Using the Rapid Alert System for Food and Feed: potential benefits and problems on data interpretation

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Abstract

The Rapid Alert System for Food and Feed (RASFF), where competent authorities in each Member State (MS) submit notifications on the withdrawal of unsafe or illegal products from the market, makes a significant contribution to food safety control in the European Union. The aim of this paper is to frame the potential challenges of interpreting and then acting upon the dataset contained within the RASFF system. As it is largest cause of RASFF notifications, the lens of enquiry used is mycotoxin contamination. The methodological approach is to firstly iteratively review existing literature to frame the problem, and then to interrogate the RASFF system and analyse the data available. Findings are that caution should be exercised in using the RASFF database both as a predictive tool and for trend analysis, because iterative changes in food law impact on the frequency of regulatory sampling associated with border and inland regulatory checks. The study highlights the variability of engagement by MSs with the RASFF database, influencing generalisability of the trends noted. As importing countries raise market standards, there are wider food safety implications for the exporting countries themselves. As this is one of the first studies articulating the complexities and opportunities of using the RASFF database, this research makes a strong contribution to literature.

Keywords: food safety, food security, RASFF, mycotoxins, sampling

1. Background

1.1 Introduction

The dominant role of information as a product of a modern economy and a determinant of business decisions is often articulated. Thus, when organisations, and the individuals that work for them, are seeking access to sources of information on instances of non-compliance with food law they should consider with care both the source of data, and how they intend to use it. There are many examples of databases developed to contain data on food law non-compliance. These databases include the European Union (EU) Rapid Alert System for Food and Feed (RASFF), the EU Food Fraud Network & Administrative Assistance and Cooperation System (EU FFN & AAC), the former US Pharmacopoeia (USP) Food Fraud Mitigation Database that has evolved to the Decernis Food Fraud Database (Decernis, 2019), and HorizonScan (Fera, 2019). These databases evolve from the joint activities of governments and the private sector, and via emergent digital tools that gather data from multiple sources, including information from official food controls, and the broadly defined media (Bouzembrak et al. 2018; Kowalska, 2019; Manning & Soon, 2019). This paper specifically focuses on the RASFF Database.

1.2 RASFF Database

Multiple studies have analysed RASFF data for incident frequency and trends (Kleter et al. 2009; Taylor et al. 2013; Tähkäpää et al. 2015; Bouzembrak & Marvin, 2016; Marvin et al. 2016; Djekic et al. 2017; Kowalska et al. 2018). However, not so many of these studies underline the need to interpret the data cautiously based on the nature of the data collection methods, which forms the research rationale for this study. Manning and Soon (2018, p. 132), in their study on food smuggling and trafficking, underlined that "purposive sampling means the [RASFF] data does not reflect the true incidence, extent and type of illegal imports especially by individuals for personal use". Pádua et al. (2019), in their study on the impact of Regulation (EU) No 1169/2011 on allergen-related recalls in RASFF, state that "although this provides official and controlled data, which can be used in risk analysis, they are restricted to the control activities from which they result and cannot be used in predictions of occurrences with food allergens."

The European Commission (EC) developed the RASFF system in 1979 and since then, the system, through continuous service (24/7), has been the cornerstone of the food safety regulatory control system and has ensured that urgent notifications are reported and answered collectively between all EU countries, as well as Norway, Liechtenstein, Iceland, and Switzerland. Food safety is the condition of foodstuffs in all stages of production, processing and distribution, required to guarantee protection of consumers' health, also taking into account normal circumstances of use, and the information available for the foodstuffs concerned (Baert et al. 2011). Food safety is only about controlling chemical, physical and microbiological hazards to minimise the risk to public health, it is also a crucial social, environmental and economic issue. Food safety is a fundamental foundation of food security, where the latter addresses "ensuring the availability and accessibility of nutritious food, for all people at all times to live a healthy life" (Gross et al. 2000). The value of the RASFF database particularly for underpinning food safety and wider regulatory compliance of food in Europe is the obligatory nature of Member State (MS) participation; the system's 24-hour operation, rapid reaction and action criteria, the quality of the metadata provided, its "free to use" accessibility and ease-of-use. The RASFF portal is therefore a key tool to ensure the flow of information to enable a swift reaction when risks to public health are detected in the food supply chain. The process aims to minimise the public health effect of trading any food that is unsafe, hazardous or does not comply with labelling or information supplied with the product.

The EC is a member and a manager of the RASFF system (EU, 2018). In combination with the actions overseen by the EC and related agencies, a strong commitment from the industry and government to improve the integrity and assurance of food supply networks, and a determination to protect consumers is expected. There is an imperative to build strong global institutions that exercise common food governance through encouraging authoritative bodies and regulatory institutions to cooperate together with private organisations within supply chains. This cooperative approach means that a wide range of governance activities can be undertaken jointly by the private and the state sector (Spink et al. 2016; Verbruggen, 2016; Verbruggen & Havinga, 2017), where these authors term this approach as the *hybridisation* of food policy. Despite the efforts of regulators and the private sector to develop and implement systems to manage food safety, consumer food poisoning and foodborne illness outbreaks still occur, and remain an important source of communicable and non-communicable human disease (Manning, 2017a). Indeed, food safety failures are recognised by governments as a major social and economic risk, threatening consumer health, producing inefficiencies in animal and plant production systems, and creating trade barriers across the global food system (Kendall et al. 2018). In summary, the RASFF database and the associated notification processes are a useful mechanism for keeping European citizens informed and safer, and making the European food industry more competitive.

1.3 Regulatory and hybrid control systems

Current policy measures aimed at preventing, managing and mitigating food safety risk can be divided into two groups. These are: (1) **ex ante preventative measures**, including the development of food safety management systems and food traceability systems; and (2) **ex post reactive measures** including control measures undertaken by national food protection agencies to address a specific incident. These measures designed to protect public health include the use of rapid alert systems and information technology systems developed to exchange data regarding non-compliances and identifying quickly any potential intentional violations of agri-food chain legislation (Kowalska, 2019).

There are regions and states for example where the private sector is very strong in food control activities, e.g. the United Kingdom (UK), or alternatively countries such as Poland that mostly rely on public governance. As the structure, efficiency and degree of public/private hybridisation of the food control system is historically, structurally, and culturally conditioned this limits the opportunity to develop official food control system instruments that are universal. At the same time, global market dynamics are driving a decreasing number of larger and larger global transnational corporations who are responsible for the world's food supply. Transnational corporations as part of their corporate compliance processes develop common food safety standards across their operating base especially in countries that lack a public official food control system. Good practices and solutions from particular trading regions are then tailored for given operating situations. The food safety governance structures within these corporations therefore have a stronger and stronger impact on the level of food safety and food legality.

Transnational corporations are motivated to invest in private standards and systems to reduce shareholder, consumer and business risk (Manning, 2018). Thus, the market environment creates a juxtaposition between self-interest, deontological and virtuous behaviour requiring investment in food traceability, food authenticity and guarding against food crime (Hoorfar et al. 2011; Davidson et al. 2017; Manning, 2017b; Fox et al. 2018; Manning, 2018; Kowalska, 2019). The corporate focus is on the protection of the economic interests of the consumer with respect to food safety and quality, and ensuring fair business practices (Korzycka & Wojciechowski, 2017). However, their strong market orientation towards shareholders' interests reflects an ethical dilemma if these interests are at odds with the interests of the consumer (Adamowicz, 2015; Kowalczyk, 2017). It can be argued that consumer interest in terms of food safety and food security is a public good that a purely market mechanism cannot supply. Even within hybrid models of food governance, society, albeit through a culturally contextualised frame, still expects the State, as a regulator, creator and guardian of social and economic order, to ensure food is safe and wholesome (Kowalska, 2019). For instance, due to the dominant regulatory culture of Polish food control bodies, the system lacks adaptive capacity in the face of changing legal, technology and market environments, and also is weak in learning from regulatory approaches in other countries (Jendza, 2016). Whilst Weber (2002) finds many benefits of bureaucratic organisations, the bureaucratic model of official food control bodies in Poland creates barriers to the cooperation between public and private organisations which is necessary for effective food safety governance (Verbruggen, 2016; Verbruggen, & Havinga, 2017). This demonstrates that even countries historically under the collective umbrella of EU legislation, such as the UK and Poland, can have very varied regulatory approaches and thus may utilise the RASFF system in different ways.

A more market orientated policy approach to food safety focuses on risk. In this regard, both EU and United States (US) food policy has increasingly focused on minimising food safety risks and associated hazards. Kendall et al. (2018) determine that a systems approach to identifying, managing and mitigating food safety risk represents a useful policy tool. Indeed making the hazard analysis critical control point (HACCP) approach compulsory post-harvest and post slaughter via regulatory levers was a milestone in such food safety policy (Manning, Luning & Wallace, 2019). Food safety management programmes derived from this approach generally focus on the unintentional contamination of food by known ingredients, pathogens, mishandling, or processing, but more recently the issue of intentional adulteration of food is gaining importance (Soon et al. 2019). To counter existing and emerging food safety risks effectively, key economic, environmental and cultural drivers of risk must be identified and these may vary across and between countries.

Since 2000, the Global Food Safety Initiative (GFSI) too has been playing a major role in "promoting a harmonised approach with a shared vision of safe food for consumers everywhere". The initiative is a world-leading institution in food safety governance; demonstrating private meta-regulation and it provides a benchmarking standard for food safety (Verbruggen & Havinga, 2014). All major transnational private food safety standards are recognised by the GFSI, including the Primus GFS Standard, Global Aquaculture Alliance Seafood, GlobalG.A.P. Produce Safety Standard, GlobalG.A.P. Integrated Farm Assurance Scheme, Global Red Meat Standard, SQF Code, IFS Food Standard, IFS PACsecure, IFS Logistics, BRC Global Standard for Food Safety, BRC Global Standard for Packaging and Packaging Materials, BRC Global Standard for Storage and Distribution, BAP Seafood Processing Standard, FSSC 22000, Canada GAP, and China HACCP (PricewaterhouseCoopers (PwC), 2017). Kendall et al. (2018) advocate this international harmonisation of food safety standards globally. As well as through private co-operation and consolidation of supply chain standards, harmonisation of approach can also be delivered through the mechanism of the United Nations Codex Alimentarius Commission derived international food safety standards and protocols.

1.4 Transparency and traceability

The principle of transparency required under Community law means that traceability has gained considerable importance with regard to food, particularly following a number of food safety incidents during which traceability systems have been shown to be weak or absent (Aung & Chang, 2014). Food traceability systems are perceived as effective elements of safety and quality systems and have the potential, in the event of a product recall, to improve safety within food chains, as well as to increase consumer confidence and to connect producers and consumers. Traceability systems should be established at all stages of production, processing and distribution of both animal and plant food products. Traceability contributes to managing risks related to food safety and plant/animal health issues, guaranteeing product authenticity, providing credible information to customers, and improving food quality by identifying the batches that potentially affected by a given non-compliance. Food scandals from the 80s and 90s such as Bovine Spongiform Encephalopathy (BSE) made products of animal origin (POAO) the main subject of the EU food law provisions (Kowalczyk, 2015). Thus, EU food traceability legislation covering POAO is much more comprehensive than the regulatory controls developed for foods of plant origin (Charlebois et al. 2014), otherwise defined as products not of animal origin or PNOAO. Since 2011, the scope of the TRAde Control and Expert System (TRACES), a multilingual online management tool that is used to notify, certify and monitor trade in animals and POAO has been enlarged through the launch of new modules for the control of feed and food of non-animal origin, as well as of plants, seeds and propagating material.

Regulation (EU) No 2017/625 known as the "Official Control Regulation" requires an integrated approach to the use of information management tools, which is why preparatory work was started to integrate food related EU-managed IT systems. These systems include the TRACES and the IT systems supporting the EU's alert systems (RASFF/AAC and EUROPHYT) through to the Information Management System for Official Control (IMSOC) (RASFF, 2018). Such integration should lead to the development of a better and more efficient communication system, hence more effective surveillance of food safety, enabling more efficient use of the available data, and reducing the administration costs associated with maintaining the former individual IT systems (TRACES, RASFF, AAC, EUROPHYT). The integration will also support the optimisation of regulatory resources, improve management control and as a result lead to an overall increase in performance. The aim of this e-government system is ultimately to ensure traceability, information exchange and risk management both within the EU and for imports from non-EU countries (EU, 2016).

1.4 Food safety and its interaction with food security

Unsafe food cannot be placed lawfully on the market, and potentially cannot be used as animal feed or for energy generation, and if this is the case the food must be disposed of and as a result becomes waste. Even if mislabelled food is re-worked or re-distributed to other destinations, much of the original economic, social and environmental value is lost. Food safety incidents, food fraud, and other market imperfections/food integrity incidents cost the global economy billions of euros a year. Thomson et al. (2012) determine the costs of multiple product recall incidents such as the 2008 Irish pork dioxin incident costing more than €4 million; and the previous 1999 Belgian dioxin incident causing a loss to the economy of €2 billion as non-inflation indexed examples. Effective management of food safety at the European level, such as through the use of the RASFF System will make identifying distribution routes for non-compliant foods and monitoring the potential status of food batches far easier thus limiting the economic burden of such recalls and wider public health costs. These include: public health treatment costs; export bans and embargoes; food recall/withdrawal and disposal costs and incident investigation costs; an increase in insurance premiums; fines for non-supply; a fall in share price or brand value and a loss of consumer and customer trust (Galvin-King et al. 2018; Kowalska & Kowalski, 2018; Manning, 2018; Renko et al. 2019).

More esoterically, the safety, availability and nutrition of food ranks among the fundamental needs for human life, affecting human health and wellbeing and increasing the length and quality of life (Wiśniewska, 2017; Lehotay, 2018). EU food law focuses on maintaining a high level of protection of human health and life through ensuring food security for all and integrity in terms of the practices in the supply chain, highlighting a wider context of the rights of individuals to safe, affordable, and nutritionally suitable food that meets all legal criteria. Unsafe foodstuffs can cause disease, illness and malnutrition, particularly affecting vulnerable groups such as pregnant women, infants, young children, the elderly and the sick. Malnutrition affects most of the world's population, all geographies, all age groups, rich and poor, men and women. There are many forms of malnutrition: from undernutrition, stunting and wasting in children under five, micronutrient deficiencies, moderate and severe thinness or underweight in adults, and conversely overweight and obesity in both children and adults (Global Nutrition Report, 2019). Every year, one in ten people in the world fall ill after eating contaminated food, and 420,000 die (WHO, 2017). Flynn et al. (2018) have rightly emphasised that "keeping the food supply safe is a never-ending task". The Global Food Security Index is a useful quantitative measure to assess the efficiency of the food security system and by implication the food safety governance of a given country (https://foodsecurityindex.eiu.com/). The index is based on 28 indicators grouped into three categories: affordability, availability, and finally quality and safety. The quality and safety score is composed of five indicators: diet diversification, nutritional standards, micronutrient availability, protein quality, and food safety. Food safety as an indicator is further composed of three sub-indicators, (i) the existence of an agency that ensures the health/safety of food, (ii) access to potable water, and (iii) the presence of a formal grocery sector (Chammem et al. 2018). In 2018 amongst 113 countries, Singapore, Ireland, the UK, the United States (US) and the Netherlands scored the highest overall Global Food Security Index score value with Singapore rated first in terms of affordability, the UK rated first in terms of availability, and France, Finland, the US and Australia ahead in terms of food quality and safety. Sierra Leone, Yemen, Madagascar, Congo (Dem. Rep.) and Burundi scored the lowest Global Food Security Index value, but Mozambique was rated last in terms of food quality and safety (The Economist Intelligence Unit, 2019). Unfortunately, there is not a Global Food Security Index calculated for all countries and European absentees in the list include Estonia, Latvia and Lithuania, which limits the value of the index in terms of cross-comparison especially in the Eastern Europe context.

2. Mycotoxins: a case study

Why are mycotoxins of particular importance when considering food safety and food security and reflecting on the role of the RASFF system in the hybridised food safety governance systems of the EU? Mycotoxins are natural contaminants of food and feed produced mainly by moulds and fungi of the genera Aspergillus, Penicillium, Fusarium and Alternaria. Mycotoxins (including aflatoxins, Ochratoxin A, and Fusarium toxins) are secondary metabolites that exert adverse negative effects both on human and animal health and may contaminate agricultural food products of vegetable and animal origin leading particularly to a loss of efficiency in animal production systems (WHO, 2018). Estimates suggest that 25%-35% of the world's crops including rice, cereals and nuts, are damaged by mould or fungal growth representing around 1 billion metric tonnes of food lost per annum (Pandya & Arade, 2016; Avery et al. 2019; Gbashi et al. 2019). As a result of the associated food loss, mycotoxin contamination presents a modern day challenge to food security in many countries as well as a chronic public health issue for those that consume foods contaminated with mycotoxins.

Due to the potential risk of contamination of some products by aflatoxins, the EC introduced special conditions governing certain foodstuffs imported from certain third countries (Commission Decision 2006/504/EC). For instance, Commission Regulation (EC) No 669/2009 of 24 July 2009 implementing Regulation (EC) No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin and amending Decision 2006/504/EC provides for an increased frequency of regulatory controls (**50% of all consignments**) to be carried out for the presence of **aflatoxins** in peanuts and derived products originating from Brazil and Ghana; basmati rice for direct human consumption from

Pakistan; melon (egusi) seeds and derived products from Nigeria; specific spices from India, and requirements for determining the presence of Ochratoxin A in dried vine fruit from Uzbekistan. Commission Implementing Regulation (EU) No 884/2014 of 13 August 2014 imposing special conditions governing the import of certain feed and food from certain third countries due to contamination risk by aflatoxins and repealing Regulation (EC) No 1152/2009 states that competent authorities shall carry out checks by taking a sample for analysis of total **aflatoxin contamination** for food on certain consignments **at a 50% frequency**, i.e. pistachios and derived products from Iran and Turkey, peanuts and derived products from Ghana, and watermelon seeds and derived products from Nigeria.

Mycotoxins can be present on agricultural commodities in the field, before harvest, post-harvest, during processing, packaging, distribution, and storage. Inappropriate or a lack of storage conditions and other environmental factors such as high temperature, high relative humidity and moisture may trigger mycotoxin formation (Cotty & Jaime-Garcia, 2007; Yeni et al. 2016; Baines et al. 2018; Zinedine & El Akhdari, 2019) especially if there is inadequate cleaning and handling processes and post-harvest drying techniques (Kabak & Dobson, 2017; Schmidt, 2017; Baines et al. 2018). Mycotoxins are more of a concern in warmer, subtropical and tropical areas than in the temperate areas of the world (Wilson et al. 2002). Mycotoxins are then transported across countries to other food markets via food supply chains (De Ruyck et al. 2015). In summary, due to their toxicity, and carcinogenicity, mycotoxins are of public health interest from both a food safety and a food security and economic perspective (Zinedine & Mañes, 2009; Barac, 2019; Bessaire et al. 2019; Ünüsan, 2019). Mycotoxin contamination can be used as a research lens not only to consider food safety in itself, but also public health more generally and issues of wider integrity of food supply chains and the impact of a food safety concern on local, national and global food security. This gives rise to several research questions:

RQ1: Does the nature of the purposive sampling process influence the RASFF dataset and as a result limit the conclusions that can be drawn from the data it contains?

RQ2: Can the RASFF dataset be used to determine risk associated with a given hazard?

The aim of the paper is to frame the challenges of interpretation and acting upon the dataset contained within the RASFF system with specific emphasis on mycotoxin contamination. Due to it being the largest reason for RASFF notifications, the lens of enquiry used is mycotoxin contamination. This approach will give insights into the value of the RASFF database for competent authorities, food organisations and individual members of the public as both a data source and as a management tool to drive corrective action to optimise public health and wellbeing. An understanding of the data and the inherent trends that are reported within the RASFF dataset over time and what this means in practice for the RASFF system as a source of information for risk assessment, risk management and risk communication is considered. The impact of raising import standards in one trading block on the food safety and food security of the exporting country itself is also considered.

3. Materials and methods

The methodological approach is to firstly iteratively review existing literature to frame the research questions, and then using mycotoxin notifications as an example, to interrogate the RASFF data system and analyse the data available in order to consider the research questions posed. We searched the following databases: Science Direct, Google Scholar, Google (to include grey literature) to primarily consider current information on food safety, food security and mycotoxin contamination. The key search terms are shown in Table 1. The terms were used in a range of combinations of the search terms i.e. through an iterative literature review method. Iterative literature review is grounded by a foundational literature search using a series of iterative searches. In undertaking the searches for a given combination of search terms the first 100 items in each search are considered for relevancy and any duplication. All relevant papers were then collected and the titles and abstracts read. The papers were then read in full (n=65) and screened for relevance and value in supporting a discursive narrative and argument. Fifty papers were used to support the primary narrative in the paper.

Take in Table 1

RASFF members are obliged to notify and to exchange information on food and feed safety issues and measures. The notifications reported in RASFF are generally available through the official portal, which features an interactive, searchable on-line database that includes detailed information on each notification, including the type, date, and reason for the notification, the hazard(s) and the nature of the product(s) involved, and the country of notification and origin (Pádua et al. 2019). The RASFF notification type is determined by three fields: (1) product type (food, feed or food contact material), (2) notification classification (alert, information, border rejection), and (3) notification basis, indicating what type of control, report or investigation lay at the basis of the notification (border control, official control on the market, company internal-check, consumer complaint, food poisoning) (RASFF Portal, 2019). A notification is classified as an 'alert' and is triggered when the food, feed or food contact material presents a serious risk on the market and rapid action is or might be required, generally aimed at withdrawing the product from the market. An 'information notification' concerns a food that does not require rapid action, either because the product is not on the market at the time of the report or the risk is low. A 'border rejection notification' is created when a foodstuff is prevented from entering the EU because it is considered to jeopardise food or feed safety (Kowalska et al. 2018; Pádua et al. 2019; RASFF Portal, 2019).

An initial search of the RASFF database highlights that one of the highest frequency of food related notifications is that associated with mycotoxins and more specifically aflatoxins. The RASFF food dataset over the period 01/01/2004-31/12/2018 is analysed. This timeframe is chosen because due to EU enlargement in May 2004 the number of MSs contributing to RASFF increased fundamentally, and using this dataset eliminates the potential for the findings to be influenced by this structural change. Further, the categorisation of action categories has changed over the time period assessed, limiting some elements of cross-comparison. Current and obsolete action categories are identified in the data analysis within the results section. The descriptive analysis of the data from RASFF were performed (frequency and percentages of the sample population) using Excel 2016. The instances of mycotoxin contamination were identified and then these were coded by product category and country. The influence of purposive sampling in light of the aforementioned the EU aflatoxin regulations plays a role here. The statutory sampling requirements of these regulations have evolved over time and thus influenced the value of the conclusions that can be derived from the data. Manning and Soon (2019) provide a wider discussion on the impact of sampling type on dataset validity and usability.

4. Results and analysis

Between September 1979 and May 2019, there were 49,522 RASFF notifications regarding food products. Analysis of RASFF data from the period 1979-2019 revealed that there were over 13,000 food safety incidents for POAO, and almost double this figure for foods of plant origin (RASFF Portal, 2019). This may be a factor of the enlargement of the TRACES System, to include feed and food of non-animal origin, as well as of plants, seeds and propagating material (EU, 2016). The rate of notification from different MSs varies allowing some countries data to influence the overall representativeness of the data for the context within all MSs (Petróczi et al. 2010; Taylor et al. 2013). Taylor et al. (2013) analysed RASFF notifications issued between 2003 and 2007, and found major variations among MSs in their relative contributions to the RASFF database. In 2016-2017, the most RASFF notifications came from Italy, the Netherlands, Spain, Germany, the UK, France, Poland and Belgium, whereas Estonia, Latvia and Lithuania were situated in the bottom ten countries (EU, 2017; EU, 2018).

Once identified, unsafe or mislabelled food cannot be legally sold in the EU, thus MSs must take appropriate action following a RASFF notification. The types of action taken have been determined from the database for the timeframe analysed (2004-2018) in order to gain a clearer picture of the economic, environmental and social implications of such interventions (Table 2). The most common actions carried out in connection with the wide variety of RASSF notifications within the studied period 2004-2018 were: re-dispatch, product recall or withdrawal, and destruction with the associated environmental impact.

Take in Table 2

With a particular focus on mycotoxins, the most frequent 2004-2018 RASFF notifications regarding food products (n=42181) related to the hazard category **mycotoxins** (n=9522) see Table 3 and Table 4. A tenth of the mycotoxins incidents were alerts with rapid action required. Other common food safety issues reported in RASFF over the period 2004-2018 were related to the presence of pathogenic microorganisms (n=5680) and high levels of pesticides residues (n=3949). Indeed these three categories together with microbial contamination other represent half of the notifications in Table 2.

Take in Table 3

An analysis of mycotoxin related incidents by product as a percentage of the total number of 'mycotoxins hazards' shows that the most notified product belonged to the category 'nuts, nut products and seeds' (72.79%), and then products were from the category 'fruits and vegetables' (12.97%) see Table 4. This compared with the most frequently notified product categories in the RASFF dataset between 2004 and 2018 being also 'nuts, nut products and seeds' (23.36%), and then products were from the category 'fruits and vegetables' (17.32%), fish and fish products (12.31%). Most of the notifications for nuts, nut products and seeds related to the hazard category 'mycotoxins'. One third of RASFF notifications for herbs and spices, 21% of the notifications for cereals and bakery products and 17% of RASFF notifications for fruits and vegetables related to the hazard category 'mycotoxins' (Table 4). Mycotoxins being identified as a "hazard" was much less frequent in the other food product categories.

Take in Table 4

The high level of notifications related to the hazard category 'mycotoxins' and especially for the category 'nuts, nut products and seeds' is due to the purposive sampling associated with EU legislation, especially Commission Regulation (EC) No 669/2009 and Commission Implementing Regulation (EU) No 884/2014 (Table 3). The effects of this policy on the trends identified in the database are evident when we analyse the share for food products in the hazard category 'mycotoxins' of **border rejections** as a total within RASFF notifications (Figure 1).

Since 2008 when the new "border rejections" type of RASFF notification was added, the vast majority of RASFF notifications for food in the hazard category 'mycotoxins' were border rejections (86.6% in 2008, 82% in 2009, 85.8% in 2010, 79.5% in 2011, 80.7% in 2012, 70.7% in 2013, 75.6% in 2014, 79% in 2015, 76.9% in 2016, 80.3% in 2017, and 77.3% in 2018). Can it be assumed that nuts, seeds and derived products are the most commonly contaminated food products presented at EU borders? Caution is required while considering this question because nuts and seeds, as shown, are subject to more frequent regulatory checks than many other food product types, demonstrating a weakness in being able to draw conclusions from this dataset. This is important in the context of implementing "risk-based" regulation where the possible drivers of RASFF notifications over the years might be complex and varied. Even in this research, the list of products subject to more frequent regulatory sampling is considered thus creating a limitation here too in terms of wider generalisability.

Take in Figure 1

When we analyse the number of RASFF notifications related to mycotoxins **by notifying country** over the period 2004-2018, we can observe considerable differences among the results (Figure 2). Germany notified the most food safety incidents associated with mycotoxins over this period (n=2624). This is followed by the Netherlands (n=1645), the UK (n=1563), Italy (n=1338), Spain (n=1005) and France (n=894). Some MSs contribute far fewer results, i.e. Ireland (n=98), Lithuania (n=77), Norway (n=58), Hungary (n=49), Malta (n=47), Luxemburg (n=46), Romania (n=41), Croatia (n=32), Latvia (n=27), and Estonia (n=15).

Take in Figure 2

Analysis of this data means that for both research questions the answer is that the nature of the purposive sampling process does influence the RASFF dataset and as a result limit the conclusions that can be drawn from the data it contains (RQ1). Further, the RASFF dataset cannot, due to the purposive nature of the data collection, be used to determine risk associated with a given food safety hazard.

5. Discussion

Food recalls, food rejections and associated food waste impact on food security in many nations in the world. Recent research has begun to highlight the fungal threat to food security (Avery et al. 2019; Moretti et al. 2019; Gbashi et al. 2019). Indeed, Avery et al. (2019) argue that investment in innovative research strategies, international, inter-disciplinary collaboration and associated policy levers are essential to control fungal growth and limit its impact on food security. A programme of regulatory mycotoxin screening and an associated database within RASFF is thus a key tool to use to promote such activities. Paster & Barkai-Golan (2008) highlight that the stringent regulatory controls around mycotoxins may lead to the countries that are seeking to export to the EU being faced with import bans and the loss of essential markets. The reduction in value can be seen with lower commodity prices and greater costs of inspection, checking and testing, greater costs for disposal, rejection or product treatment as well as compensation for claims made by customers (Gbashi et al. 2019). This, Paster & Barkai-Golan argue, could mean that such countries export the portion of commodities that will meet these stringent EU standards to the EU itself, whilst inferior products are consumed in the domestic market, or at the rural household level affecting local food safety standards and public health at the rural household scale. Indeed a study by Otsuki et al. (2001) suggests that a 10% tighter aflatoxin standard in the EU will reduce EU edible groundnut imports by 11% thus lowering trade flows from countries who rely heavily on the export trade. Gbashi et al. (2019) concur stating that exports of nuts, cereals, oil seeds and dried goods could fall by as much as 64% and lead to a loss of brand value as a result. This creates a challenge concerning the potential negative externalities of setting of regulatory and market standards in one global market and the resultant impact on the domestic markets that are differentiating their commodity products into different "value" chains i.e. what they can export and then what can be consumed in the domestic market by humans or livestock (Misihairabgwi et al. 2019). At a more basic food security level, increasing export market standards can influence what food can access the export market and the local market and what food is left to be eaten by the household as it is "not fit" for sale.

Actors along the supply chain in low and middle income countries have a low level of incentives to improve food safety in the supply chain and the public sector lack both capacity and resources to enforce regulations, if they exist (Hoffmann et al. 2019). Where toxicity and carcinogenicity of mycotoxins is proven as a public health issue, it is questionable whether the setting of different food safety standards in various countries is morally right (Zinedine & Mañes, 2009; Barac, 2019; Bessaire et al. 2019; Ünüsan, 2019). Further, in some studies observed differences in gut microbiomes were unique to specific locations and lifestyle (Yatsunenko et al. 2012). Liew and Mohd-Redzwan (2018) revealed that the gut microbiota is capable of eliminating mycotoxin from the host (human or animal) naturally, provided the host is healthy with a balanced gut microbiota. However, this is not the case with those having a lower quality of diet. In Southern Africa, chronic mycotoxin exposure has been linked to malnutrition, impaired growth, higher disease incidence e.g. hepatitis B virus, cancer, and neural tube defects amongst other health impacts (Misihairabgwi et al. 2019). In sub-Saharan Africa, around 250,000 hepatocellular carcinoma-related deaths due to aflatoxin toxicity occur per year (Wagacha & Muthomi, 2008) showing this balance between food quality, food safety and meeting food security needs (Mwalwayo & Thole, 2016). Indeed in times of extreme food insecurity, Wielogorska et al. (2018) argue that calorie intake is prioritised before the food safety issues associated with mycotoxins. Sirma et al. (2018) in their work on Sub-Saharan food security ask whether there is a trade-off between ensuring food availability and increased focus on food safety risk or is food security compromised by food safety policy? In policy terms, is absolute food safety a realistic social goal, where food is scarce and is there a regulatory relativity with respect to aflatoxins? How much does the lack of awareness of health implications of mycotoxins influence consumption behaviour in countries where the population is at risk of food insecurity? Sirma et al.'s study highlights differentiated aflatoxin standards across four African countries and the juxtaposition between ever increasing food standards and the "realities that make compliance impossible" i.e. the challenges of the creation of un-workable market standards where the ability to create food standards and regulatory policy exceeds the ability of governments to effectively implement them. Whilst regulatory authorities may set maximum mycotoxin levels, these regulations are simply not effective in subsistence farming communities where food is produced for direct consumption (Alberts et al. 2019). Further, Beed (2012) asserts that it is essential to prevent the 'dumping' of mycotoxin contaminated food e.g. consignments that have failed to gain entry into EU markets into local and non-regulated African markets. Dumping practice can therefore be driven by increasing standards in some trading blocks.

Dumping is when an "exporter" exports its product at a price (i.e. the 'export price') which is below the price the product is usually sold for in the destination market (i.e. the 'normal value') thus impacting on the economic market and often causing organisational failure for domestic supply (Sibanda, 2015). Therefore, dumping mycotoxin contaminated food into the African human food chain during acute and chronic food security incidents also contributes to the public health challenge in that region (Mwalwayo & Thole, 2016). Across Africa, the availability of data and information on the level of incidence, public health importance, prevention and control of mycotoxins is limited for both consumers and those working in the food supply chain (Gbashi et al. 2019). Therefore, raising levels of awareness and promoting public education on the health implications of mycotoxins should be addressed especially in African rural settings (Mupunga et al. 2017). This example serves to show the systems level interaction between food safety standards setting in one country/region and then food security and public health issues in another.

Food safety and protection of public health is a worldwide priority. There are several currently available measures aimed at preventing and mitigating food safety incidents, including access to the RASFF database for information. This database is freely available for food business operators. The RASFF system is being used by different stakeholders firstly as an Early Warning Rapid Alert (EWRA) system to mitigate the effects of trading hazardous products, and secondly at the same time, as the basis for risk and vulnerability analysis within the agrifood chain. It is in this latter role where caution should be exercised (Manning & Soon, 2019). Therefore, RASFF may be considered by some stakeholders as both an ex ante and ex post measure for addressing food safety hazards and threats. This means that depending on its role (ex ante or ex post) the rationale for its use will be different. An EWRA can be described as: "a centralised hazard database or electronic network that provides a platform for communication through which member states can alert each other about relevant hazards that may be disseminated (in real time potentially)" (Marvin et al. 2009, p. 347). This definition focusses on the communication aspects of an EWRA system in notifying of potential issues without necessarily providing a quantification of risk. EWRA systems have also been described by the FAO (2013, p. v) as: "systems that predict or detect issues (often outbreaks of disease) of potential serious consequence early on in the epidemiologic curve. The rapid alert portion to the system provides information to the public or key stakeholders in a quick fashion to allow for timely response to the issue identified. These are generally associated with ongoing and known hazards and do not predict potential emerging risks." This definition also suggests that systems of this kind have a notification role and not a role in quantifying risk. Thus, EWRA systems are distinctly different in both aims and derived data from alternative foresight methodologies that seek to determine risk or vulnerability.

Horizon scanning is a forward-thinking methodology that can be generally applied to improve either institutional planning or policy making where the focus is on potential future situations, hazards or opportunities' i.e. horizon scanning tools have properties which allow for forecasting and prediction (FAO, 2013). This shows a clear distinction from between predictive methodological tools and EWRA systems. However, as Bouzembrak and Marvin (2016) suggest, RASFF records can be used to build a Bayesian Network (BN) model for effective prediction of risk and the use of BN can support risk managers in their decision-making in both private and public organisations. Thus, RASFF, as part of a wider predictive model, can play a role in horizon scanning for food safety hazards, including mycotoxins.

In terms of an ex post measure, the RASFF system is a solid basis for surveillance of food safety in Europe. The obligatory participation of the MSs in RASFF strengthens cooperation to improve food supply chain integrity within a hybridised model of public and private actors delivering food policy. However with regards to ex ante mechanisms, there are limitations in extrapolating from the data in the RASFF system to identify levels of risk. Ex ante mechanisms for risk assessment and for risk-based policy therefore need to utilise appropriate datasets, but also recognise their limitations (Manning & Soon, 2019). The argument of this paper is drawn together in Figure 3 showing the interaction between food security, food safety and food governance systems. Food security is affected by affordability, availability, food quality and food safety as highlighted in the Global Food Security Index. Affordability and availability of food is influenced, inter alia, by firstly, the level of food production and the amount of import/export, and then the proportion of food loss or food waste in the supply chain and/or domestic situation. The ability to deliver food in the supply chain that is of a sufficient standard in terms of food safety and food quality will limit product non-compliance and limit the lost calories associated with reuse, rework or rejection. What underpins food safety and food quality and thus food security is effective food governance systems that can manage the food supply chain and also minimise non-compliance, food loss and food waste.

Public regulatory systems sit at the heart of such governance for example the EU RASFF system. Thus, RASFF data should be analysed objectively as regulatory sampling requirements change over time and have a major impact on increased frequency of testing and also the purposive sampling of some foodstuffs originating in selected countries. The impact of aflatoxin sampling policy on RASFF performance shows that there is a need within a risk based regulatory approach for a comprehensive knowledge and level of awareness amongst individuals in organisations driving their strategic and operational decisions using this dataset. Another obstacle hindering analysis of RASFF data is the presence of major variations among MSs in contributions to the RASFF database, thus as some countries are represented far more fully than others, it is difficult to utilise the data for situational (national) risk assessment. Despite the limitations described in this paper, the RASFF data is still a vital basis for future legislative amendments e.g. the EU provisions regarding mycotoxins to protect public health (Ledzion et al. 2010). It is imperative that every EU MSs ensures compliance and appropriate testing regimes in their country, and if in the future private sampling data is utilised in risk-based regulation that there is a clear protocol for how such data will be verified and used by regulators. Some authors propose that some countries are much better gatekeepers of food safety than others (Petróczi et al. 2010; Taylor et al. 2013). The national level anomalies identified in their work include: (a) differences in border detection levels amongst MSs; (b) variance in contributions of individual MSs to the RASFF database; and (c) variance in national arrangements of food control systems (in accordance with "Official Control Regulation"). This creates the possibility for some countries to become a "back door" for allowing some products to enter the common market of the EU with the resultant free movement of food within the EU (Kowalska et al. 2019).

6. Conclusion

Food safety incidents influence the global population and economy; and national arrangements for the safety of food and the integrity of food supply chains. Due to the purposive sampling and major variations among MSs in their contribution to the RASFF database, care has to be taken with using the RASFF data for predictive ex ante measures. The RASFF database is still a valid EWRA and as such a source of information concerning food safety incidents. Such information is crucial for elaboration of the national food control plans and underpinning risk-based regulation. However, RASFF data trends should be interpreted with caution as food law regulation is changing over time and purposive sampling has a major impact on increased checks and thus the potential of detecting non-compliance.

When looking at food security, food integrity and food governance with respect to the global dimension of food standards setting, the RASFF system is a useful mechanism for keeping European citizens informed and safer. Due to the toxicity, carcinogenicity, and negative economic impact of mycotoxin contamination, and as a potential marker for the impact of climate change on food safety and food security, mycotoxins specifically are of academic interest, and can be used as a lens not only to consider food safety but also public health and food security more generally. This study also considers the wider food safety implications of raising market standards in a given trading area for those countries seeking to export to that region. It is important to ensure that raising food safety standards in the supply chain does not lead to public health implications for those communities that are currently seemingly disconnected from such value chains. Negative externalities can arise, such as product dumping of food rejected by the EU in a target country, and the implementation of value chains for the export market leading to lower food safety standards in the food retained for local consumption in the domestic market of the exporting country. This process occurs at a system level rather than a simple linear cause-effect relationship and is worthy of further examination especially as there is an increasingly market focused element to standards setting and governance.

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Table 1. Key search terms in the study (Source: own elaboration)

Primary term	Secondary term
Aflatoxin AND	Contamination
Food AND	Traceability
Food fraud AND	RASFF
Food safety AND	Climate change
	Food security
	Nutrition AND security
	Mycotoxin
	RASFF
	Risk assessment
	Security
Fungal AND	Climate change
	Contamination
	Food security
	Risk assessment
Mycotoxin AND	Climate change
	Contamination
	Health
	Production
	Risk assessment

Table 2. Actions identified in the RASFF database following notification being issued over the period 01/01/2004-31/12/2018 (Source: own elaboration based on (RASFF Portal, 2019, accessed 4 July 2019)).

Action identified in the database	No. of cases (2004-2018)
Current action categories	
Re-dispatch	8784
Withdrawal from the market	5981
Destruction	5016
Official detention	3101
Recall from consumers	2946
Import not authorised	2194
Informing the authorities	1078
Informing the recipient(s)	1016
Retain to the consignor	1016
No action taken	951
Seizure	753
No stock left	665
Placed under customs seals	650
Withdrawal from the recipient(s)	554
Public warning – press release	416
Detained by the operator	313
Physical/chemical treatment	286
Informing the consignor	208
Relabelling	157
Use in feed	55
Use for another purpose than food/feed	35
Removal of offer online	6
Obsolete action categories	
Product recall or withdrawal	1591
Re-dispatch or destruction	920
Prohibition to trade – sales ban	347
Reinforced checking	242
Physical treatment - blanching	238
Destination of the product changed	106
Physical treatment – sorting	103
Destination of the product identified	80
Physical treatment – heat treatment	43
Prohibition to use	8
Physical treatment – freezing	3

Table 3. No. of RASFF notifications *per hazard category* over the period 01/01/2004-31/12/2018 (Source: own elaboration based on (RASFF Portal, 2019, accessed 4 July 2019))

Hazard category in RASFF	**No of cases**	**%**
Mycotoxins	9522	21.95
Pathogenic micro-organisms	5680	13.09
Pesticide residues	3949	9.10
Microbial contaminants (other)	3216	7.41
Food additives and flavourings	2637	6.08
Composition	2609	6.01
Metals	2528	5.83
Foreign bodies	1781	4.10
Adulteration/fraud	1267	2.92
Allergens	1209	2.79
Poor or insufficient controls	1431	3.30
Residues of veterinary medical products	1336	3.08
Organoleptic aspects	819	1.89
Parasitic infestation	652	1.50
Biological contaminants (other)	637	1.47
Novel food	590	1.36
Genetically modified food (GMO)	584	1.35
Environmental pollutants	554	1.28
Natural toxins (other)	371	0.86
Migration	369	0.85
Labelling absent/incomplete/incorrect	364	0.84
Packaging defective/incorrect	361	0.83
Radiation	361	0.83
Not determined/other	174	0.40
Industrial contaminants	121	0.28
Process contaminants	114	0.26
Feed additives	80	0.18
TSEs (Transmissible Spongiform Encephalopathies)	60	0.14
Chemical contaminants (other)	12	0.03

Table 4. No. of RASFF notifications *per food product category* over the period 01/01/2004-31/12/2018 (Source: own elaboration based on (RASFF Portal, 2019, accessed 9 July 2019))

Food product category	All hazards		Hazard category – mycotoxins	
	No of cases	**% of the total number of RASFF notifications**	**No of cases**	**% of the total number of 'mycotoxins hazards'**
Nuts, nut products and seeds	8588	20.36	6931	72.79
Fruits and vegetables	7305	17.32	1235	12.97
Herbs and spices	2494	5.91	757	7.95
Cereals and bakery products	2043	4.84	422	4.43
Cocoa and cocoa preparations, coffee and tea	731	1.73	59	0.62
Confectionary	795	1.88	27	0.28
Non-alcoholic beverages	450	1.07	18	0.19
Other food product/ mixed	366	0.87	17	0.18
Dietetic foods, food supplements and fortified foods	2191	5.19	16	0.17
Milk and milk products	803	1.90	15	0.16
Prepared dishes and snacks	554	1.31	12	0.13
Ices and desserts	100	0.24	4	0.04
Soups, broths and other condiments	586	1.39	4	0.04
Wine	35	0.08	2	0.02
Fats and oils	410	0.97	1	0.01
Fish and fish products	5193	12.31	1	0.01
Honey and royal jelly	271	0.64	1	0.01
Alcoholic beverages	85	0.20	0	0.00
Animal nutrition (obsolete)	3	0.01	0	0.00
Bivalve molluscs and products thereof	994	2.36	0	0.00
Cephalopods and products thereof	465	1.10	0	0.00
Crustaceans and products thereof	1512	3.58	0	0.00
Eggs and egg products	311	0.74	0	0.00
Food additives and flavourings	104	0.25	0	0.00
Food contact materials	545	1.29	0	0.00
Gastropods	43	0.10	0	0.00
Meat and meat products (other than poultry)	2523	5.98	0	0.00
Molluscs and products thereof (obsolete)	177	0.42	0	0.00
Natural mineral water	65	0.15	0	0.00
Poultry meat and poultry meat products	2390	5.67	0	0.00
Water for human consumption (other)	49	0.12	0	0.00
Total	**42181**	**100**	**9522**	**100**

Figure 1. Number of *RASFF notifications related to mycotoxins* over the period 01/01/2004-31/12/2018 including mycotoxins in nuts and seeds and border rejections (Source: RASFF Portal, 2019)

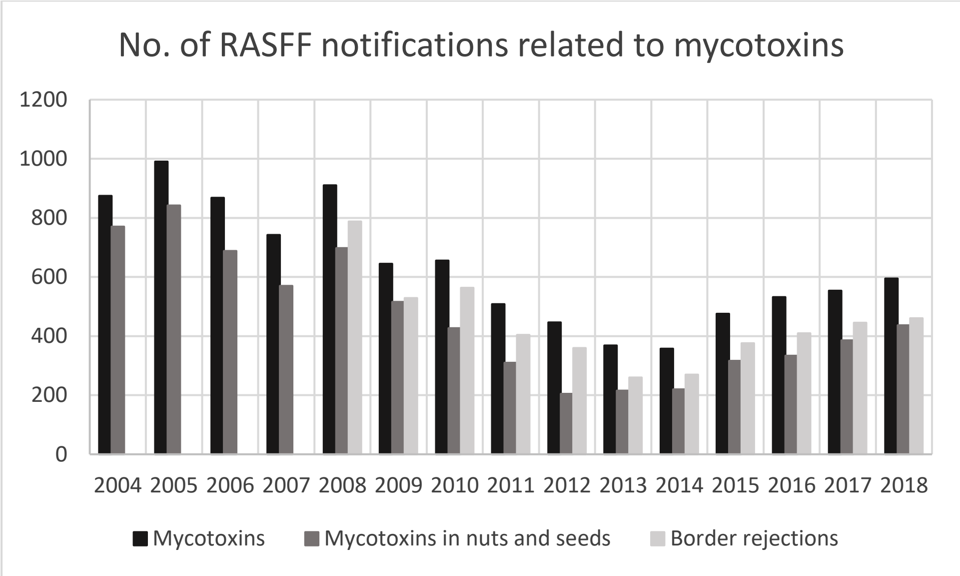
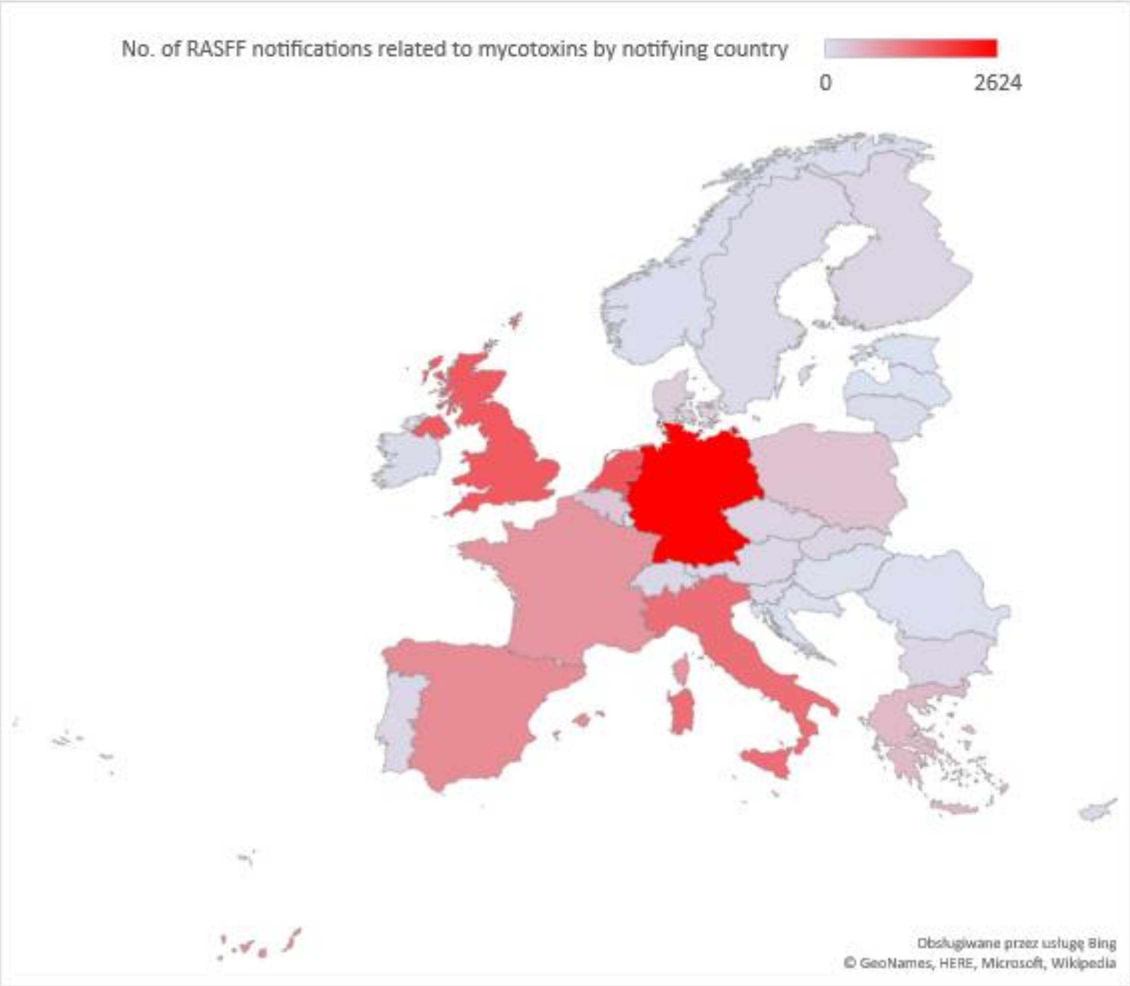


Figure 2. Overview of RASFF notifications related to mycotoxins *by notifying country* over the period 2004-2018 (Source: RASFF Portal, 2019)



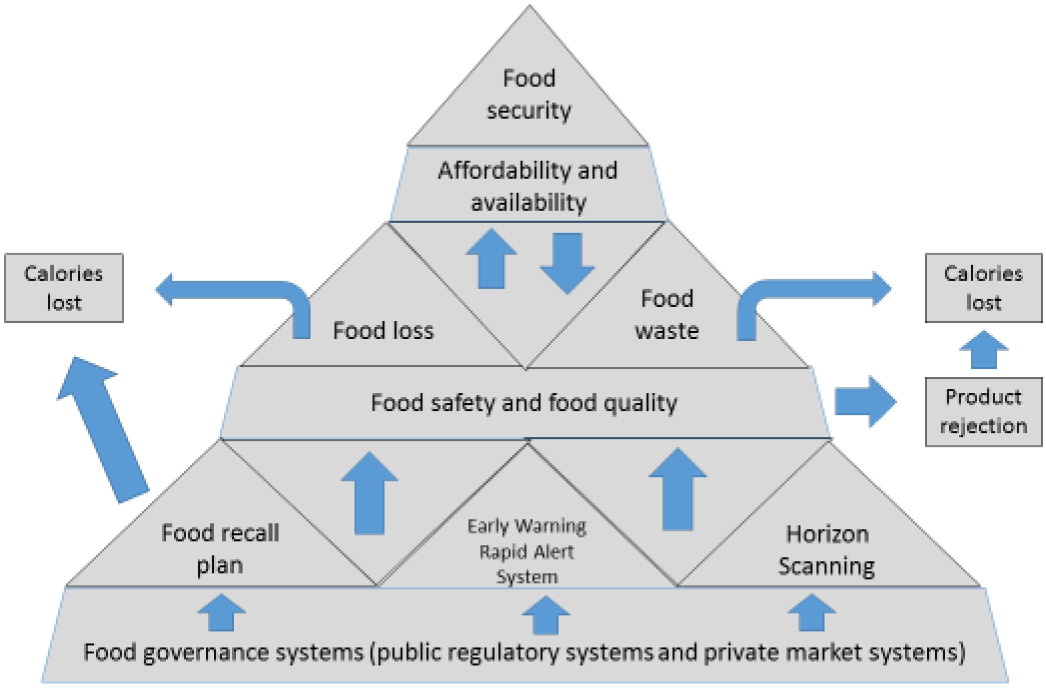


Figure 3. Interaction between food governance systems, food safety and food security (Source: own elaboration)