

Recent food safety and fraud issues within the dairy supply chain (2015–2019)

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ABSTRACT

Milk and milk products play a vital role in diets around the globe. Due to their nutritional benefits there has been an increase in production and consumption over the past thirty years. For this growth to continue the safety and authenticity of dairy products needs to be maintained which is a huge area of concern. Throughout the process, from farm to processor, different sources of contamination (biological, chemical or physical) may occur either accidentally or intentionally. Through online resources (the EU Rapid Alert System for Food and Feed (RASFF) and HorizonScan) safety and fraud data were collected from the past five years relating to milk and milk products. Cheese notifications were most frequently reported for both safety alerts (pathogenic micro-organisms) and fraud incidences (fraudulent documentation). Alongside the significant number of biological contaminations identified, chemical, physical and inadequate controls (in particular; foreign bodies, allergens, industrial contaminants and mycotoxins) were also found. Although the number of incidents were significantly smaller, these contaminants can still pose a significant risk to human health depending on their toxicity and exposure. Grey literature provided a summary of contamination and fraud issues from around the globe and shows its potential to be used alongside database resources for a holistic overview. In ensuring the integrity of milk during ever changing global factors (climate change, competition between food and feed and global pandemics) it is vital that safety and authenticity issues are continually monitored by industry, researchers and governing bodies.

1. Introduction

Due to the high nutritional value of milk for both infants and adults, demand is on a global scale. Over the past thirty years, worldwide milk production has increased from 522 million tonnes in 1986 to 798 million tonnes in 2016 (53% increase) (FAO, 2018). More recently, the Food and Agriculture Organization of the United Nations (FAO) reported 6 billion people consume milk and dairy products with the main populous living in developing countries (FAO, 2019b). Milk is a fundamental part of the diet and as such production continues to increase primarily as a result of global demands. In addition, factors such as economic and population growth, increase in incomes and changes in consumption which reflects a more 'western' diet have also contributed to this increased demand. The increase in these factors is also reflected in the countries which produce the largest quantities of milk. In 2016, India accounted for 20% of the world's milk production followed by the USA (12%) and China (5%). Moreover, milk production from India and Pakistan is expected to continue to grow with a predicted 22% increase in global production by 2027 (OECD/FAO, 2018).

As a result of increased milk production, the safety and authenticity of milk (and its products) has become an area of growing focus and concern. The safety of milk and milk products can be affected when contamination from either biological, chemical or physical agents become a risk to the consumers health. The definition for a contaminant has been provided by Codex Alimentarius as "any substance not intentionally added to food or feed for food producing animals, which is present in such food or feed as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food or feed, or as a result of environmental contamination. The term does not include insect fragments, rodent hairs and other extraneous matter" (Codex Alimentarius Commission (CAC), 1995). In addition to accidental contamination, deliberate contamination of milk and milk products can occur through fraud issues. This has been shown in the melamine incident reported in China in 2008. Melamine was found to be present in infant formula to increase the nitrogen content due to milk being diluted with water. The impact of this was devastating with infant deaths

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reported in China along with an additional 47 countries affected due to receiving melamine contaminated products (Gossner et al., 2009). It is therefore essential that the entire dairy supply chain is reviewed to identify potential points of contamination and furthermore, is vital that milk and milk products are screened and tested for different contaminants before reaching the consumer.

Within the dairy supply chain, chemical, biological and physical contamination can occur at any part with numerous hazards being introduced at primary production and processing stages (Fig. 1). Some of these hazards include toxins (fungi and plant), pesticides, heavy metals, veterinary drugs and organic pollutants being transferred into milk. To date there have been extensive literature reviews that have identified these potential hazards in the dairy supply chain (Colak et al., 2007; Fischer et al., 2011a, 2011b; Jooste et al., 2014; van Asselt et al., 2016, 2017). Depending on the level of the contamination, many of these compounds can be detrimental to both human and animal health and result in spoilage of the product and economical damage to the industry. The detection of fraud within the supply chain is typically challenging, especially in the cases where the exact type of fraud which has occurred isn't obvious or easily detected. Historically, the addition of water to milk has been commonly used to increase its volume for economical gain by fraudsters. As technologies develop to detect potential adulterants in milk, fraudulent suppliers also adapt to finding new 'alternatives' to increase the milks value (Singh and Gandhi, 2015). To help monitor and assess contamination/fraud issues within the dairy sector there are various regulations, governing bodies and companies performing their own checks, to help identify or predict risks (Thompson and Darwish, 2019; Ulberth, 2020).

The aim of this study is to provide an insight into recent safety and fraud issues within the dairy sector over a five-year period (2015–2019). For safety issues relating to milk and milk commodities the Rapid Alert

System for Food and Feed (RASFF) provides free access to food and feed safety information between EU member states. This online portal, established in 1979 by the European Commission, aims to prevent unsafe food and feed products reaching the general populous (European Commission, 2019b). For issues relating to adulteration/fraud within the dairy sector, the HorizonScan database created by Fera was referred to. This database collects information on emerging international food fraud and safety issues from more than 100 food safety authorities and other sources (Fera, 2019b). Scientific literature was also referred to for the issues highlighted within the databases and grey literature was reviewed (news articles and reports) to identify any developing threats that might not be mentioned within these databases.

2. Methodology

2.1. RASFF and HorizonScan data collection

Data was extracted from the online RASFF portal (European Commission, 2020b) from the January 1, 2015 to the December 31, 2019. The following criteria were applied within the search:

- i) *Product category:* milk and milk products and dietetic foods, food supplements, and fortified foods.
- ii) *Notification, Type, Hazard and Keywords:* were left clear to include all notifications relating to the product categories.

From HorizonScan (Fera, 2020) the following criteria was applied:

- i) *Commodity group:* Products of animal origin (dairy).
- ii) *Dashboard features:* Fraud issues (vulnerability assessment).

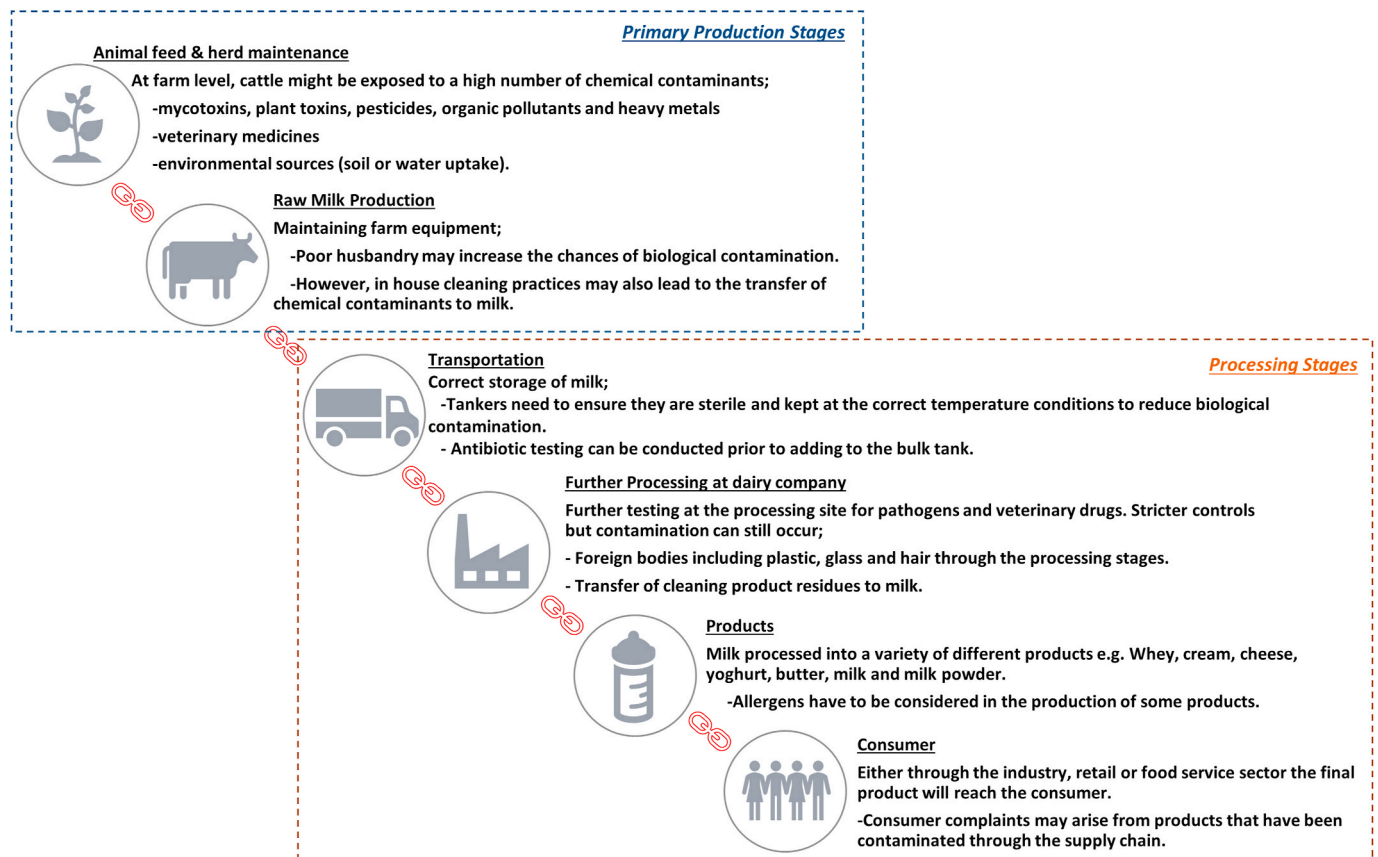


Fig. 1. Simplified dairy supply chain identifying areas of contamination in the primary and processing stages (based on information detailed in van Asselt et al., 2017).

Both datasets were exported separately into Microsoft Excel (Microsoft Corp., Redmond, USA) for extraction of data and filtering (using the application of pivot tables). For HorizonScan fraud notifications, the dates were filtered after exporting the data, from January 1, 2015 to December 31, 2019 in excel. Notifications not within the five years were excluded.

2.2. Classification of commodities and categories within the databases

To help group the list of different commodities within RASFF, eight general dairy groups were identified, and each alert assigned to one of the following: milk, milk powder, butter, cheese, yoghurt, infant formula, cream and other dairy products. For the RASFF notifications food safety hazards were grouped into the following fourteen hazard categories; pathogenic micro-organisms, non-pathogenic micro-organisms, industrial contaminants, mycotoxins, allergens, food additives and flavourings, heavy metals, legal veterinary products, foreign bodies, packaging defective/incorrect, adulteration/fraud, poor or insufficient controls, organoleptic aspects and labelling absent/incomplete/incorrect.

Within HorizonScan the following groups were already defined within the product of animal origin (dairy); cow's milk, cream, milk powder, yoghurt, milk-based beverages, others (e.g. caseins), butter and ghee, condensed milk, whey powder, cheese and ice-cream. For fraud notifications within HorizonScan, assigned categories are provided for each notification; adulteration/substitution, expiry date changes, fraudulent documentation, produced without inspection and unapproved premises.

2.3. Literature data collection and inclusion criteria

To support the data collected from the online databases, grey literature was also reviewed using Google search engine for news articles between 2015 and 2019. Initial searches included key words 'global milk issues', 'dairy integrity issues', 'dairy contamination', 'dairy scares', 'dairy alerts', 'dairy incidents', 'dairy hazards', 'dairy fraud', 'dairy adulteration'. 'Cow's milk' was also substituted for the term 'dairy'. Criteria for inclusion or exclusion was based on the context of the titles and if the evidence provided a detailed description of a contamination or integrity issue within the dairy sector. When no description of the incident was provided or the document was not in English, the article was not included.

3. Results and discussion

3.1. Dairy safety issues

When attempting to monitor any safety issues for milk and milk products, the EU RASFF database has been shown to be an effective monitoring tool (van Asselt et al., 2017). To date (accessed on June 18, 2020) there have been 1094 notifications concerning milk commodities from the first notification in 1983, with the category milk and milk products contributing ~2% of the total notifications within the RASFF portal (European Commission, 2020b). The last five years (2015–2019)

were exported and organised into a database format to assist with data mining. The information was reviewed for this study to identify if there were any emerging trends and/or if observations agree with previously established findings. Within the five-year period there were 355 notifications relating to milk and milk products, which can be divided into alerts (n = 246), information for follow up (n = 60), information for attention (n = 48) and border rejection (n = 1). Generally, alerts are the most serious notification types and will occasionally require rapid action by other countries along with the notifying country reporting the issue (European Commission, 2018). To help organise the collected data, details provided within the subject of the notification have been assigned to one of the fourteen hazard categories (see Table 1) which can then be assorted into one of the contaminant groupings; biological, chemical, physical and inadequate controls. For instance, if a notification relating to *Listeria monocytogenes* is detailed, this has been categorised within the pathogenic micro-organism category which falls under biological contaminants. Table 1 shows the fourteen hazard categories that can be grouped under biological, chemical, physical contaminants and inadequate controls. The numbers correspond to the frequency of notifications over the time period.

From Table 1 it is evident the largest number of notifications concerning milk and milk products were biological hazards with 265 notifications, which is greater than the combined total of chemical, physical and inadequate controls. Due to the high proportion of notifications relating to biological contaminants the following sections have been divided into two; i) biological hazards and ii) chemical hazards, physical hazards and inadequate controls.

3.1.1. Biological contaminants associated with milk commodities reported in RASFF

It has already been recognised that due to the nature of milk, it provides optimal conditions (suitable pH and moisture content) for the growth of many different bacteria. Some of the harmful micro-organisms include; *Salmonella*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Staphylococcus aureus*, *Yersinia enterocolitica*, *Bacillus cereus*, *Clostridium botulinum*, *Mycobacterium bovis*, *Brucella abortus* and *Brucella melitensis* (FAO, 2019a). A range of established measures are in place to ensure milk and milk products are safe from consumption of viable pathogenic bacteria including; heat processing conducted within the industry (MacDonald et al., 2011), EU legislation and global standards (European Commission, 2005; Joint FAO/WHO Codex Alimentarius, 2019) and regular testing by EU Reference Laboratories for *Coagulase Positive Staphylococci*, *Salmonella*, *Campylobacter*, *E. Coli* and *Listeria monocytogenes* (European Commission, 2020a). Nevertheless, raw milk production and commercialisation is legal within EU laws and can therefore pose a risk for some products if not prepared and stored properly (Elliott et al., 2019).

As previously mentioned, notifications have been assigned to eight general dairy groups (cheese, milk, infant formula, milk powder, other dairy products, yoghurt, butter and cream) which can be cross-referenced with the frequency of biological hazards as shown in Fig. 2.

The data presented in Fig. 2 highlights several noteworthy observations including *Listeria monocytogenes* having the highest number of notifications predominately occurring in cheese products (which is often

Table 1

RASFF alerts from 2015 to 2019 categorised under biological, chemical, physical contaminants and inadequate controls.

Biological contaminants	F	Chemical contaminants	F	Physical contaminants	F	Inadequate controls	F
Pathogenic micro-organisms	249	Industrial contaminants	6	Foreign bodies	43	Packaging defective/incorrect	4
Non-pathogenic micro-organisms	16	Mycotoxins	6			Adulteration/fraud	5
		Allergens	7			Poor or insufficient controls	3
		Food additives and flavourings	5			Organoleptic aspects	3
		Heavy metals	2			Labelling absent/incomplete/incorrect	3
		Legal veterinary products	3				
T	265		29		43		18

F = frequency of notification and T = totals.

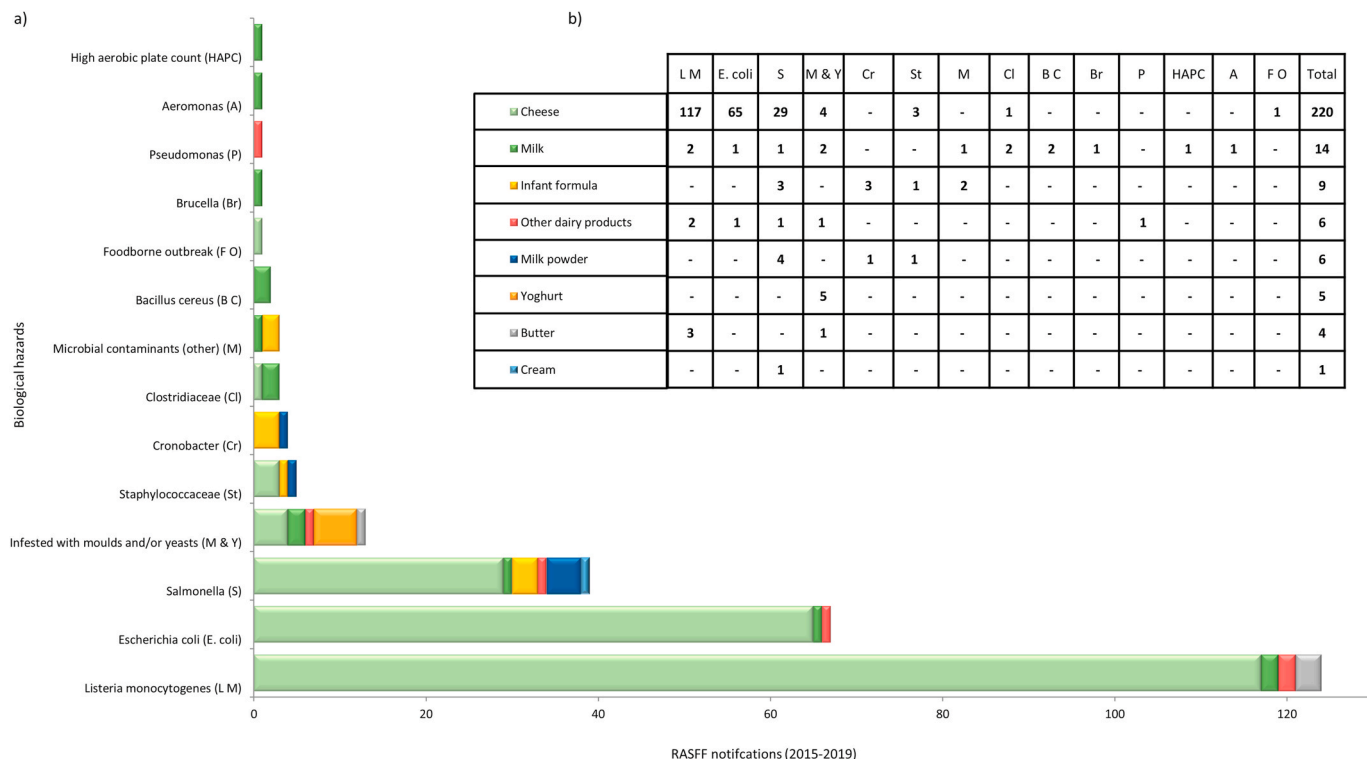


Fig. 2. Biological hazards associated with milk and milk products from RASFF from 2015 to 2019, a) Bar chart showing the total notifications for each hazard and b) cross-referencing table showing the commodities and hazards.

made from raw milk) originating from France. Interestingly, although the number of notifications is high for *Listeria monocytogenes*, only ~5% are classed as food poisonings with the majority (~74%) arising from company checks. The data perhaps reflects the EU’s strict surveillance and annual reporting for zoonotic pathogens for milk products (EFSA/ECDC, 2019).

The data also allows observations to be made in relation to which

hazard appears most frequently across the food groups. The combined data shows *Salmonella* appearing in the following commodities respectively; cheese, milk powder, infant formula, milk powder, milk, other dairy products and cream. Outside of the EU, milk quality may not be so tightly regulated and therefore could be more at risk from safety and fraud issues (see section 3.2).

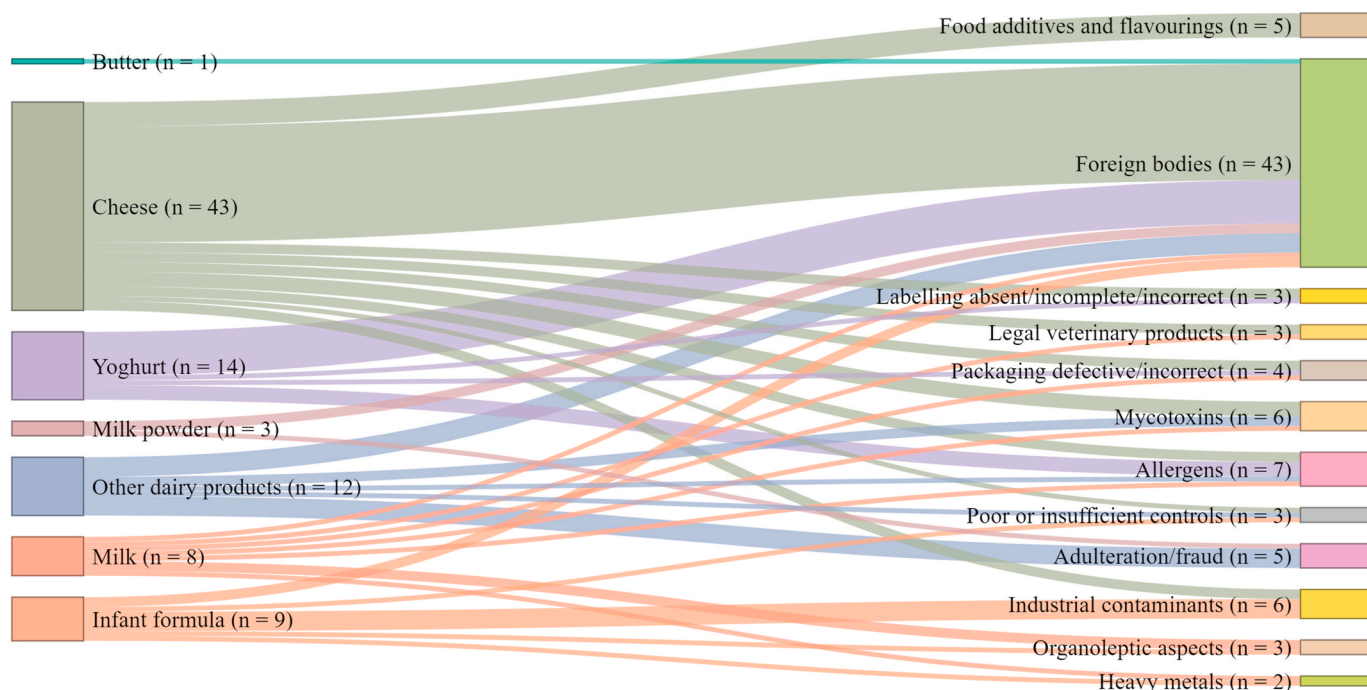


Fig. 3. Milk and milk products and their identified chemical, physical hazards and inadequate controls notified within the RASFF portal from 2015 to 2019.

3.1.2. Chemical, physical contaminants and inadequate controls associated with milk commodities reported in RASFF

As observed from Table 1 the number of notifications relating to chemical, physical contaminants and inadequate controls is a lot smaller than seen with biological contaminants, however, these contaminants can still pose a significant risk to human health depending on their toxicity and exposure. Fig. 3 has combined the hazards for chemical, physical and inadequate controls to identify which products correspond to each hazard.

Cheese shows the highest number of notifications (n = 43) and crosses over 9 different hazard groups including; food additives, foreign bodies, labelling issues, legal veterinary products, mycotoxins, allergens, industrial contaminants, packaging defective and poor controls. Foreign bodies show the highest number of alerts (n = 43), followed by allergens (n = 7), mycotoxins (n = 6) and industrial contaminants (n = 6). Table 2 shows each of the hazard headings along with the descriptions that has been provided in the alerts. Within the five-year period only legal veterinary drugs have been reported within the RASFF notifications. It should be noted that prior to this time period and more recently (2020), illegal veterinary drugs have appeared in the alerts, specifically chloramphenicol which has appeared in 41 notifications relating to milk/milk products. Likewise, there have been no notifications relating to unapproved pesticides from 2015 to 2019, however, in 2001 curdled milk and cheese products contained the prohibited substance hexachlorocyclohexane (n = 4).

Although the number of chemical hazards could be considered as low over the five years (n = 29), the contaminants that are present highlight some of the well documented and monitored issues within the dairy industry; antibiotics, aflatoxin (M1), heavy metals, industrial contaminants along with packaging contaminants. Within the RASFF notifications, limited information is provided in relation to the background and the possible origin of the contaminant. The data does show that more notifications are reported at the processing and manufacturing stages (e.g. foreign bodies, packaging defective, poor or insufficient controls, organoleptic aspects and labelling) than seen at possible farm level contamination (e.g. veterinary drugs, mycotoxins and heavy metals). Identification of the root cause within the notifications could help in identifying where potential gaps in testing occur along the processing stages. Most farmers and processors do employ intervention/monitoring methods including GLOBAL Good Agricultural Practices (GLOBALG.A.P) or Hazard Analysis Critical Control Points (HACCP) systems to help in reducing economic loss and possible contamination outbreaks along the dairy supply chain. For these systems to work effectively a record of potential food safety hazards alongside an identification of the most important hazards to be included in the system is required (van Asselt et al., 2016).

3.1.3. Prioritising hazards within RASFF

To aid in data occurrence interpretation, a risk prioritisation approach can be employed to help understand the severity a contaminant might pose from human consumption. Previously, a pilot risk register was developed for the pig and poultry meat sectors on the island of Ireland as a collaborative research project funded by Safefood (Elliott et al., 2016). The study developed a testing priority for chemical and microbiological hazards in poultry and pork production based on information gathered from the RASFF database. To prioritise hazards, both the frequency of occurrence and the hazard severity need to be considered i.e. *Level of risk = 'Likelihood of hazard occurrence' x 'Hazard Severity'* (Elliott et al., 2016). The data collected over the five years can be applied to the likelihood of the hazard occurrence. Scientific information relating to acute effects, carcinogenicity, genotoxicity and long-term effects were assessed for the hazards and the sum of the effects provided in scores provided in Table 3.

The largest score corresponds to industrial contaminants and the smallest relates to non-pathogenic micro-organisms. Further details in relation to the risk registers development can be accessed through the

Table 2 Breakdown of chemical, physical and inadequate control notifications from RASFF notifications from 2015 to 2019.

	Hazards										Totals
	Chemical					Physical			Inadequate controls		
IC	M	F & F	HM	LVP	F	PD	A/F	PC	O	L	
Mineral oil (2)	Aflatoxin (M1) (6)	Lysozyme (E-1105) (3)	Lead (1)	Tetracycline (1)	Glass fragments (7)	Bulging packaging (2)	Illegal import (5)	Failure in the sterilisation process (1)	Unsuitable organoleptic characteristics (1)	Incorrect expiry date (3)	
Dioxin & dioxin like polychlorobiphenyls (1)	Gluten (2)	Dehydroacetic acid (E-265) (1)	Iron (1)	Cloxacillin (1)	Plastic fragments (16)	Defective packaging (1)	Poor traceability records (1)	Poor traceability records (1)	Spoilage (2)		
3-monochloro-1,2-propanediol (3-MCPD) (2)	Lactose (1)	Natamycin (E235) (1)	Presence of bacterial inhibitor (1)		Metal (11)	Risk of breakage (1)	Unauthorised and undeclared product (1)				
Monethylene glycol (MEG) (1)	Nuts (1)				Other (rubber, fiber strings, general foreign body) (7)						
	Celery (1)				Animal (bird & insects) (2)						
	Milk (1)										
	6	5	2	3	43	4	5	3	3	3	6

IC = industrial contaminants, F = foreign bodies, PD = packaging defective/incorrect, M = mycotoxins, A/F = adulteration/Fraud, A = allergens, PC = poor or insufficient controls, F&F = food additives & flavourings, O = organoleptic aspects, HM = heavy metals, L = labelling absent/incomplete/incorrect, LVP = veterinary products.

Table 3
Hazard severity score (developed by Elliott et al., 2016)

Hazard category	Score	Hazard category	Score
Industrial contaminants	38	Approved pesticides	14
Heavy metals	33	Parasitic infestation	13
Prohibited veterinary products	31	Allergens	12
Mycotoxins	28	Legal veterinary products	8
Unauthorised pesticides	19	Food additives and flavourings	7
Unauthorised Veterinary Products	16	Composition	5
Pathogenic micro-organisms	15	Non-pathogenic micro-organism	5

Safefood Ireland website (<https://www.safefood.eu/Publications/Research-reports/Development-of-a-pilot-risk-register-for-the-pig-a.aspx>).

For each of the eight product categories, the frequency of the RASFF alerts were multiplied by the score for the hazard provided in Table 3. Table 4 shows the priority testing for milk for the six identified hazards and the order for testing; pathogenic micro-organisms, heavy metals, mycotoxins, non-pathogenic micro-organisms, allergens and legal veterinary products.

Pathogenic micro-organisms are shown as the top priority hazard for testing based on the risk score (165). For the other hazards (heavy metals, mycotoxins, non-pathogenic micro-organisms, allergens and legal veterinary drugs) the frequencies are low, however, based on their scientific severity scores, can now be prioritised. The application of the risk register provides scientific reasoning for prioritising the different contaminants. As previously mentioned, the testing priority has been adapted for chemical and microbiological hazards. Consideration, however, needs to be given to physical contaminants and inadequate controls as they are not included within the priority ranking. Table 5 shows the priority status for the remaining dairy commodities collected from RASFF.

For all milk and milk products (except infant formula and yoghurt) pathogenic micro-organisms were identified as the priority hazard (i.e. testing that should be undertaken; primary, secondary and tertiary). Secondary testing showed more variation and identified heavy metals, mycotoxins, pathogenic and non-pathogenic organisms being identified. Within the last column of Table 5, unscored hazards were identified and relate to physical hazards and inadequate controls where scientific information (acute effects, carcinogenicity, genotoxicity and long-term effects) cannot be applied.

3.1.4. Occurrences of safety and adulteration issues reported in grey literature

To support the findings from RASFF, grey literature was reviewed from 2015 to 2019. Grey literature can provide an insight into current safety and adulteration issues in milk and milk products that may not be

Table 4
Priority status for milk based on alerts from RASFF and the hazard severity score.

Commodity	Hazard	Likelihood (from RASFF)	Hazard Severity score	Risk Score	Priority Status
Milk	Pathogenic micro-organisms	11	15	165	Primary
	Heavy metals	1	33	33	Secondary
	Mycotoxins	1	28	28	Tertiary
	Non-pathogenic micro-organisms	3	5	15	Other
	Allergens	1	12	12	Other
	Legal veterinary products	1	8	8	Other

included in online databases. Articles can be uploaded to websites immediately and provides free access to news issues concerning milk contamination. Some benefits of grey literature include a greater level of detail and inclusion of general information as compared to published papers, although findings will sometimes be biased and unsupported as a peer review is rarely conducted. A brief summary of some of the potential grey literature available online relating to milk safety and fraud is shown in Table 6.

3.2. Milk fraud issues

As discussed, milk and milk products have become a common fraud target as highlighted by the melamine scandal (Gossner et al., 2009). Moore et al. (2012) also stated that milk has been listed as one of the most common targets for adulteration which has been reported in scholarly records. Specifically, milk fraud has become a reoccurring problem in developing countries due to the lack of awareness by food safety authorities. One of the easiest methods to commit fraud is by the addition of water to milk. Furthermore, if the water is contaminated with chemical or biological hazards this will further increase the risk to the consumer. Due to the dilution of various nutrients within milk, fraudsters will use various materials to increase the nutritional value, therefore making it harder to detect. Some of the most reported materials include milk powder, urea, cane sugar, melamine, formalin, caustic soda and detergents (Handford et al., 2016). Based on the RASFF data, there have only been 5 notifications relating to fraud (illegal import) of milk-based products (Iranian sauce, soymilk drink and milk powder). Many cases of fraud incidents will go undetected, so the number reported either on RASFF or through media sources will be lower than the number of fraudulent incidents actually being perpetrated. To help respond to fraud cases from the RASFF portal, the EU Food Fraud Network (FFN) was established in 2013 and links the national food fraud contact points for each EU member along with Iceland, Norway, Switzerland and the European Commission's Directorate-General for Health and Food Safety. Online access to fraud occurrence data from the EU FFN is limited with only annual reports available to the public (European Commission, 2019a). A variety of both private and public online databases have been created for food fraud incidents and Manning and Soon (2019) provided an informative overview for the following database; RASFF, Food Fraud Risk Information Database, Decernis, Food Adulteration Incidents Registry (FAIR), Food Integrity Network (FIN), European Commission's Joint Research Centre Europe Media Monitor (EMM) system, the FDA Recalls, Market withdrawals and Safety Alerts Database, UK Food Surveillance System (UKFSS) database and Private laboratory databases. For the purpose of this study, the HorizonScan database created by Fera was employed to collect data relating to dairy fraud issues.

3.2.1. Fraud occurrence data within horizonscan

HorizonScan collects data relating to both food security and fraud alerts daily from official sites (including food safety agencies and RASFF alerts) alongside independent sources (Fera, 2019a). Within HorizonScan the five headings have been assigned to fraud issues; i) Adulteration/substitution (fraudulent health certificate/documentation), ii) produced without inspection, iii) unapproved premises, iv) expiry date changes and v) unauthorised/unsuitable transport (Bouzembrak et al., 2018). To try and expand on the fraud data reported in RASFF, fraud incidents from 2015 to 2019 were extracted from the database for the following groups; cow's milk, butter and ghee, condensed milk, cream, cheese, ice cream (& similar frozen confections), milk powder, milk based beverages, others (caseins) and yoghurt. In total 145 notifications related to fraud issues in milk and milk commodities and included adulteration/substitution (fraudulent documentation), unapproved premises, produced without inspection and expiry date changes. Fig. 4 shows the number of alerts which have been assigned to each of the fraud categories.

Table 5
Risk register for milk products based on RASFF alerts and the associated hazard severity scores.

Commodity	Primary	Secondary	Tertiary	Other	Other	Other	Other	Physical or inadequate controls
Cheese	Pathogenic micro-organisms	Mycotoxins	Industrial contaminants	Food additives & flavourings	Allergens	Non-pathogenic micro-organisms	Legal veterinary drugs	Foreign bodies, Labelling issues, Packaging issues, Poor controls.
Infant formula	Industrial contaminants	Pathogenic micro-organisms	Heavy metals	Non-pathogenic micro-organisms	–	–	–	Foreign bodies, Organoleptic aspects, Poor controls.
Others (e.g. caseins)	Pathogenic micro-organisms	Mycotoxins	Allergens	Non-pathogenic micro-organisms	–	–	–	Adulteration, Foreign bodies, Poor controls.
Butter & ghee	Pathogenic micro-organisms	Non-pathogenic micro-organisms	–	–	–	–	–	Foreign bodies.
Yoghurt	Allergens	Non-pathogenic micro-organisms	–	–	–	–	–	Foreign bodies, Labelling issues, Packaging issues.
Milk powder	Pathogenic micro-organisms	–	–	–	–	–	–	Adulteration, Foreign bodies.
Cream	Pathogenic micro-organisms	–	–	–	–	–	–	–

Table 6
Summary of safety and fraud issues relating to milk and milk products found in grey literature from 2015 to 2019.

Year	Country of origin	Contaminant	Commodity	Issue	Reference
2015	United States	Campylobacter	Milk	Warning released in relation to the consumption of raw milk in California. 6 reported ill due to the consumption of raw milk containing campylobacteriosis.	Food Safety News (2015)
2016	Scotland	<i>E. Coli</i>	Unpasteurised cows' milk cheese	Outbreak suspected in July and September of 2016 with 26 cases identified due to the consumption of cheese.	Health Protection Scotland (2017)
2018	India	Maltodextrin, sucrose and ammonium sulphate	Milk	Spot testing of 227 milk tankers revealed 8 samples positive for maltodextrin, sucrose and ammonium sulphate.	Mendonca (2018)
2018	Pakistan	Chemicals, powder, polluted water and urea	Milk	A total of 15, 833 L of milk discarded due to the addition of harmful chemicals, powder, polluted water and urea, to increase thickness and quantity.	Arynews (2018)
2018	India	Water	Milk	Addition of water to milk and selling the milk in branded pouches.	Hindu, 2018
2018	India	Skimmed milk powder and sweet oil	Milk	Fake milk being produced and sold, from combining skimmed milk powder and sweet oil together.	Telangana Today (2018)
2018	Pakistan	Water	Milk	Three milk tankers were tested and adulterated with water (41% water in 20,000 L, 50% water in 10,000 L and 21% water in 2000 L).	Hashmi (2018)
2018	Pakistan	Ghee, urea and powder	Milk	Milk adulterated with Ghee, urea and powder milk.	The International News, 2018
2018	India	Not specified	Milk	Government checks revealed around 30% of milk sold in India is adulterated. 7717 samples analysed and 2307 were 'non-conforming'.	The New Indian Express, 2018
2018	India	Milk powder, palmolein oil, soya bean and water	Milk powder	Milk powder, palmolein oil and soya bean in water used to make around 860 L of milk.	The Times of India, 2018
2018	The Netherlands	Underreporting	–	Underreporting of the size of dairy herds. Farmers registering multiple calves being born to one cow.	Pieters (2018)
2018	Ukraine	Radiation	Milk	Radiation readings for cow's milk up to 140 miles from Chernobyl still over the government's legal limit. Levels are predicted to remain till 2040 and even longer for the limits for children.	Pérez-Peña (2018)
2018	England	Contaminated water system	Milk	Around 55 dairy cows died due to contamination in the farms isolated water system. Milk did not reach the producer and was discarded as soon as the cows became ill.	Thompson (2018)
2019	Bangladesh	Lead, pesticides, antibiotics and microbial contaminants.	Milk & cow feed	High levels of contaminants (lead, pesticides, antibiotics and pathogens) recorded in milk by the National Food Safety Laboratory (NFSL). Tetracycline was above the permissible limit.	Chaity and Al Amin, 2019.
2019	Bangladesh	Adulteration	Milk & cow feed	Government authorities to conduct enquiry into findings previously found by the NFSL. Outcomes to include identifying criminals involved in the adulteration of the dairy sector.	Neo (2019)
2019	Wales	Unknown	Milk	"Funny Taste" of milk highlighted by customers on social media. No food safety risk to customers and no recall of products. The source is believed to have originated from well water from a single farm.	Mears (2019)
2019	India	Not disclosed	Cheese (Paneer)	During an ongoing anti-adulteration drive, various commodities including 500 kg of paneer were found to be adulterated. Examples included the use of synthetic colours for bleaching.	The Times of India, 2019
2019	New Mexico	Per- and polyfluoroalkyl substances (PFAS)	Milk	Contamination of groundwater from near-by air force base, affecting ~4, 000 cows. 15, 000 gallons of milk being discarded each day due to the contamination.	Linn (2019)

Cheese commodities show the highest number of fraud notifications relating to fraudulent documentation (n = 73), followed by adulteration/substitution (n = 21), unapproved premises (n = 3), produced without inspection (n = 2) and expiry date changes (n = 2). Yoghurt

commodities have the second highest number of notifications (n = 13), followed by butter and ghee (n = 12). The majority of alerts (72%) arose from official inspection by the Czech Agriculture and Food Inspection Authority, with the remaining collected from other food agencies (8%

Milk and milk products



Fig. 4. Types of fraud identified from Horizonscan alerts from 2015 to 2019 for milk and milk products.

Spain, Slovakia, India, UK, Canada, Russia and Germany), RASFF (8%), press releases (8%) and unknown sources (5%).

Milk adulteration/substitution includes the addition of undeclared ingredients such as water, fat, protein and species substitution. Focusing on the adulteration/substitution cases (n = 39), alerts were examined to observe if specific undeclared ingredients could be defined from the data (Table 7).

Interesting observations can be made from the data collected in Table 7 in relation to milk commodities and issues relating to adulteration/substitution cases. Initial observations show that ‘other’ issues have the highest number of notifications which included weight and dried weight less than indicated on packaging (n = 7), lack of lactic acid (n = 3), tampering (n = 1), illegal supply (n = 1), chicory extract instead of coffee used in yoghurt (n = 1) and spurious cheese (n = 1). The alerts relating to weight being less than indicated on packaging were also reported within fraudulent documentation notifications (see Table 8) and show the cross over between fraud groups.

Within the fat category, only four notifications specify the fat adulterants that have been used including palm oil (ghee), vegetable fats (butter and cheese), and a mixture of fats (animal, palm oil and Vanaspati oil for fake ghee). The remaining notifications only specify that the product has a lower fat content than stated on the label (n = 12).

Only one notification related to feta cheese that had been made of 100% cows’ milk, rather than 70% sheep milk and 30% goats’ milk as stated on the label.

The mixed category included two notifications from India for cheese and milk detailing a mixture of different adulterants used; cow’s milk that had been adulterated with water, harmful chemicals, powder and urea and cheese had been adulterated with sulphuric acid, skimmed milk, detergent and urea.

Within adulteration/substitution cases relating to fraudulent documentation are closely linked and many cases could be classed as both (Table 8). The fraudulent documentation category includes 90 notifications relating to the seven dairy products; butter and ghee, cheese, condensed milk, ice-cream (& similar frozen products), milk powder, others (e.g. caseins) and yoghurt.

The highest number of notifications relate to the physio-chemical parameters (particularly in cheese) for salt (n = 29), dry matter (n = 21) and fat content (n = 10). Cheese products have the highest number of notifications relating to the content of salt being higher than stated on the label.

Fraud data collected from databases do not show the true number of cases relating to these types of incidents as many will go undetected. It can be presumed that the numbers will be much higher than those

Table 7 Adulteration/substitution cases from Horizonscan 2015–2019 relating to milk and milk products and undeclared ingredients.

Commodities	Water (addition)	Fat content		Species substitution	Mix	Unknown	Other
		addition	less				
Butter & ghee	4	3	1				
Cheese		1	10	1	1		8
Cow’s milk					1	1	
Cream			1				1
Other (e.g. caseins)							1
Milk-based beverage							1
Yoghurt						1	3
Totals	4	4	12	1	2	2	14

Table 8
Fraudulent documentation cases from HorizonScan 2015)–2019 relating to milk and milk products.

Commodities	Absence of health certificates	COO mis-labelling	Fraudulent product packaging	Higher fat content than declared on the packaging	Illegal import	Less dry matter/solid content than declared on the label	Lower fat content than declared on the packaging	Lower protein content than declared on the packaging	Mix	Other	Poor traceability	Salt content higher than stated on label	Weight is lower than indicated on packaging
Butter & ghee	1 ^a												
Cheese		2	1			21	10	2	1	1	1 ^a	1	5
Condensed Milk												29	
Ice-cream (& similar frozen confections)										1 ^a	1		
Milk powder					4 ^{a,3}								
Others (e.g. caseins)							1						
Yoghurt		1		1			4	2	1	2	4	30	5
Totals	1	3	1	1	4	21	15	2	1	2	4	30	5

^a The notification is from RASFF.

reported here. It is also hard to estimate if the number of cases is increasing or decreasing over time.

4. Future prospects and conclusions

While milk production is predicted to further increase, global factors such as climate change, political instabilities, increase in global population, competition between food and feed (Augustin et al., 2013) and more recently the coronavirus pandemic, may hinder production. This instability may cause fluctuations within the dairy industry and subsequently may cause unpredictability in the quality and safety of milk (and its products). It is evident through reviewing scientific literature, news articles and monitoring databases that contamination issues occur in the dairy industry on a global scale. Over the five years that were investigated, cheese notifications were most frequently reported for both safety alerts (pathogenic micro-organisms) and fraud incidences (fraudulent documentation) from RASFF and HorizonScan. Alongside the biological contaminations identified, chemical, physical and inadequate controls (in particular; foreign bodies, allergens, industrial contaminants and mycotoxins) were found. Although the number of incidents were significantly smaller, these contaminants can still pose a significant risk to human health depending on their toxicity and exposure. Using a risk prioritisation approach for the identified biological and chemical hazards allowed possible testing to be ranked in order (primary, secondary and tertiary). Fraud notifications from HorizonScan also showed cases where adulterants including water, chemicals, detergents, urea and skimmed milk were added to cow's milk and cheese. In addition, to online database resources, grey literature was reviewed to provide an insight into what is being reported through media outlets online in relation to milk safety and fraud. As eliminating contaminants and fraud within the sector represents a significant challenge, monitoring alerts and issues via a range of resources has become crucial, especially with a view towards the influence of varying parameters. Using online databases and grey literature, it is possible to provide and evaluate a broader scope of issues which is fundamental to ensuring the reduction of fraud and contamination associated with milk.

Declaration of competing interest

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

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