Food Control 96 (2019) 479–487

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Analysis of RASFF notifications on food products contaminated with *Listeria monocytogenes* reveals options for improvement in the rapid alert system for food and feed

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ARTICLE INFO

Keywords:
European food safety
RASFF
Reporting
Notification
Listeria monocytogenes
Contamination
Germany

ABSTRACT

Tools for supranational communication of food safety risks like the European Rapid Alert System for Food and Feed (RASFF) play an increasingly important role in consumer protection along global supply chains. They allow for a coordinated response to emerging public health threats such as *Listeria monocytogenes* (*Lm*), the causative agent of the foodborne disease listeriosis. As a result of disease severity and the rising number of human listeriosis cases in Germany since 2011, an effective reporting system on *Lm* contamination in food products has become more crucial than ever to counteract this trend. Therefore, we analysed RASFF notifications on food products contaminated with *Lm* and distributed in Germany, 2001 to 2015, assessed trends in the reported data and addressed options for improvement in the current notification system.

In RASFF *Lm* notifications concerning Germany from 2001 to 2015, there was often a discrepancy between country of origin and notifying country, indicating that the food safety risk was not always recognised at the earliest possible time point of the product's life span. In addition, in our dataset, most *Lm* notifications were driven by official controls when the respective product was already on the market. However, starting in 2005, there was an increasing trend for company's own checks. This trend of making food manufacturers accountable for the detection and notification of contaminated products in the production line is a first step into the right direction as it might help to reduce the number of contaminated food products that enter the market.

Besides its function as a reporting tool, the RASFF may also facilitate the identification of risk factors associated with *Lm* contamination so that the problem can be tackled at its root. Unfortunately, information about packaging and food processing was only mentioned in a minority of *Lm* notifications. Hence, risk factors cannot be easily identified. In the future, a comprehensive database including additional metadata together with the RASFF notification should be established.

Although a solid basis for the surveillance of *Lm*, there is still room for improvement in RASFF to speed-up the flow of information. This might help to identify food safety risks that can be harmful to European consumers much faster, more effectively prevent the spread of risk bearing food products and consequently reduce the burden of listeriosis.

1. Introduction

Globalisation of food trade opens the door for the spread of foodborne infectious diseases. In 2016, a total of 2536 human listeriosis cases were reported in the European Union (EU), corresponding to an incidence rate of 0.47 per 100,000 population (EFSA & ECDC, 2017). Although comparably rare (e. g. incidence rate for salmonellosis 21.2 per 100,000 population), listeriosis has the highest hospitalisation rate of all foodborne zoonoses under EU surveillance (EFSA & ECDC, 2017). Together with its high case fatality rate (16.2% in 2016), it is rightly considered a major EU-wide public health concern (EFSA & ECDC, 2017). The most affected groups are elderly people, immunocompromised patients and pregnant women where the disease is often associated with severe clinical manifestations including

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https://doi.org/10.1016/j.foodcont.2018.09.033
Received 6 July 2018; Received in revised form 25 September 2018; Accepted 26 September 2018
Available online 04 October 2018
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septicaemia, meningitis and spontaneous abortion (Schlech & Acheson, 2000).

The causative agent of listeriosis is *Listeria monocytogenes* (*Lm*). The saprophytic bacterium is widely distributed in the environment and can be found in plants, soil, sewage and livestock (Farber & Peterkin, 1991). It is highly adaptable and able to cope with a wide range of environmental stress factors, including temperatures from 0 to 45 °C, a pH range from 4.1 to 9.6 and salt concentrations up to 10% *w/v* NaCl (Lungu, Ricke, & Johnson, 2009; Milillo et al., 2012). These properties allow the pathogen to survive even in preserved foodstuffs stored in cold chains of modern food production and retail systems, thereby constituting a serious problem in food industry.

The vast majority of human listeriosis cases are supposed to be foodborne (Swaminathan & Gerner-Smidt, 2007). There are two ways in which *Lm* can find its way into the food chain: either via primary contamination of raw animal products or via cross-contamination during food processing. In the latter case, niche adaptation of the pathogen, insufficient hygiene measures in food processing plants and as a consequence persistence of *Lm* play an important role (Carpentier & Cerf, 2011). Especially in ready-to-eat (RTE) products, per definition "food intended […] for direct human consumption without the need for cooking or other processing effective to eliminate or reduce to an acceptable level micro-organisms of concern" (European Commission, 2005), *Lm* contamination poses a risk to human health. Therefore, Regulation (EC) 2073/2005 was implemented in 2005 to define microbiological food safety criteria which also apply for *Lm* in RTE foods (European Commission, 2005). Typical examples of such RTE products are deli meat, salads, sandwiches and cheese. If intended for infants or special medical purposes, *Lm* has to be absent in 25 g of the RTE product placed on the market during its shelf life. For all other target groups, during shelf life, a limit of 100 CFU/g applies. However, a further distinction is made between products that are, or are not able to support growth of *Lm*. If the RTE product is able to support growth of *Lm*, at the time before the food has left the immediate control of the food business operator who has produced it, absence of *Lm* in 25 g RTE product is mandatory as well. An exception only applies when the food business operator shows that the limit of 100 CFU/g is not exceeded during shelf life (European Commission, 2005). Despite these well-defined criteria, listeriosis infections still show an alarmingly increasing trend (ECDC, 2016).

In order to manage interconnected food safety issues arising from international trade, the Rapid Alert System for Food and Feed (RASFF) was initiated in 32 countries of the EU and the European Economic Area (EEA) (European Commission, 2017a). Based on Regulation (EC) 178/2002 and Regulation (EC) 16/2011, the RASFF is intended to provide information on food-related, serious, direct or indirect risks to human health to allow an immediate and coordinated response to emerging threats (European Commission, 2002, 2011). RASFF notifications reported by a national food safety authority are verified by the European Commission (EC) as the manager of the system and disseminated to contact points of network members. Affected products can then be traced back and measures can be taken. There are three main types of RASFF notifications: alert, information and border rejection notifications (European Commission, 2017b). Border rejection notifications concern products rejected at the external borders of the EU/EEA, whereas the other two notification types relate to products inside the EU/EEA. Alert and information notifications mainly differ in the speed and type of reaction that is necessary after release of the notification: alert notifications do, whereas information notifications do not require rapid action in other RASFF member countries. Regardless of the notification type, every notification is based on the identification of a risk to human health. Since implementation of Regulation (EC) 16/2011 in 2011, a further subdivision of information notifications into "information notification for follow-up" and "information notification for attention" was introduced (European Commission, 2011). An "information notification for follow-up" is related to a product that is or may be placed on the market in another country and hence similar to an alert notification, although not requiring rapid action. An "information notification for attention" is released if the product is only present in the notifying country, if it is no longer on the market or if it has not even been placed on the market.

In our study, we analysed RASFF notifications on pathogenic micro-organisms (PMF) with a special focus on *Lm*, associated with contaminated food products. Based on RASFF *Lm* notifications affecting Germany, 2001 to 2015, we assessed trends in the reports available and tried to identify shortcomings in the current notification system. Although a solid basis for the surveillance of *Lm*, there is still room for improvement in the RASFF to allow for a more detailed risk assessment and earlier reaction to improve consumer safety and finally reduce the burden of listeriosis.

2. Methods

Data were extracted from the RASFF portal (European Commission, 2017b). Search criteria for RASFF PMF notifications with involvement of Germany were "Notified from: 01/01/2001", "Notified till: 31/12/2015", "Product type: food", "Category: pathogenic micro-organisms" and "Country: Germany (DE)" (query from 20/06/2016, last update 12/06/2017). Search criteria for RASFF *Lm* notifications independent of the country involved were "Notified from: 01/01/2001", "Notified till: 31/12/2015", "Category: pathogenic micro-organisms" and "Hazard: *Listeria monocytogenes*" (query from 04/04/2016, last update 12/06/2017). As the years 2001–2003 contained incomplete data on origin and distribution of the contaminated food products, the whole datasets for this period were excluded from analysis. Data on RASFF *Lm* notifications in Germany (period 2001 to 2015) were extracted from the German Federal Office of Consumer Protection and Food Safety (BVL) database using an SQL-based algorithm and completed with information from the original RASFF pdf-documents.

Data selected from all three datasets were transferred to Microsoft Excel 2010 (Microsoft Corp., Redmond, USA) to create descriptive statistics, including frequency distributions (Pivot tables, with filtering). The main filter categories took into account a country's role in notification. A country can publish a notification (notifying country), it can be affected by a notification if the product is distributed in the country (affected country) or it can be country of origin of a product. Involvement of a country is stated if at least one of these three conditions is met.

The script for generation of the Chord diagram (Fig. 3) is available at https://github.com/mattflor/chorddiag.

3. Results

3.1. RASFF PMF notifications, involving Germany

Between 2004 and 2015, 1303 PMF notifications with involvement of Germany were published. Of these, 71% (n = 935) were notified by four countries: Germany (29%, n = 381), Denmark (19%, n = 249), France (13%, n = 169) and Italy (10%, n = 136). A total of 719 notifications (55%) were related to products distributed in Germany, while 455 (35%) were related to products exported from Germany without being distributed in Germany. The remaining 129 notifications (10%) were related to products where Germany was involved in the notification process, but neither as country of origin nor as affected country. In 381 PMF notifications (29%) Germany was notifying country, country of origin in 562 notifications (43%) and affected country in 719 notifications (55%). The number of PMF notifications with Germany as notifying country or country of origin was fluctuating from 2004 to 2015 (18–48 notifications per year as notifying country, 31 to 74 notifications per year as country of origin), as well as the share of *Lm* notifications of all PMF notifications (4–31% per year with Germany as notifying country, 6–29% per year with Germany as country of origin).

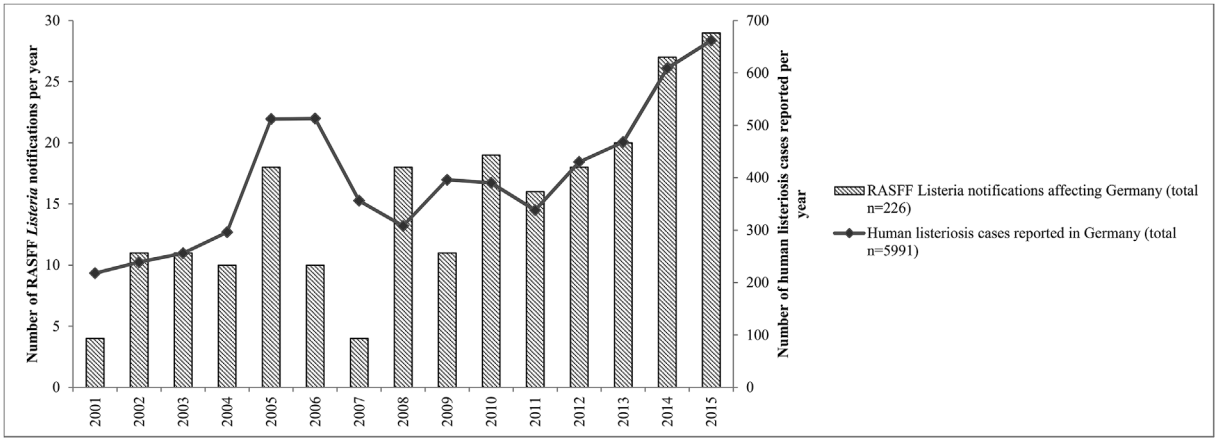

Fig. 1. RASFF *Listeria monocytogenes* notifications for food products affecting Germany (dashed) and human listeriosis cases officially reported in Germany (black), 2001–2015. As a result of the fact that human listeriosis cases cannot be linked to a certain RASFF notification, no reliable causal relationship can be attested. Still, an increasing trend can be seen in both datasets.

In contrast to that, PMF notifications affecting Germany have been increasing since 2011 from 54 to 111 per year in 2015. However, the proportion of *Lm* notifications in these years remained relatively stable between 24 and 31%.

3.2. RASFF Lm notifications

Among all European PMF notifications from 2004 to 2015, 968 concerned *Lm* (*Lm* notifications). France and Italy were notifying countries in almost half of these notifications (France 25%, n = 242; Italy 24%, n = 235), followed by Germany (6%, n = 62), the Netherlands (5%, n = 45), Spain (5%, n = 44) and Poland (4%, n = 43). In 27% (n = 266) of cases, Italy was affected, in 26% (n = 254) of cases, it was France. Germany, Belgium and the Netherlands were among the affected countries in 20% (n = 198), 15% (n = 146) and 11% (n = 106) of notifications, respectively.

3.3. RASFF Lm notifications, involving Germany

From 2001 to 2015, a total of 312 Lm notifications with involvement of Germany were published. The number of *Lm* notifications with Germany as country of origin (total n = 98, 31%) ranged between 2 and 15 notifications per year. Out of these notifications, 73 (74.5%) concerned products of German origin, meant for export only. Products mentioned in 16 notifications (16.3%) were distributed both in Germany and abroad, whereas 9 notifications (9%) were related to

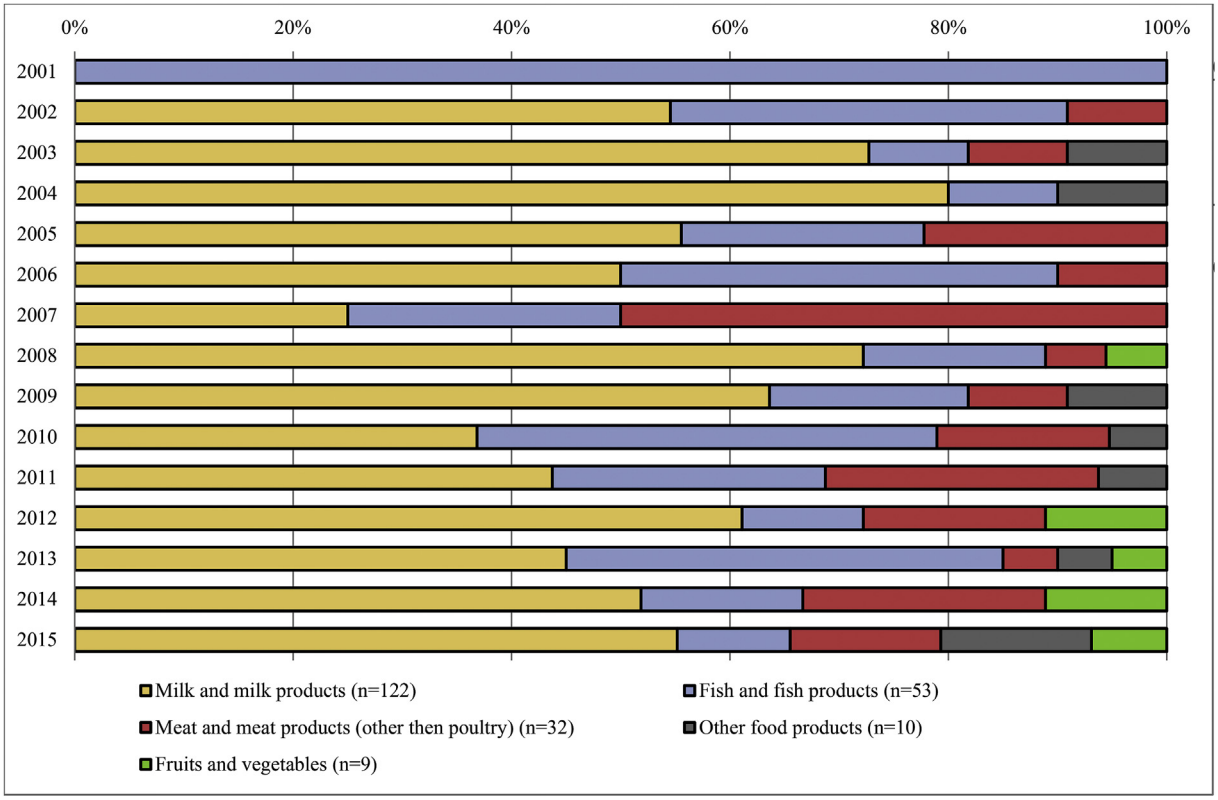

Fig. 2. RASFF *Listeria monocytogenes* notifications for products affecting Germany (n = 226), 2001–2015. Percentages of notifications related to a product category (simplified categories) per year of notification are shown.

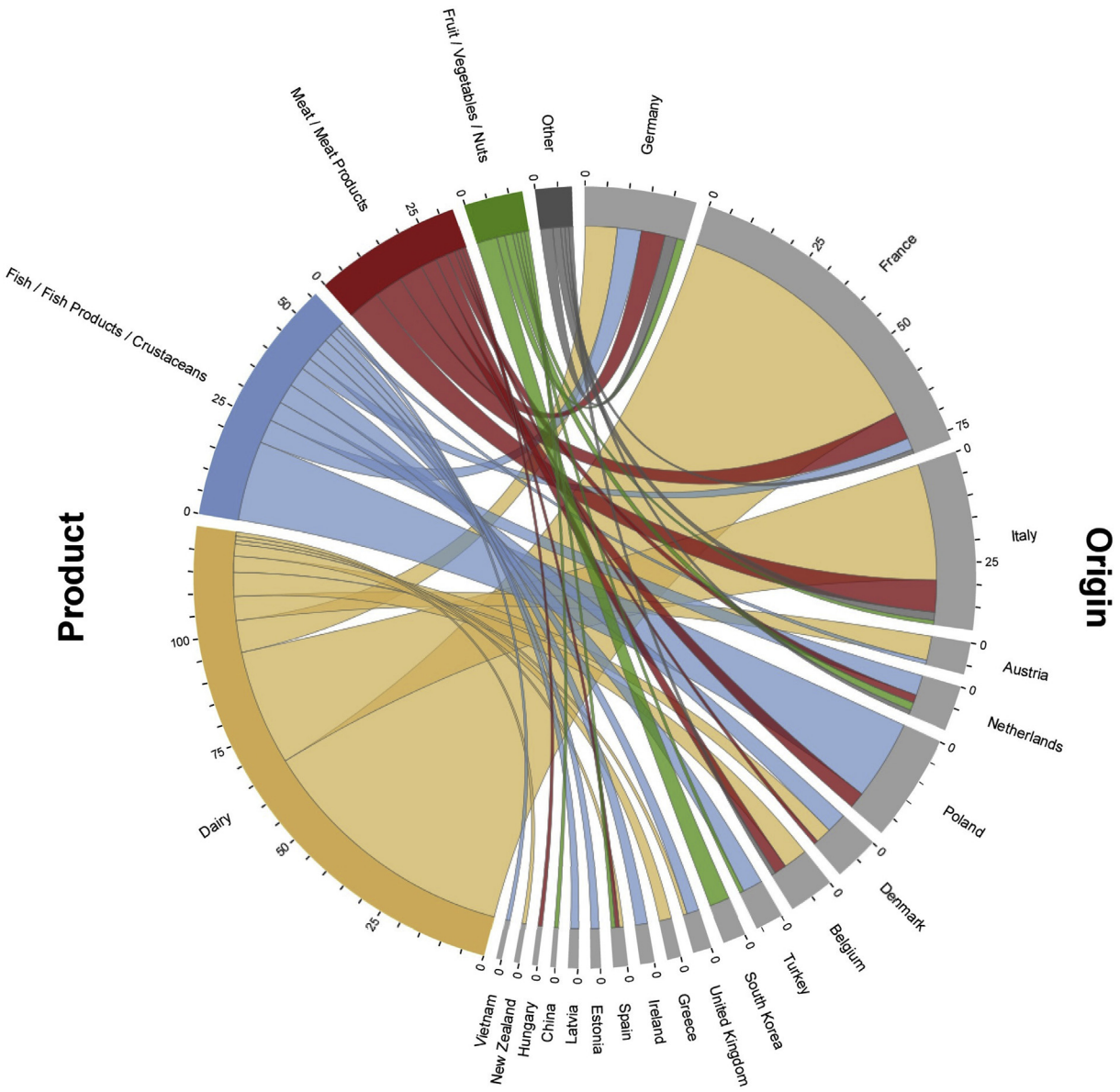

Fig. 3. Product categories of RASFF *Listeria monocytogenes* notifications affecting Germany, by country of origin, 2001–2015. Arc lengths on the outer circle are proportional to the number of notifications of a product category or to the number of notifications with a specific country of origin.

products of German origin, only distributed in Germany. The proportions per year were variable from year to year, but consistently with a main focus on exported products.

3.4. RASFF Lm notifications, affecting Germany

At total of 226 Lm notifications were published between 2001 and 2015 for products affecting Germany. For 33% (n = 75) of these notifications, Germany was the notifying country, followed by France (30%, n = 68), Italy (9%, n = 20) and Austria (6%, n = 13). In Germany, notifications were primarily made in two German Federal States: Baden-Württemberg (33%, n = 25) and Hesse (17%, n = 13). *Lm* notifications affecting Germany have been increasing since 2011, culminating in 29 notifications in 2015. Likewise, the number of human listeriosis cases reported has been increasing in Germany since 2011, reaching a maximum of 662 cases in 2015 (SURVSTAT@RKI 2.0) (Fig. 1).

Products affecting Germany had their origin in 15 EU member states and five non-European countries. Eight notifications were related to multiple countries of origin. Products from four countries accounted for 73% (n = 165) of the notifications: France (34%, n = 77), Italy (17%, n = 39), Germany (11%, n = 25) and Poland (11%, n = 24). *Lm* notifications for products of French origin were mainly notified by France (61 of 77 notifications, 79%). Italian, Polish and German products were mainly notified by Germany (21 of 39, 54%; 14 of 24, 58%; 22 of 25, 88%, respectively) (Table 1).

3.4.1. Notification basis

Most of the 226 *Lm* notifications affecting Germany between 2001 and 2015 were based on official controls on the market (54%, n = 122). From these, most were notified by Germany (45%, n = 55), followed by France (18%, n = 22) and Italy (12%, n = 15). For Germany, Italy and also Austria, the overall percentage of notifications based on official controls on the market clearly exceeded that of notifications based on company's own check (55 based on official controls *versus* 16 based on company's own check, 15 *versus* 4 and 10 *versus* 2, respectively). In contrast to that, notifications from France were mainly due to findings in company's own checks (22 based on official controls *versus* 44 based

Table 1
RASFF *Listeria monocytogenes* notifications affecting Germany, 2001–2015, by country of origin and country of notification.
Note: For eight notifications, there was more than one country of origin (multiple attributions).

Country of origin	Country of notification																Sum
	AT	BE	CZ	DE	DK	EE	ES	FR	GR	IE	IT	LU	NL	PL	UK	NO	
AT	6			1													7
BE		6		1				2					1				10
DK				1	5			1			2					1	10
EE						2											2
FR	1			8				61			2	1	1			3	77
DE	1		1	22				1									25
GR				2					1								3
HU														1			1
IE								1		2							3
IT	3			21			1	2			11					2	40
LV				1							1						2
NL	3	1		4					1				1				10
PL				14				1			1			8			24
ES				2											1		3
UK				1							2				1		4
CN		1															1
NZ													1				1
KR									1				4				5
TR				2									4				6
VN											1						1
Sum	14	8	1	80	5	2	1	69	3	2	20	1	12	9	2	6	

AT-Austria, BE-Belgium, CZ-Czech Republic, DK-Denmark, EE-Estonia, FR-France, DE-Germany, GR-Greece, HU-Hungary, IE-Ireland, IT-Italy, LU-Luxembourg, LV-Latvia, NL-Netherlands, NO-Norway, PL-Poland, ES-Spain, UK-United Kingdom, CN-China, NZ-New Zealand, KR-South Korea, TR-Turkey, VN-Vietnam.

on company's own check). Overall, company's own check contributed to 42% (n = 95) of all *Lm* notifications affecting Germany, 2001 to 2015. While the number of notifications based on official controls on the market has been fluctuating between 3 and 15 per year from 2001 to 2015, notifications based on company's own check first appeared in 2005 from which on they showed an increasing trend (3 in 2005 to 17 in 2015). In five cases (one per year from 2008 to 2011, and another one in 2014), food poisoning was mentioned as notification basis. In three notifications, a RASFF notification was issued as a result of an official control in a non-EU member state (one in 2011, two in 2012).

3.4.2. Affected food categories

The majority of *Lm* notifications affecting Germany, 2001 to 2015, concerned milk and milk products (54%, n = 122), followed by fish and fish products (23%, n = 53) and meat and meat products other than poultry (12%, n = 26). Within the milk and milk products, the majority of notifications were related to soft cheese (n = 82, 67% of milk and milk products) (Table 2). While notifications based on company's own check mainly concerned milk and milk products (63%, n = 60), a large number of notifications based on official control on the market were related to fish and fish products (31%, n = 38). From 2001 to 2015, the proportion of food categories complained in *Lm* notifications every year varied, shifting the main focus between milk and milk products, fish and fish products and meat and meat products other than poultry (Fig. 2). In the product category milk and milk products, 54% (n = 66) of *Lm* notifications were related to products from France. For 38% (n = 20) of the notifications concerning fish and fish products Poland was stated as country of origin. For the meat and meat products, the country of origin was very diverse (Fig. 3).

3.4.3. Involved companies

Products of 30 companies (from a total of 176 companies) were the cause of two or more notifications between 2001 and 2015. Twelve out of these companies were mentioned in notifications in two separate years, two companies caused notifications in three different years and one company was associated with notifications in six different years. With respect to milk and milk products, France had the highest number of companies (n = 10) involved in two or more notifications, totalling 25 notifications. Concerning the category of fish and fish products, 17 notifications were associated with two Polish companies.

Table 2
RASFF *Listeria monocytogenes* notifications for products affecting Germany, 2001–2015, by food category.

Product category	Total
Milk and milk products	122
soft cheese	82
unspecified	12
fresh cheese	10
semi-soft cheese	8
semi-hard cheese	6
hard cheese	2
sour milk cheese	2
Fish and fish products	53
Meat and meat products (other than poultry)	26
Fruits and vegetables	9
Poultry meat and poultry products	6
Prepared dishes and snacks	4
Cereals and bakery products	2
Crustaceans and products thereof	1
Nuts, nut products and seeds	1
Soups, broths, sauces and condiments	1
Other food product/mixed	1

3.4.4. Notification types

Lm notifications affecting Germany were classified as “alert notification” in 175 of 226 notifications (77%), with the majority of alerts issued by France (37%, n = 65) and Germany (23%, n = 41). The remaining 51 notifications (23%) were information notifications. Due to a lack of further subdivision before 2011, 31 of them were only classified as “information notification”. After the subdivision of the category in 2011, 13 notifications were classified as “information for attention” and 7 “information for follow-up”. Germany was responsible for the majority of the three kinds of information notifications (between 57 and 71%).

3.4.5. Additional metadata

3.4.5.1. Packaging type and slicing category. Information for example

Table 3
RASFF *Listeria monocytogenes* notifications for products affecting Germany, 2001–2015, by food category and stabilisation category or raw/non raw category; for other product categories data are missing (unspecified).

Food category	Total	Metadata category
Milk and milk products	122	
raw	49	raw/non-raw
non-raw	12	
unspecified	61	
from raw milk	49	stabilisation
from pasteurised milk	10	
salted	5	
from sour milk	2	
from raw and pasteurised milk	1	
unspecified	55	
Fish and fish products	53	
raw	48	raw/non-raw
unspecified	5	
smoked	39	stabilisation
graved	2	
salted	2	
graved, marinated	1	
marinated	1	
smoked, salted	1	
unspecified	7	
Meat and meat products (other than poultry)	26	
raw	9	raw/non-raw
non-raw	3	
unspecified	14	
cooked	3	stabilisation
smoked	2	
dried	1	
fermented	1	
salted	1	
unspecified	18	
Poultry meat and poultry products	6	
non-raw	1	raw/non-raw
unspecified	5	
cooked	1	stabilisation
unspecified	5	
Crustaceans and products thereof	1	
non-raw	1	raw/non-raw
cooked	1	stabilisation

about packaging or food processing was only provided for a minority of *Lm* notifications affecting Germany. Data on packaging type was available for 16% (n = 37) of notifications, information about the slicing category in 23% (n = 51) of notifications. In the category fish and fish products at least for 20 of 52 notifications (38%), the packaging type was specified. Among these, 15 products (75%) were packaged under vacuum conditions. For the same category, slicing information was available for 34 (65%) notifications. These products were mainly filleted (50%, n = 17) or sliced (38%, n = 13). For meat and meat products other than poultry, information on slicing category was available for only 5 out of 26 notifications (19%), with four products sliced (80%) and one cut (20%).

3.4.5.2. Raw/non-raw status and stabilisation category. The majority of *Lm* notifications affecting Germany concerned raw products (47%, n = 107), but a large proportion of notifications lacked information (45%, n = 101) (Table 3). The raw/non-raw status can be differentiated from the stabilisation category of a product. As in some notifications, not both of the corresponding metadata fields were filled, information could not be combined. *Lm* notifications for milk and milk products mainly concerned the stabilisation category “from raw milk” (42%, n = 49). However, in 45% (n = 55) of notifications in this product category, the stabilisation method was not specified. Within the fish and fish products, smoking was the most reported stabilisation category (73%, n = 38). In this category, only for 14% of notifications (n = 7), no specification was made.

3.4.5.3. Storage temperature, best before date and microbiological threshold values. The majority of food products for which information on the storage temperature was available (specifications made in 66% of the 226 *Lm* notifications, n = 149) were chilled. For about 70% of the chilled products of each category, additional quantitative information on *Lm* contamination was available. Among these, 57–61% exceeded the microbiological limit value of 100 CFU/g. Only in five products, sampling was carried out after the best before date whereas 154 (68%) contaminated products were sampled before. For 73% (n = 113) of the products sampled before the best before date, quantitative information on *Lm* contamination was available. In 83% out of these cases (n = 94), the microbiological threshold value of 100 CFU/g was exceeded. For those products that were sampled after the best before date, quantitative information was available for three of the five samples. Two exceeded the limit, whereas one was below.

4. Discussion

4.1. RASFF notifications - Main players and development over time

Four countries were the main players in releasing PMF notifications involving Germany between 2004 and 2015: Germany, Denmark, France and Italy. Germany, France and Italy are among the most populated EU countries and also among those with the highest gross domestic product at market prices (German Federal Statistical Office, 2017). This could be part of the explanation of their RASFF notification activities, but trade relations and also country-specific differences in awareness and resulting efforts in the national food surveillance systems might play an important role. Furthermore, the market shares of RTE products for the different countries are likely to influence their notification rates.

PMF notifications affecting Germany have been increasing since 2011. Interestingly, the proportion of *Lm* notifications remained relatively stable. Nevertheless, due to the increasing number of PMF notifications, also more *Lm* notifications affecting Germany were published from 2011 to 2015. Although possibly caused by a real increase in microbial food contamination, in times of overall advances in microbiological food surveillance, this trend could also be a result of an increase in awareness, efforts and reporting.

4.2. Notifying country versus country of origin - Discrepancies and possible solutions

Independent of the country affected, France and Italy were the notifying countries in about half of the *Lm* notifications between 2004 and 2015. France and Germany almost covered the total number of notifications dealing with products of French and German origin, respectively (France notifying in 61 of 77 notifications, Germany notifying in 22 of 25 notifications; Table 1). For several other countries, a greater imbalance was observed. Italy and Poland were country of origin in more notifications than notifying country with respect to all notifications on products of Italian and Polish origin, respectively (Italy notifying in 10 of 39 notifications, Poland notifying in 8 of 24 notifications; Table 1). A satisfactory RASFF activity is reflected by the fact that a country does not only recognise contamination in products produced in the respective country but also in products shipped from other EU/EEA countries. If country of origin and notifying country match to a large extent, hazards could possibly be published at an earlier time of the product's life-cycle, thereby more effectively preventing the spread of risk-bearing foodstuffs.

Out of all *Lm* notifications affecting Germany, 2001 to 2015, only in 33% of notifications, Germany itself was the notifying country. In 30%, the notification was released by France and in 9% of cases by Italy. This could be related to the fact that products mentioned in the corresponding *Lm* notifications in 34% of cases had their origin in France and in 17% of cases in Italy. In contrast to that, only a small proportion of

notifications (11%) were related to products of German origin. While *Lm* notifications for products of French origin were mainly reported by France; Italian, Polish and German products were mainly notified by Germany. This probably explains the divergence between the proportion of notifications notified by Germany and the proportion of affected products of German origin. Again, this shows the interconnectedness of EU countries in means of food safety issues through trade and underlines the value of a comprehensive early-warning system like the RASFF. However, it also demonstrates that notification activities within the EU could benefit from harmonisation. According to Regulation (EC) 882/2004, it is up to the EU member states to ensure that official controls are carried out regularly, on a risk basis and with appropriate frequency (European Commission, 2004). Hence, surveillance activity is regulated by individual country legislation and thereby subject to variations. To achieve higher food safety standards, harmonised and sometimes enhanced national surveillance activity might be needed.

A further limitation to harmonisation lies in the Regulation (EC) 2073/2005 on microbiological criteria for foodstuffs. This regulation defines criteria for *Lm* in RTE food products (European Commission, 2005). These criteria differentiate between food products that are unable or able to support growth of *Lm*. If the food product is unable to support growth of *Lm*, bacterial concentration in products placed on the market must not exceed 100 CFU/g during shelf life. For food products that are able to support growth, this applies as well. However, in this latter case, an additional, stricter criterion is also valid, namely absence of *Lm* in 25 g before the food product has left the final control of the food business operator who has produced it. These specifications do not leave room for interpretation. However, there is no strict consensus on the classification of foodstuffs as "able to support growth" or "unable to support growth". Either a pH $<$ 4.4 and $a_w < 0.92$ or a combination of pH $<$ 5.0, $a_w < 0.94$ and NaCl $>$ 16% are generally considered as intrinsic food conditions that do not support growth (Buchanan, Gorris, Hayman, Jackson, & Whiting, 2017). For all other categories, however, scientific proof is needed to verify that the microbial limit of 100 CFU/g will not be exceeded during shelf life (European Commission, 2005). Unfortunately, limited data exist on growth rates of *Lm* in different foodstuffs, making it sometimes difficult to provide evidence for a very specific product without performing a time-consuming shelf life study (U. S. Food and Drug Administration, 2014). Therefore, in the case of sufficient justification, data for comparable foodstuffs can be used as a reference. In this way, however, a little scope for interpretation may be introduced for the decision whether a very specific product does or does not enable *Lm* growth and as a consequence whether contamination is considered as hazardous or not. Accordingly, different country specific interpretations may lead to different RASFF notification activities. The most comprehensive way to deal with this limitation could be an overall zero tolerance limit in RTE food products like already active in the USA (Chen, Ross, Scott, & Gombas, 2003). However, this strategy has its weaknesses as well. Besides the considerable expense associated with its implementation, its advantages over the EU-wide 100 CFU/g limit are controversial (Chen et al., 2003; Tompkin, 2002). In a microbial risk assessment performed by Chen and colleagues for example, the risk reduction potential of a non-zero strategy outperformed that of the zero tolerance one (Chen et al., 2003). Overall, a compromise has to be pursued to further standardise recognition of *Lm*-related food safety issues and to achieve the highest possible reduction of foodborne listeriosis infections.

4.3. Notification basis - "The sooner, the better."

Most of *Lm* notifications affecting Germany, 2001 to 2015, were based on official controls on the market, followed by company's own checks. In our dataset, notifications following company's own checks did not appear before 2005. This is in line with implementation of Regulation (EC) 2073/2005 in 2005 as a consequence of the White Paper on Food Safety published by the European Commission in 2000 (European Commission, 2000, 2005). As a reaction to several food safety crises in the 1990s, this White Paper aimed to revolutionise food safety. One key vision was a complete recast of the different control requirements in order to ensure that all links in the food production chain are covered by effective controls. As a result, more responsibility was assigned to food business operators (European Commission, 2005). Among other things, they were obliged to appropriately test against the defined microbiological criteria, inducing the sudden appearance of company's own checks in 2005. Since then, they showed an increasing trend. This is very laudable as, in contrast to official controls on the market, company's own checks usually detect a microbiological contamination before the product is sold on the market or even earlier in the product's life-cycle. As a result, the risk of a consumer to eat foodstuff concerned is far lower as when a control happens when the product is already on the market. In many cases where quantitative information was available on *Lm* contamination in a RASFF notification, the threshold value of 100 CFU/g (European Commission, 2005) was exceeded even in chilled products and also before the best before date showing the importance and also the value of the early-warning system. If timely intervention measures like product recalls are taken, public health risks can efficiently be decreased. While for example in Germany, Italy and Austria official controls on the market prevail, the majority of notifications from France are a result of company's own checks. Overall, a promising trend can be observed as, since 2013, the number of company's own check based notifications per year exceeds that based on official controls on the market. Hopefully, this development will help in the long run to ameliorate the quality of food products that enter the market and thus help to prevent foodborne infections.

4.4. RASFF notifications types for risk assessment

A large majority of *Lm* notifications affecting Germany between 2001 and 2015 were alert notifications where rapid action by other RASFF members was required. This highlights the importance of an EU-wide, fast communication system like the RASFF to quickly and comprehensively manage the risk posed by a contaminated food product. However, information notifications also play an important role. "Information notifications for follow-up" for example are similar to alert notifications. The only difference is the status of reaction of all countries involved at the time of publication of the RASFF notification. In their case, the report was released after measures had been taken. Even though not requiring rapid action, they report about a risk for the consumer that occurred and concerned multiple EU countries, hence providing valuable information on the overall prevalence of *Lm* contamination. The same is true for "information notification for attention". This type of notification is probably the weakest concerning the need for rapid action as distribution of the concerned product was restricted to one country, the product is no longer on the market or has not even been placed on the market. Still, a potential risk for consumers was identified. In conclusion, although only alert notifications might use the entire power of the EU-wide communication tool RASFF, also information notifications essentially contribute to a comprehensive risk assessment and are therefore an indispensable and valuable part of RASFF notification activities.

4.5. Identification of risk factors for Lm contamination

The majority of *Lm* notifications affecting Germany, 2001 to 2015, concerned milk and milk products followed by fish and fish products and meat and meat products other than poultry. This goes along with the fact that products from these three categories were also reported as causative in 59% of the foodborne outbreaks caused by *Lm* in the EU/EEA between 2008 and 2015 (EFSA Panel on Biological Hazards, 2017). Probably as a result from the risk-based character of the RASFF notification system, these categories were associated with most of the *Lm* notifications.

In the category of milk and milk products, the majority of notifications were related to products from France, whereas a large share of concerned fish and fish products originated from Poland. This is also reflected in the involvement of specific companies from the two countries into notifications. Regarding the market shares of France and Poland for products of these two categories, this is not surprising. While France had the highest number of companies involved in notifications for milk and milk products, two Polish companies were involved in 17 notifications in the category of fish and fish products. Together with the fact that some companies were associated with notifications over several years, this proves the stability of *Lm* contamination in various production plants. Undetected sources of the bacterium may persist for years and can consequently lead to repeated re-contamination of foodstuffs (Carpentier & Cerf, 2011). Although identification and notification of contaminated food products are relevant to take adequate countermeasures and to protect consumer health, this approach will be not sufficient to improve food safety in the long run. Reporting alone will not suffice to contain *Lm* contamination of foodstuffs and thus prevent human infections. In order to really address the problem, its root has to be addressed. On the one hand, this could be achieved through improved hygiene measures, for example using the seek-and-destroy strategy (Butts, 2003; Malley, Butts, & Wiedmann, 2015). Persistent *Lm* strains in food processing plants have been identified as the most common post processing contaminants (Tompkin, 2002). Hence, the seek-and-destroy strategy aims to identify harbourage sites and niche locations, where bacterial strains withstand cleaning and sanitation measures. Shortly, it combines different disassembly stages of equipment with repeated sampling and sanitation measures (usually flood or heat) until proven elimination of contamination (for detailed description see (Malley et al., 2015)). On the other hand, also overall more strict internal controls could help to tackle the problem of *Lm* contamination at its root. In this context, the increasing quality of company's own checks is a first step in the right direction.

Cross-contamination during the processing is one of the most important reasons for *Lm* contamination of foodstuffs. Hence, in order to identify specific entry routes of *Lm* into the food chain, additional information on product properties and additives would be desirable. Unfortunately, information for example about packaging or food processing was only provided for a minority of RASFF notifications. For instance, the packaging category of a product could be interesting to know, because different atmospheres (vacuum, modified, normal etc.) might selectively support bacterial growth thereby giving an advantage to *Lm* proliferation (Tsigarida, Skandamis, & Nychas, 2000). Furthermore, the slicing category could be a valuable type of information, as instruments used in this processing step are suspected to be a common source of contamination (Lin et al., 2006). In the future, it would thus be useful to provide as much information concerning a product in the RASFF notification as possible to establish a more comprehensive database and to better identify risk factors.

A first promising step towards simplification and harmonisation of reporting was made through introduction of the interactive RASFF (iRASFF) in 2011 which replaced Microsoft Word-templates for notification by an online IT application (European Commission, 2015). Dropdown menus are available in all official EU languages for the key data (product category etc.) that can later be found in the RASFF portal. Companies or hazards are stored in a database, but it is still possible to integrate a free-text description. However, concerning additional metadata, no uniform rule exists. While for example information on storage temperature can be selected in a dropdown menu, no such possibility exists concerning packaging type, which is a free-text field. In general, all of these metadata fields are not mandatory which is why information might not be available in some notifications. On the one hand, this appears necessary as in the case of missing information, the notification would otherwise not be publishable. However, an explicit "not specified" option in a mandatory field could help to handle this problem and on the other hand promote the provision of crucial additional information to improve risk assessment and thus European food safety.

5. Conclusion

The number of RASFF *Lm* notifications in food products distributed in Germany and the number of human listeriosis cases reported have been increasing in parallel from 2011 on. As a result of the fact that human listeriosis cases can usually not be linked to a certain RASFF notification, no proven causal relationship can be attested. Nevertheless, the common trend in both notifications is alarming. Due to the fact that food contamination is not a "one country" problem, communication between countries maintaining close trade relations, a European surveillance system like the RASFF and hence timely reaction to food safety issues are of crucial importance. Furthermore, EU-wide identification and communication of potential consumer risks provide a major contribution to risk assessment. However, improvements in the current system and better exchanging and linking between food safety and public health authorities will be indispensable in order to further promote this development.

First, a key performance indicator could be a largest possible match between country of origin and notifying country in RASFF notifications, thus enabling risk communication and interventional measures at a very early time point of the product's life cycle. This can be achieved by further extension of company's own checks. However, also overall enhanced national surveillance activities would be beneficial. Secondly, although a powerful tool for communication, reporting alone via the RASFF system will not be sufficient to contain *Lm* contamination of foodstuffs. To be able to address the root of the problem, more metadata should be made available together with the RASFF notifications to allow identification of risk factors. For that purpose, adjustment of the reporting system setting more value on information about product properties would be desirable.

Funding

This work was supported by a grant of the Federal Ministry of Health (GE 2016 03 26) in the framework of the German Research Platform for Zoonoses.

Declaration of interests

None.

Acknowledgement

We would like to express special thanks to the Department 1 (Food, Feed and Commodities) from the German Federal Office of Consumer Protection and Food Safety (BVL) for providing us with RASFF notifications from their database and accompanying documents.

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