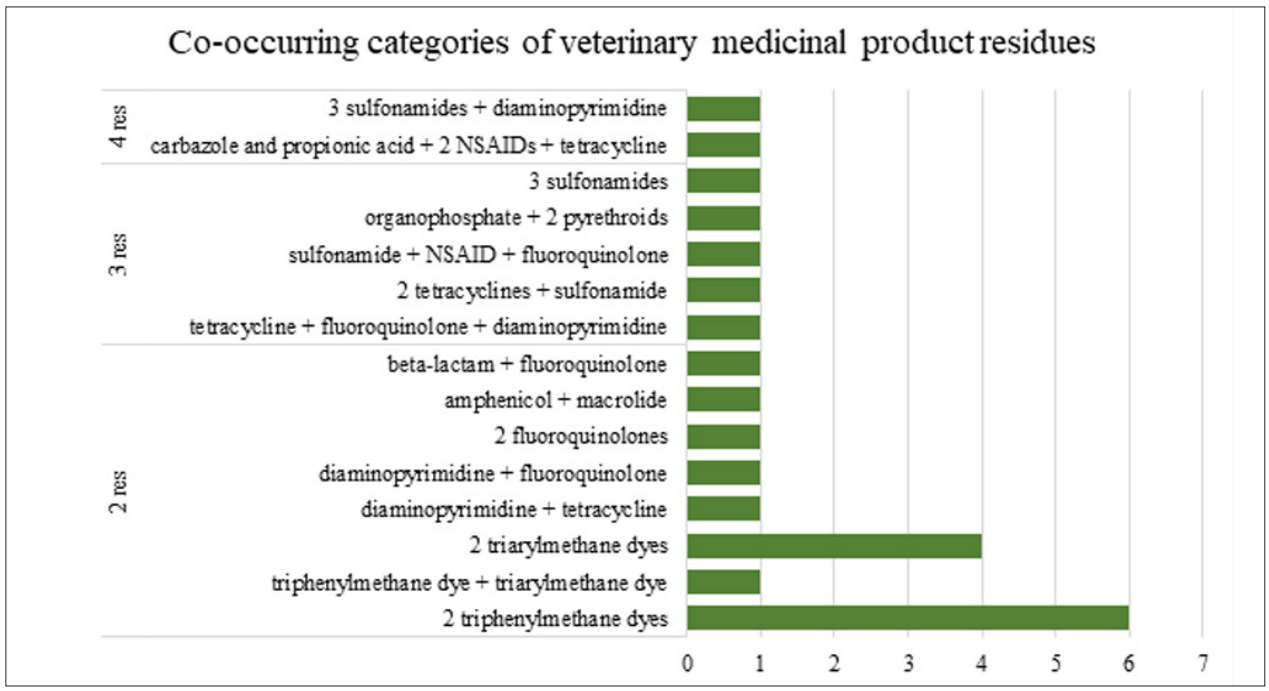


Figure 2. Distribution of the RASFF notifications (2020-2025) related to residues of veterinary medicinal products in food, concerning the food categories.

green, 13 malachite green, 5 leucocrystal violet, 3 crystal violet), tetracyclines (6; 6 oxytetracycline) and poultry/poultry products (30) – tetracyclines (17; 15 doxycycline, 1 chlortetracycline, 1 oxytetracycline), while significantly fewer notifications were related to honey and royal jelly (13) – sulfonamides (6; 2 sulfamethazine, 1 sulfadiazine, 1 sulfamethoxazole, 1 sulfacetamide, 1 sulfathiazole), amphenicols (3; 3 chloramphenicol), fluoroquinolones (2; 1 ciprofloxacin, 1 enrofloxacin), diaminopyrimidines (2; 2 trimethoprim), eggs/egg prod-

ucts (15) – nitrofuran derivatives (5; 5 furazolidone), tetracyclines (3; 3 doxycycline), fluoroquinolones (3 enrofloxacin), milk/dairy products (4) – amphenicols (2; 2 chloramphenicol), other food product/mixed (3) – amphenicols (2; 2 chloramphenicol), cephalopods/cephalopod products (1) – tetracyclines (1; 1 oxytetracycline), and animal by-products – pyrimidines (1; 1 thiouracil) (**Figure 2**).

Co-occurrence of residues was observed in 23 cases, predominantly involving 2 residues, while two cases involved 4 residues and five cases involved 3 residues (**Figure 3**). Six notifications reported the presence of 2 triphenylmethane dyes (leucomalachite green + malachite green), and four notifications reported 2 triarylmethane dyes (leucocrystal violet + crystal violet; crystal violet + victoria pure blue BO). Single notifications were reported for the following combinations: triphenylmethane dye + triarylmethane dye (leucomalachite green + leucocrystal violet), diaminopyrimidine + tetracycline (trimethoprim + oxytetracycline), diaminopyrimidines + fluoroquinolones (trimethoprim + enrofloxacin), 2 fluoroquinolones (ciprofloxacin +



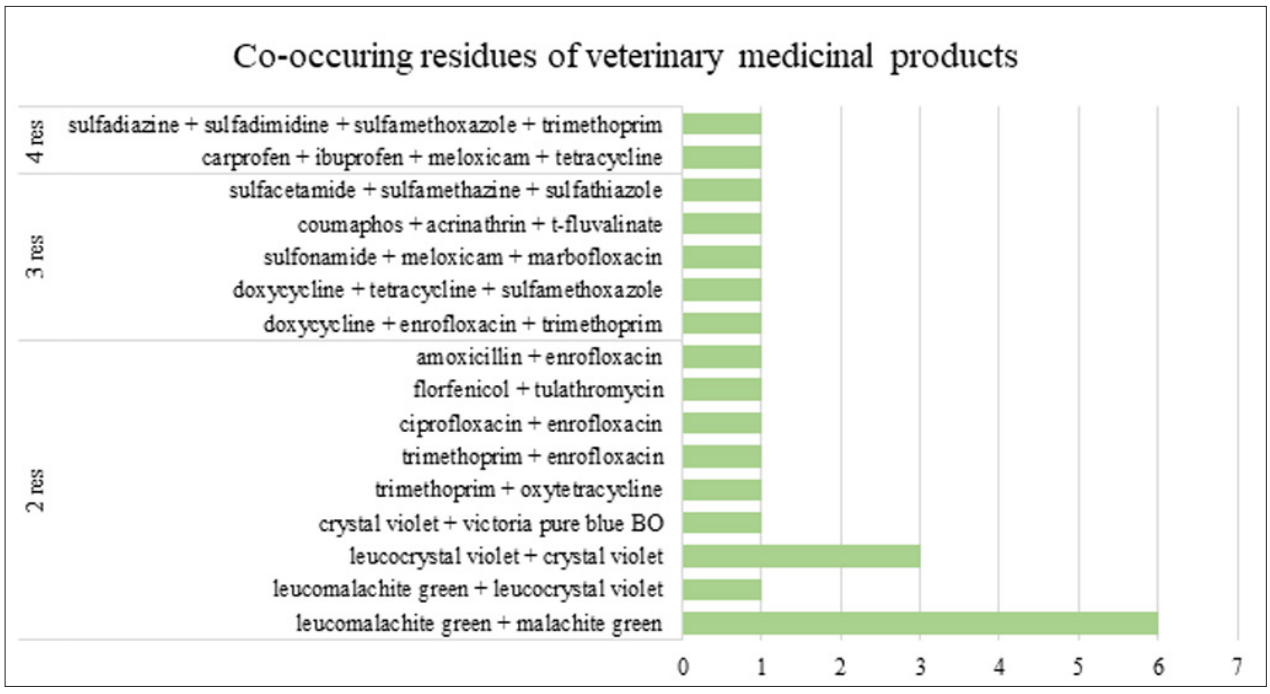


Figure 3. Distribution of the RASFF notifications (2020-2025) related to the co-occurrence of residues of veterinary medicinal products in food.

enrofloxacin), amphenicol + macrolide (florfenicol + tulathromycin), beta-lactam + fluoroquinolone (amoxicillin + enrofloxacin), tetracycline + fluoroquinolone + diaminopyrimidine (doxycycline + enrofloxacin + trimethoprim), 2 tetracyclines + sulfonamide (doxycycline + tetracycline + sulfamethoxazole), sulfonamide + nonsteroidal anti-inflammatory drug + fluoroquinolone (sulfonamide + meloxicam + marbofloxacin), organophosphate + 2 pyrethroids (coumaphos + acrinathrin + t-fluvalinate), 3 sulfonamides (sulfacetamide + sulfamethazine + sulfathiazole), carbazole and propionic acid + 2 nonsteroidal anti-inflammatory drugs + tetracycline (carprofen + ibuprofen + meloxicam + tetracycline), and 3 sulfonamides + diaminopyrimidine (sulfadiazine + sulfadimidine + sulfamethoxazole + trimethoprim) (**Figure 3**).

Monitoring the number of registered notifications on the RASFF portal over the six years (2020–2025) reveals a continuous increase in notifications concerning the presence of residues of veterinary medicinal products in food, ranging from 25 notifications in 2020 to 51 in 2025 (**Figure 4**). More than half of the notifications were classified as „information" (56.0%, including information for attention and information for follow-up). The total number of alerts and border rejections during the observed period was comparable, with alerts prevailing in some years (e.g., 12 alerts in 2024) and border rejections in others (e.g., 17 border rejections in 2025) (**Figure 4**). Nevertheless, across all study years, the most frequent risk decision was „serious", accounting for 47.8% of all notifications (**Figure 4**).

DISCUSSION

The study reveals that, among the 230 notifications related to the presence of residues of veterinary medicinal products, certain countries of origin as well as specific food categories stand out. The observed pattern is consistent with results obtained from more extensive RASFF datasets and international food safety monitoring programs [10-12].

During the six years observed, Vietnam accounted for the largest share of notifications (57/230), primarily in fish, crustaceans, and products thereof. This pattern reflects the fact that nearly half of all notifications concerning veterinary drug residues in fish products were associated with Vietnam (49.1%), identifying it as the leading consignor country among veterinary drug residues–related non-compliance in the EU markets. These findings also indicate a continuation of the trend observed by Guardone *et al*., who monitored the presence of veterinary drug residues in fish and fish products over the period 2001–2021 [10]. In second place in terms of the number of recorded notifications was India, with 26 notifications, almost all related to crustaceans and products thereof. This finding is consistent with a previous study covering the period 2001–2023 [12]. Similarly, it reflects ongoing concerns regarding intensive aquaculture practices in South and Southeast Asia, predominantly in Vietnam, India, and China, where improper use of veterinary drugs has been repeatedly detected in exported seafood [10,12]. Among EU Member States, Poland, the Netherlands, and Belgium were the most frequently reported countries of origin, primarily for meat and poultry contamination. Overall, RASFF analyses indicate that, within

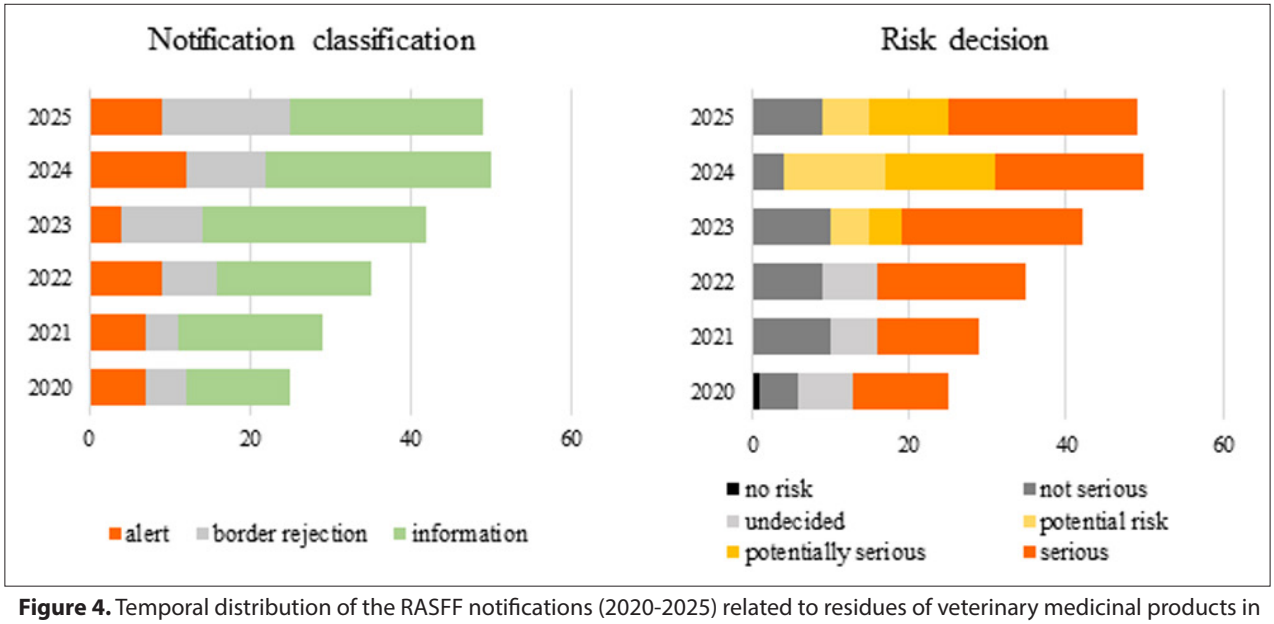


Figure 4. Temporal distribution of the RASFF notifications (2020-2025) related to residues of veterinary medicinal products in food by (A) Notification classification and (B) Risk decision.

these food categories over the past six years, Poland has emerged as the leading country of origin, with all three mentioned countries surpassing Italy and the United Kingdom in reported cases of meat and poultry contamination [12].

The evaluation of the main commodities reported for non-compliant use of veterinary medicinal products highlighted meat, crustaceans, fish, and poultry as the primary food categories, whereas honey, eggs, and dairy products contributed relatively fewer notifications. This distribution mirrors findings from other studies, highlighting meat, poultry, and aquaculture products as the principal sources of consumer exposure to veterinary drugs [11,12], but with a different order of dominance in earlier periods. Crustaceans predominated between 2002 and 2009, during which annual notifications consistently exceeded 100, with a pronounced peak in 2002. Fish, meat, and products thereof followed, while honey and royal jelly, as well as poultry/poultry products, were reported less frequently. Over the entire period, from 2001 to 2023, the cumulative number of notifications for these food categories reached 885, 359, 358, 316, and 221, respectively, suggesting a gradual improvement in compliance and highlighting the role of the RASFF system in mitigating risks to public health [12]. These findings reflect both the intensity of production practices in these sectors and the widespread use of veterinary drugs, underscoring the need for targeted surveillance and risk management strategies to mitigate potential public health risks.

In contrast, honey and royal jelly, eggs/egg products, milk and dairy products, other food products and mixed products, cephalopods/cephalopod products, and animal by-products were only sporadically implicated, collectively representing a minor share of the total number of notifications. Comparison of these results with studies covering earlier periods indicates a substantial decrease in the number of notifications associated with honey, particularly after 2008 [11,12]. The reduced number of notifications may result from multiple factors, including differences in authorization practices, particularly the restricted use of veterinary medicinal products in apiculture [8-9]. Additionally, stricter regulatory frameworks governing product control, including clearly defined, commodity-specific sampling priorities [13], as well as withdrawal period requirements, are likely to contribute to this observed pattern. However, lower notification numbers should not be interpreted as indicative of negligible risk. Rather, they reflect the combined influence of regulatory and monitoring practices on detection and reporting, as well as ways of veterinary drug use, underscoring the importance of interpreting notification data within the context of surveillance design rather than as a direct measure of underlying risk.

Further analysis by food category revealed that nitrofuran metabolites (mainly furazolidone and nitrofurazone) and tetracyclines (doxycycline, oxytetracycline, and tetracycline) were dominantly detected in meat/meat products (17.7% and 11.3%, respectively) and crustaceans/crustacean products (51.8% and 14.8%, respectively). In both food categories, the absolute proportion of nitrofuran metabolites slightly decreased when comparing the results of the present study with RASFF monitoring data over the 2001–2023 period [12]. Nevertheless, their occurrence remains a point of concern, given that the use of nitrofurans in food-producing animals is prohibited in the European Union, as these compounds and their metabolites are genotoxic, carcinogenic, and are also associated with non-neoplastic adverse effects in animals [14]. The use of tetracyclines is currently limited to therapeutic and prophylactic purposes, as well as growth promoters in livestock and aquaculture, while their use in human medicine has been almost completely discontinued. Their presence in food has been associated with adverse health reactions, whereas they are most frequently linked to environmental concerns [15]. Moreover, tetracyclines were the most frequently detected class of residues in poultry and poultry products (56.7%). Triphenylmethane and triarylmethane dyes were largely confined to fish (94.6%) and crustacean products (29.6%), where they consistently represented the most frequently detected residues, highlighting persistent concerns regarding their use, which is not registered for food-producing animals in the EU, as well as in the USA and Canada [10]. Besides their use as industrial colorants, these dyes have also been illegally applied in aquaculture as antifungal, antiparasitic, and antimicrobial agents, due to their low cost. When ingested through fatty tissues of fish, they can exhibit toxicological effects, including genotoxicity and carcinogenicity [10,16,17]. For eggs, reports were relatively few. The three most frequently detected classes of veterinary drug residues were nitrofuran metabolites (33.3%), tetracyclines (0.2%), and fluoroquinolones (enrofloxacin; 0.2%), which aligns with studies covering a broader period of interest [12]. Similarly, honey and royal jelly showed fewer notifications overall, including sulfonamides, chloramphenicol, fluoroquinolones, and diaminopyrimidines residues classes. Consistent with the study of Janković *et al.* [18], sulfonamides (46.2%) were the most frequently detected, raising particular concern, as certain sulfonamides can be mildly toxic to blood cells. Sporadic detections of chloramphenicol in milk and dairy products, as well as in mixed food products, alongside the presence of oxytetracycline in cephalopods and cephalopod products, and thiouracil in animal by-products, underscore that non-compliance with withdrawal periods, illegal or off-label use of veterinary drugs remain important drivers of residue occurrence across diverse food matrices.

Most notifications reported the presence of only two residues (16 cases), suggesting relatively simple yet recurrent co-occurrence patterns. These were predominantly associated with triphenylmethane and triarylmethane dyes, including malachite green, leucomalachite green, crystal violet, leucocrystal violet, and related residues, substances commonly applied in aquaculture practices. In contrast, notifications involving more complex residue profiles, comprising three to four compounds belonging to different classes of veterinary medicinal product residues, underscore a mixture exposure scenario rather than isolated misuse. This complexity raises particular concern, as it implies potential consumer exposure to additive or interactive effects of multiple residues present within a single food product.

CONCLUSIONS

This study demonstrates that food contamination with residues of veterinary medicinal products is not uniformly distributed across global trade, but is largely driven by country- and product-specific production practices. Accordingly, the evaluation of RASFF notifications identified Vietnam, India, and China as the principal countries of non-compliant consignments entering the EU, underscoring South and Southeast Asia as critical regions for residue-related risk control. Across food categories, nitrofuran metabolites, triphenyl/triaryl methane dyes and tetracyclines dominated the notifications, with clear food category-residue patterns:

- meat and meat products were mainly linked to nitrofuran derivatives and tetracyclines,
- crustaceans to nitrofuran derivatives and triphenyl/triaryl methane dyes,
- fish to triphenyl/triaryl methane dyes,
- poultry/poultry products to tetracyclines, and
- honey and royal jelly to sulfonamides.

The frequent occurrence of multiple veterinary drug residues, particularly in aquatic food products containing triphenylmethane and triarylmethane dyes, suggests repeated or overlapping treatments with structurally or functionally related compounds.

These findings underscore the importance of risk-based, targeted monitoring strategies and strengthened international cooperation to reduce consumer exposure to veterinary drug residues through food.

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COMPETING INTERESTS

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.

CRediT authorship contribution statement

M.J.: Conceptualisation, Methodology, Investigation, Data Curation, Visualization, Writing – original draft; U.G.: Investigation, Data Curation; LJ.T.: Conceptualisation, Methodology, Writing – review & editing.

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Ostaci veterinarskih lekova u hrani prema RASFF-u

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Kratak sadržaj

Veterinarski lekovi se široko koriste za prevenciju i lečenje bolesti, kao i za uvećanje prirasta mase životinja. Međutim, njihova neadekvatna upotreba može dovesti do prisustva detektabilnih koncentracija rezidua u hrani, što se sve češće povezuje sa značajnim javnozdravstvenim problemom – antimikrobnom rezistencijom. Korišćenjem podataka iz RASFF-a u periodu od 2020. do 2025. godine, ova studija evaluira kontaminaciju hrane reziduama veterinarskih lekova. Tokom šestogodišnjeg perioda zabeleženo je ukupno 230 notifikacija, pri čemu su pet najčešće prijavljivanih zemalja porekla bile: Vijetnam (57; najčešće riba/riblji proizvodi i ljuskari/proizvodi od ljuskara) > Indija (26; gotovo isključivo ljuskari) > Poljska (24; živinsko meso/meso i proizvodi) > Holandija (15; gotovo isključivo meso i proizvodi od mesa) > Ukrajina (13; gotovo isključivo jaja i proizvodi od jaja) > Belgija (12; meso/živina i proizvodi). Prema kategorijama hrane, najčešće prijavljene klase rezidua veterinarskih lekova bile su: meso i proizvodi od mesa osim živine (62; 11 derivata nitrofurana, 7 tetraciklina) > ljuskari/proizvodi od ljuskara (54; 28 derivata nitrofurana, 16 trifenil/triaril metanskih boja, 8 tetraciklina) > riba/riblji proizvodi (37; 35 trifenil/triaril metanskih boja) > živina/proizvodi od živine (30; 17 tetraciklina). Iako je većina notifikacija klasifikovana kao informacije (56,0%), gotovo polovina (47,8%) je ipak procenjena da predstavlja ozbiljan rizik po javno zdravlje. Ovi nalazi ukazuju na potrebu za strogim, na riziku zasnovanim monitoringom rezidua veterinarskih lekova u hrani. U tom kontekstu, RASFF ima važnu ulogu u zaštiti zdravlja potrošača, kako unutar EU, tako i globalno.

Ključne reči: *veterinarski lekovi; antimikrobne rezidue; bezbednost hrane; javno zdravlje; RASFF.*