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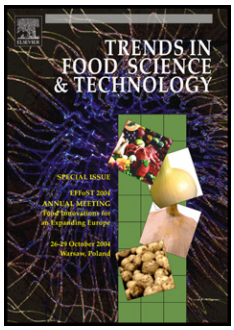

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Trends in Product Recalls within the Agri-Food Industry: Empirical Evidence from the USA, UK and the Republic of Ireland

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Trends in Product Recalls within the Agri-Food Industry: Empirical Evidence from the USA, UK and the Republic of Ireland

Abstract

The increasing frequency of product recalls within the agri-food industry has led many to question food safety. Research studies also often focus on biological hazards without considering how past, present and emerging risks change over time. We undertake a systematic review of the different biological, operational and chemical hazards within the agri-food industry using a dataset of 2,070 registered food recalls in the USA, UK and Republic of Ireland between 2004-2010. We show product recalls have become more frequent over time and operational hazards, rather than biological and chemical hazards, are the most frequent recall type within the agri-food industry.

Introduction

Product safety within the agri-food industry has received heightened awareness in recent years following a number of high profile food scares (Roth *et al*., 2008; Warriner & Namvar, 2009; Chan & Lai, 2009). In 2010, the US agri-food industry experienced one the largest food recalls in its history when over 500 million eggs were recalled from White County Farms due to a Salmonella outbreak (Food & Drug Administration, 2010). Within the United Kingdom, a large-scale recall of food products was announced in 2005 due to contaminated Sudan 1 dyes entering the food supply chain, and more recently in 2008, the Republic of Ireland conducted its largest nationwide recall in its history due to a dioxin contamination (Banati, 2011). Further, one of the key causes of food borne infections is contaminated agri-food products entering the farm-to-fork supply chain. Research by the US Centers for Disease Control and Prevention (2011) estimates that contaminated food is responsible for an estimated 48 million illnesses, 128,000 hospitalizations, 3,000 deaths, and 1,000 reported disease outbreaks each year within the USA.

Product recalls can also have a substantial detrimental effect on firm performance. Detailed empirical research has found that product recalls can have a significant negative impact on firms across a range of performance measures, including operational performance (Hendricks & Singhal, 2005), share price (Thomsen & McKenzie, 2001; Salin & Hooker, 2001; Wang *et al.*, 2002), customer sales (Thomsen *et al*., 2006), consumer demand (Marsh *et al*., 2004), market movements (Palma *et al*., 2010), food prices (Li *et al*., 2010; McKenzie & Thomsen, 2001), and prices on the futures market (Lusk & Schroeder, 2002). For example, Thomsen *et al* (2006) found that sales of recalled brands declined, on average, by 22% to 27% during the four to eight week time period after a recall announcement of Listeria. Consequently, the greater frequency and severity of food recalls has caused many to become concerned about the safety, quality and integrity of products within the agri-food industry (Wilcock et al., 2004; Stinson et al., 2008).

With the exception of research by Kleter et al (2009) and earlier studies by Vierk *et al* (2002), Teratanvat and Hooker, (2004) and Salin *et al* (2006), comparatively little research has examined the key patterns and trends in the frequency of different product recalls within the agri-food industry. In particular, we know little about how the frequency of different biological, chemical and operational hazards have changed over time, and the implications for food

scientists, managers and consumers. Many studies also focus on the higher frequency biological hazards, such as Listeria, Salmonella and E-Coli, with less attention paid to lower frequency biological hazards, operational or chemical hazards, and new and emerging food safety hazards, such as food fraud. A comprehensive review of all sources of agri-food recalls would shed light on the key patterns and trends within the agri-food industry and key sub-industries. To address these gaps, we review the key patterns and longitudinal trends in the frequency of different biological, chemical and operational product recalls registered with the food regulators within the USA, UK and the Republic of Ireland between 2004 and 2010.

Literature Review

A food recall occurs when a firm removes their products from the marketplace due to concerns that the product may adversely affect consumer health (Teratanavat & Hooker, 2004). By comparison, market withdrawal notifications focus on the voluntary removal of products that do not violate government regulations, and stock recovery procedures that occur when firms voluntarily remove products yet to be distributed to consumers from the supply chain (Teratanavat & Hooker, 2004). Consequently, a product recall is considered by many to be the management practice of last resort to prevent unsafe products from being purchased and consumed by the general public. Firms inform their customers of the risk of purchasing and consuming their products by announcing a product recall which provides details of the types of products affected, and the negative health risks and symptoms that can be caused by consuming the product.

Over the past ten years a number of studies have begun to investigate longitudinal trends in different types of product recalls within the agri-food industry (Vierk *et al*., 2002; Teratanvat & Hooker, 2004; Salin *et al*., 2006; Kleter *et al*., 2009). Vierk *et al* (2002) examined the prevalence of particular food recalls using data from the US Food and Drug Administration (FDA) which showed that of the 280 recalls within one year, 24% were due to undeclared allergens, especially within the egg, peanut, dairy and wheat industries. Teratanvat and Hooker (2004) explored the longitudinal trends in meat and poultry recalls between 1994 and 2002, using data from the US Food Safety and Inspection Service (FSIS). Their results revealed that 57% of product recalls in the meat and poultry industry were attributable to bacterial contaminations, such as E-Coli and Listeria, 18% were caused by production contaminations, 14% were due to undeclared ingredients and mislabelling, and 10% were the result of under-processed products. Salin *et al* (2006) studied longitudinal trends in food recalls from 2000 to 2003 using data from both the FSIS and the FDA. Of the 713 food recalls in this three year period, 79 were classified as major recalls that involved recalling 100,000 pounds of agri-food products, while ten recalls were determined to be mega recalls that caused over 1 million pounds of agri-food products to be recalled. Finally, Kleter *et al* (2009) conducted a detailed analysis of EU food safety alert notifications between 2003 and 2007 using data from the European Commission's Rapid Alert System for Food and Feed (RASFF). They found that chemicals were the most frequent hazard, accounting for 44% of all notifications, followed by mycotoxins (29%), and microbiological hazards (17%). To date, Kleter et al (2009) represents the most comprehensive investigation of food safety trends, but focuses only on European countries and information and alert notifications, rather than food recalls.

Methodology

We compiled a database of product recalls from the USA, UK and Republic Ireland between 2004 and 2010 by aggregating detailed data from a number of different government organizations responsible for collection of food recall statistics within each country. In the USA data was collected on registered food recall announcements and reports provided by the Food and Drug Administration (2011) and the Department of Agriculture's Food Safety and Inspection Service (2011). For the United Kingdom (UK), data was obtained from registered recall announcements of the Food Standards Agency (2011), while in the Republic of Ireland data was gathered from the Food Safety Authority of Ireland (2011). These government organizations and countries provide the most detailed and accurate longitudinal data records on product recalls within the respective national agri-food industries. All product recall announcements and reports from these government organizations were analyzed, screened and inputted into a series of datasets. Data was collected on the frequency of product recalls, date of the recall, title of the recall, product(s) affected, amount recalled, reason for the recall, who caused the recall, who detected the recall, and how the recall was identified.

A number of data screening procedures were used to enhance the accuracy of the data, including the identification of post-hoc corrections, ex-post amendments, and withdrawal notifications of recall announcements. We also triangulated our dataset with similar data from the USA Centre for Disease Control (Centre for Disease Control), the European Centre for Disease Prevention and Control (ECDPC), industry reports, journal articles, company websites, press releases and news articles to ensure that these government organizations were collecting accurate data on product recalls within the agri-food industry. To aid consistent data collection, each product recall was coded using the hazard categories developed by the Rapid Alert System for Food and Feed (RASFF, 2009). The RASFF hazard categories were chosen because, to date, it is the most comprehensive categorization for classifying food hazards and has been used in previous food safety research (Kleter *et al*., 2009). The RASFF hazard categories identify nine main types of food hazard: *veterinary drugs* (e.g. Chloramphenicol, Streptomycin), *food additives* (e.g. too high content of Suphites, unauthorized food additives), *composition* (e.g. unauthorized Sudan 1, suffocation risk), *heavy metals* (e.g. Cadmium, Mercury), *mycotoxins* (e.g. Aflatoxins, Fumonisins), *pesticide residues* (e.g. Amitraz, Carbendazim), *food contact materials* (e.g. migration of Lead, migration of Nickel), *microbiological hazards* (Listeria, Salmonella, E-Coli), and *foreign bodies, and other causes* (e.g. melamine, allergens, dioxins). Additional categories were also used from prior research on EU food alert notifications by Kleter *et al* (2009), including BSE, Calicivirus, Hepatitis A virus, Norovirus, and Nitrates/Nitrites. A number of recalls in these three countries did not fit into the existing RASFF hazard categories, so were assigned a separate code to enable them to be retained in the analysis.

Once all of the recall data had been entered for the three countries, it was found that there were 137 different types of recall that did not fit into the RASFF hazard categories. These hazards were then analyzed to identify common themes and recoded into new categories. Many of these recalls were caused by operational failures within the firm, such as incorrect labelling, undeclared ingredients, manufacturing defects, metal, glass, plastic or chemical contamination, food fraud, and packaging defects. These new categories were classified according to the original information provided in the recall announcements and reports. Although the RASFF hazard categories cover the main biological and chemical causes of product recalls, some causes and hazards were missing. Therefore, additional biological and operational hazards identified by Kleter *et al* (2009) were incorporated into the data analysis.

After detailed data screening, 2,070 product recalls were identified across the three countries over the seven-year time period from January 1st 2004 to December 31st 2010. The majority of these recalls, some 74%, were reported in the USA, accounting for 1,523 food recalls. The remaining 26% of all the product recalls originated within the UK and the Republic of Ireland, representing 547 recalls. This over-representation of product recalls within the USA is to be expected given the size of its food industry and its greater population. Due to the comparatively low frequency of product recalls within the Republic of Ireland, we merged this product recall data with the records from the UK to form a new combined category. For 12 product recalls (representing 0.58% of all the recall announcements), the report stated that the recall was caused by more than one factor, in these cases both causes were reported in the dataset. In addition, two product recalls were announced that did not identify a specific cause of the problem, this data was retained within the dataset. We also ensured that a recall event was included only once in the dataset, excluding subsequent downstream customer recalls triggered by the original recall.

Food recalls: An overview

Longitudinal trends

Figure 1 illustrates the frequency of 2,070 product recall announcements in the USA, and the UK and Republic of Ireland over the period January 1st 2004 to December 31st 2010. There is a growing trend of product recalls within the agri-food industry, illustrated by the rise in the total number of product recalls from 58 in Quarter 1 (Q1) of 2004 to 88 in Quarter 4 (Q4) in 2010. Although quarterly data exhibits a high degree of variability, since Quarter 2 (Q2) of 2006 there has been a noticeable increase in the total number of product recalls. In particular, there has been a significant rise in the number of product recalls in the USA since Quarter 4 (Q4) of 2006, which has been sustained from 2008 to 2010. Throughout this three year period a number of large scale product recalls occurred in the USA that may help explain, in part, this recent higher frequency of recalls. For example, in 2009 the USA experienced one of its most extensive product recalls, caused by a Salmonella outbreak in peanuts manufactured by Peanut Corporation of America. Following this, a multi-state recall was announced in 2010 recalling over 500 million eggs due to a Salmonella outbreak.

To identify whether increases in the frequency of biological hazards help to explain the recent rise in product recalls, we analyzed the changing incidence of the main biological product recalls (i.e. Salmonella, Listeria, and E-Coli). These three biological hazards account for the greatest share of biological product recalls within the dataset. A sharp increase in the frequency of Salmonella recalls was identified, which may explain the greater frequency of total recalls within the USA. Additionally, a number of other factors may also be responsible for this growing trend of product recalls including the evolution of new strains of biological hazards (e.g. the Shiga toxin producing E-Coli (STEC) outbreak in Germany in 2011), changes in government regulations and food safety standards, new developments in detection technology, and the shift towards global sourcing and importing from low-cost countries with lower food safety standards. Further, the growing frequency of food recalls may indicate that managers, firms, regulators, customers and consumers are becoming more capable at detecting food safety concerns and outbreaks. Except for several notable exceptions, such as the Sudan 1, Sudan 4 and Para Red dye recalls in 2005, no conspicuous overall trends were identified in the frequency of product recalls within the UK and the Republic of Ireland. The graph in Figure 1 illustrates no clear trend, but

does appear to fluctuate around an average of 20 recalls per quarter throughout the seven year period.

<< Insert Figure 1 >>

Product recall mechanism

We also analyzed how the potentially unsafe products were detected and the mechanisms used to recall products from the market. Based upon the 1,388 announcements that stated who detected the recall, regulators identified the majority of food hazards (67%), followed by the firm (21%), consumers (6%), customers (3%), suppliers (2%), retailers (<1%) and distributors (<1%). These categories are based on the information provided by firms in their recall announcements, and as such some categories may overlap in conceptualization (e.g. customers and retailers). The data shows that a significant proportion of food hazards are identified by regulators and towards the end of the supply chain (i.e. by consumers, customers, retailers, and distributors) (i.e. reactive product recalls), rather than by the quality control procedures and risk management practices used by firms and their suppliers (i.e. proactive product recalls).

The data was also reviewed to identify how the hazard was detected. Using data from 1,046 product recall announcements (representing 51% of the total number of product recalls) which provide this information, we see that product sampling was the most frequently used method of detecting hazards (43%), followed by product testing (26%), consumer/customer complaints (16%), and inspections (9%). Many product recall announcements did not provide details about the specific type of sampling, testing or inspection that had been used, and were thus excluded from the data. Further, approximately 27% (557) of recall announcements were caused by firms that had experienced a previous recall. Finally, in terms of the mode of notification used to recall the product from the marketplace, 51% of recall announcements used date codes (e.g. production date, distribution date sell by date, use by date), 24% used product codes (e.g. lot number, batch codes, Universal Product Codes), 8% used a combination of date codes and product codes, whilst 17% of announcements did not state any form of recall information codification.

Industry specific risks

To review which sub-industries within the agri-food industry were more prone to product recalls, detailed data on the type of products recalled in each recall announcement were examined. Using this data, we then classified the recalled products into 25 different sub-industries following the same categorisation approach used previously by Kleter *et al* (2009) in their examination of European food alerts. Furthermore, within each sub-industry we identified the three most frequent product recalls in order to identify the largest share of food safety hazards across sub-industries. For example, the most frequent recalls are, on average, responsible for 38% of recalls within each sub-industry, followed by 21% (average) for the second most frequent recall, and 13% for the third most frequent recall.

Table 1 presents the distribution of industry specific product recalls, showing that the processed foods industry is responsible for the largest number of product recalls, constituting 24% of all recall announcements in the USA, and the UK and Republic of Ireland. Defective ingredients account for the largest share of product recalls within the processed foods industry (27%), followed by undeclared ingredients (21%), and Salmonella (8%). The meat and meat products industry represents 13% of all product recalls within the dataset, making it the second

most frequent sub-industry at risk from product recalls. E-Coli and Listeria were particular risks in this industry accounting for 33% and 19% of recalls, respectively. Firms that operate within the fruit, vegetables and salads industry were responsible for 10% of all product recalls, with the three most frequent causes of product recalls being Salmonella (27%), undeclared ingredients (22%) and incorrect labelling (21%). The dairy industry and fishery products industry were each responsible for 6% of recalls throughout the seven year time period, and were both adversely affected by Listeria, responsible for 35% and 31% of recalls within each industry, respectively. The remaining sub-industries were each responsible for 5% or less of product recalls, and include some product categories that are traditionally associated with high food safety concerns such as the poultry meat and products industry, and the egg and egg products industry.

<< Insert Table 1 >>

Product recall types

Based upon the RASFF hazard categories and similar research by Kleter *et al* (2009), each product recall was classified into one of three different groups: (i) operational product recalls (55% of total recalls); (ii) biological product recalls (36% of total recalls); and (iii) chemical product recalls (9% of total recalls).

Operational product recalls

Operational product recalls include incorrect labelling, packaging defects, production contaminations, production defects, unauthorized ingredients, incorrect ingredient levels, and food fraud. Operational product recalls were the most frequent type of recall within the dataset, and were responsible for 55% of all the product recalls (1,132 separate product recall announcements). This is a surprising finding suggesting that more research is needed to investigate the causes and consequences of organizational failures, human errors, managerial misjudgements, machinery defects, and technical glitches, which are responsible for the largest share of food safety hazards. Within the USA, and the UK and Republic of Ireland, operational product recalls were the most frequent type of food hazard, responsible for 53% and 59% of recalls respectively. Although the frequency of operational recalls displays no clear trend, it remains consistently high throughout the seven year time period, averaging 29 recalls per quarter in the USA and 11 recalls per quarter in the United Kingdom and the Republic of Ireland. Since Q4 2006 there has been a growing number of operational product recalls in the USA, and a recent rise in operational product recalls in the UK and the Republic of Ireland since Q2 2010. As operational product recalls are largely caused by preventable human errors, this data suggests that firms need to focus on improving their quality control and risk management practices to prevent and mitigate the effect of operational hazards.

We also classified operational product recalls into different categories based upon the descriptions within the food recall announcements and reports (Table 2). Operational product recalls were dominated by three main operational hazards, incorrect labelling, undeclared ingredients and production contamination, which together account for the majority of operational product recalls (79%). The results in Table 2 reveal that incorrect labelling accounts for the largest share of operational product recalls (i.e. 37%), followed by undeclared ingredients (25%) and production contamination (17%). Interestingly, incorrect labelling was far more prevalent in USA (43%) than UK and Republic of Ireland (21%), though this was the reverse for production

contamination (e.g. metal, glass, plastic) where the USA, and UK and Republic of Ireland, experienced recall rates of 8% and 41%, respectively. Undeclared ingredients that are the second main cause of operational product recalls within the agri-food industry, as they account for approximately 25% of all product recalls that are attributable to operational hazards. In other words, the root cause of many operational hazards occurs when production managers, procurement managers, and professional buyers fail to declare an ingredient that is present within the product, inadvertently source an unauthorized ingredient from a supplier, or allow the wrong ingredient level to be used during production. Other causes included production defects, food fraud, packaging defects, foreign bodies, spoilage, incorrect ingredient levels and unauthorized ingredients, which represent only a small proportion of operational product recalls. In the majority of cases the recall is caused by, or associated with, human errors in judgement or failures in machinery or equipment. Overall, operational product recalls were found to originate throughout the different functions of the firm, especially within the production and purchasing departments.

Finally, although only accounting for 3% of all operational product recalls, corporate fraud represents a growing concern within the agri-food industry. Each of the different types of food fraud were identified from the recall announcements and further investigations into these cases. The 38 cases of product recalls involving fraudulent activities revealed the majority were due to products being produced without regulator inspection (32%), products sold containing prohibited materials (24%), products produced by unapproved production plant (16%), and illegal sourcing/importation (13%). Other less frequent causes of food fraud related to product mislabelling (5%), adulterated products (3%), unsanitary production processes (3%), product quality compliance with firm specifications (3%), and legal/regulation compliance (3%).

<< Insert Table 2 >>

Biological product recalls

Biological product recalls, which include Salmonella, Listeria, E-Coli, Biotoxins, Moulds, and disease contaminations, are the second most frequent type of food hazard. In total, 742 product recalls pertain to a biological cause, representing 36% of all recall announcements in the USA, UK and Republic of Ireland. These biological product recalls were dominated by three key biological hazards, Salmonella, Listeria and E-Coli, which together accounted for 86% of all biological product recalls. Biological product recalls were found to be more prevalent in the USA, accounting for 41% of all USA recalls, in comparison to 22% for the UK and the Republic of Ireland. On average, the USA experienced 22 biological product recalls per quarter throughout the last seven years, and has experienced a growing and sustained trend of biological recalls since Q1 2006. The rise in biological product recalls since Q4 2008 is attributable, in part, to a substantial increase in the frequency and severity of Salmonella outbreaks in the USA. For example, Salmonella recalls in the USA have increased substantially over the past three years, rising from 16 in 2008, to 71 in 2009, and 67 in 2010. By contrast, the UK and Republic of Ireland experienced no clear trend in biological product recalls, averaging 4 biological product recalls per quarter throughout the seven year time period.

Within Table 2, biological product recalls have been classified and ordered according to their biological typology and frequency over the seven year time period. Bacterial contaminations are the most frequent type of biological hazard, representing 96% of all biological product recalls, followed by biotoxins (2%) (e.g. Aflatoxins and Fumonisins), moulds

(2%), and a small number of biological and disease contaminations. Similar to results by Teratanavat and Hooker (2004), our review indicates that the high frequency of bacterial contaminations is due to three main biological hazards: Salmonella, Listeria, and E-Coli. First, Salmonella was responsible for the largest group of any of the biological hazards, constituting 37% of all biological product recalls within this seven year study, with high occurrences in the USA, and the UK and Republic of Ireland. In a similar vein, recent research by the Centers for Disease Control and Prevention (2011) finds that Salmonella infections are the most common reported infection with 17.6 illnesses per 100,000 people, and are responsible for the largest number of hospitalizations and deaths from food infections in the USA. Research has also identified a rise in Salmonella infections in the USA since 2006, and that Salmonella infections result in an estimated $365 million in direct medical costs each year in the USA (Centers for Disease Control & Prevention, 2011).

Listeria is the second most frequent biological recall (34%), especially in the USA where it accounts for 37% of all biological product recalls. Listeria contaminated food can often lead to Listeriosis, a leading cause of death from foodborne illnesses in the USA, especially among children, older adults, pregnant women and people who are immunocompromised (Centers for Disease Control & Prevention, 2009). In particular, research by the Centers for Disease Control and Prevention (2011) suggests that Listeria has one of the highest hospitalization rates in the USA, and reported cases of Listeriosis in the USA have increased in recent years, rising from 665 cases in 2002 to 851 cases in 2009 (Centers for Disease Control & Prevention, 2009).

Escherichia Coli (E-Coli) represents the third most frequent type of biological hazard within our study, accounting for 111 individual recalls throughout the seven year time period (15% of all biological product recalls). Finally, only a small proportion of biological product recalls were attributable to biotoxins, moulds, and biological and disease contaminations, although there was a notably high proportion of recalls in the UK and Republic of Ireland caused by aflatoxins and moulds (Table 3). We also identified a number of biological causes of product recalls in the USA, UK and Republic of Ireland that were not included under a RASFF hazard category. These biological hazards include a wide range of biological causes, such as Ochratoxin A, parasites, Marine Biotoxins, Calicivirus, Hepatitis A virus, Norovirus, Zearalenone, BSE, and Microbial toxins.

<< Insert Table 3 >>

Chemical product recalls

Chemical product recalls constitute the smallest proportion of total recalls in the dataset, representing 9% of all recalls, but encompass a wide variety of chemical hazards, ranging from dyes, allergens, melamine, and drugs, to dioxins, irradiation, food additives, 3-MCPD, pesticides, heavy metals, food contact substances and iodine. Chemical product recalls were more common within the UK and Republic of Ireland (19%), in comparison to the USA (6%), mainly due to a series of recalls associated with Sudan 1, Sudan 4 and Para Red dyes in 2005. Overall, the incidence of product recalls caused by chemical contaminations does not display any clear trend, with an average of three chemical recalls per quarter in the USA and four chemical recalls per quarter in the UK and the Republic of Ireland. The frequency of chemical product recalls does however appear to be driven by a number of large multi-state and multi-country recalls. For example, the high number of chemical product recalls in 2004 and 2005 were due to the Sudan 1, Sudan 4 and Para Red dye contaminations that primarily affected firms within the UK, while the

peak in chemical product recalls in Q2 2007 was due to a large increase in the number of recall announcements attributable to Melamine. In a similar vein, the largest peak in chemical product recalls in Q4 2009 was the result of a substantial rise in the number of Melamine recalls in the USA, which also coincided with the largest food recall in Ireland's history caused by a dioxin contamination in its poultry industry (Banati, 2011).

The RASFF hazard categories were used to codify the majority of chemical hazards, with additional categories included from prior research by Kleter *et al* (2009). Table 3 presents the different chemical product recalls, categorized by different chemical hazard categories and ordered according to their frequency. The most frequent category of chemical product recall was related to the unauthorized use of dyes within agri-food products, representing 34% of all chemical recalls. These were attributable to a large-scale food recall in 2004 in the United Kingdom of Sudan 1, Sudan 4, and Para Red dyes. Twenty-two percent of chemical product recalls were caused by allergens detected within agri-food products, constituting the second most frequent type of chemical product recall, especially in the USA. The third most frequent category of chemical product recall was melamine, representing 15% of all chemical hazards in this study. Chemical contaminations and drugs were each responsible for 9% of all chemical product recalls, especially veterinary drugs, drug contaminations, drug residues, and Chloramphenicol. Although dioxins were found to occur only 8 times in the sample period, representing 4% of chemical product recalls, they were associated with one of the largest food recalls in the Republic of Ireland in 2008. Finally, irradiation, food additives, 3-MCPD, pesticides, heavy metals, food contact substances and Iodine each represent less than five percent of all the chemical product recalls in Table 3. A wide variety of chemical hazards were not associated with any food recalls between 2004-2010, including different types of allergens (e.g. undeclared Suplhites), drug contaminations (e.g. Furazolidone, Leucomalachite Green, and Nitrofuran Metabolite SEM), food additives (e.g. E 452–Polyphosphates, colour additives), pesticides (e.g. Amitraz, Carbendazim, Chlormequat), heavy metals (Arsenic, Madmium, Mercury), food contact substances (e.g. 4, 4-Diaminodiphenylmethane, Formaldehyde, Phthalates), and other chemical hazards (e.g. feed additives, nitrates, pollutants).

<< Insert Table 4 >>

Conclusions

The growing number of product recalls within the agri-food industry has caused many to question the ability of retailers, producers and suppliers to provide safe products. It is against this background that we reviewed the key patterns and longitudinal trends in the prevalence of food recalls in the USA, UK and the Republic of Ireland from 2004 to 2010. We identify a growing trend of product recalls within the agri-food industry, with the majority of recalls detected by regulators rather than by suppliers, firms and distributors along the farm-to-fork supply chain. Considerable inter-industry variations were also observed in the frequency of different recalls, with the processed food industry accounting for the largest share of recalls, followed by the meat and meat products industry and the fruit, vegetables and salads industry.

Contrary to expectations and prior research that places a large emphasis on biological hazards, we identify that operational hazards are the most common cause of product recalls within the agri-food industry. These findings highlight the need for future research to investigate how these avoidable operational hazards can be prevented during production and procurement. For example, future research might examine how statistical quality control (Hubbard, 2003), lean

production (Simons & Zokaei, 2005), HACCP (Kumar & Budin, 2006), FMEA (Bertolini *et al*., 2006), supply chain traceability (Roth *et al*., 2008), and supply chain risk management (Tang, 2006) are being used within the agri-food industry to prevent operational hazards. The results from this study also identify that biological product recalls, such as Listeria, E-Coli and especially the growing incidences of Salmonella outbreaks in the USA continue to represent a significant cause of food recalls. Although at present chemical product recalls account for a small proportion of product recalls, the longitudinal data reveals that particular rare-event chemical recalls, such as the Irish pork dioxin contamination, can have a significant detrimental effect on individual agri-food industries. We also identified a large number of biological and nonbiological hazards that are not currently being detected, or are not major causes of product recalls within the agri-food industry.

Limitations: Although every effort was made to capture the frequency and details of product recalls throughout the seven-year period, the data within this study focuses only on registered product recalls. It is possible that many quality defects, ingredient contaminations and food borne illnesses go undetected within the agri-food supply chain. While undoubtedly some defective products entered the food supply chain, but have not been reported to these government organizations, it seems likely that the key product recalls are being detected and included in this study. Moreover, although this approach to data collection from different organizations and countries has been used by previous research in the food safety literature (Nepusz *et al*., 2008; Kleter *et al*., 2009), it has not been possible to entirely rule out inter-country and inter-industry variations in definitions, reporting mechanisms and data collection procedures.

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Fig. 1. Longitudinal trends in product recalls by country (2004-2010)

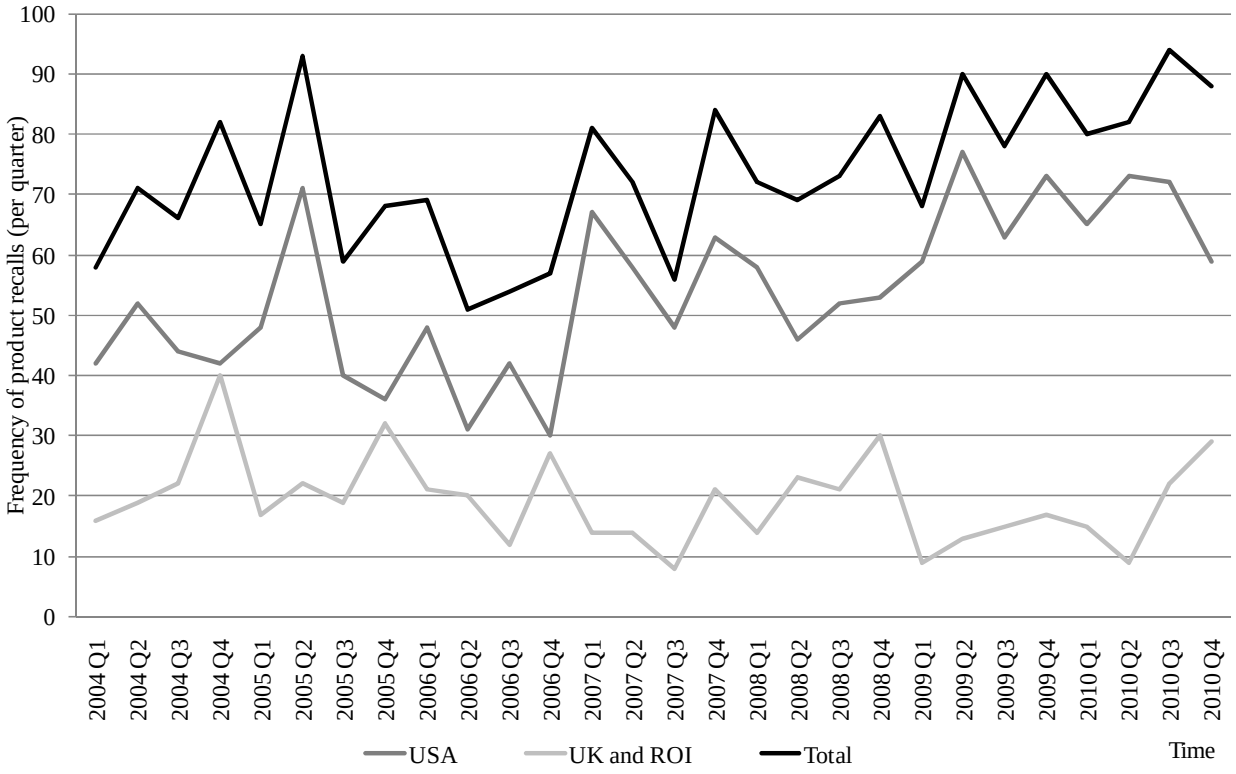

Table 1. Frequency of product recalls by sub-industry (2004 – 2010)

Sub-industry	**Total (%[a])**		**Most frequent recalls in each industry**		
	(USA[b], UK & ROI[c])		*First[d]*	*Second*	*Third*
Processed foods	**24**	*(24, 24)*	Defective Ingredient (27%)	Undeclared ingredient (21%)	Salmonella (8%)
Meat and meat products	**13**	*(15, 5)*	E. Coli (33%)	Listeria (19%)	Incorrect labeling (16%)
Fruit, vegetables and salads	**10**	*(13, 3)*	Salmonella (27%)	Undeclared ingredient (22%)	Incorrect labeling (21%)
Dairy	**6**	*(7, 4)*	Listeria (35%)	Incorrect labeling (14%)	Undeclared ingredient (10%)
Fishery products	**6**	*(6, 4)*	Listeria (31%)	Bacterial contamination (22%)	Incorrect labeling (15%)
Nuts and nut products	**5**	*(4, 7)*	Salmonella (65%)	Incorrect labeling (13%)	Undeclared ingredient (10%)
Snack	**5**	*(5, 6)*	Incorrect labeling (36%)	Undeclared ingredient (21%)	Manufacturing defect[5] (8%)
Confectionary	**4**	*(3, 6)*	Incorrect labeling (33%)	Undeclared ingredient (21%)	Metal contamination (11%)
Poultry meat and products	**4**	*(4, 3)*	Listeria (33%)	Incorrect labeling (24%)	Manufacturing defect (10%)
Soups broths and sauces	**4**	*(3, 4)*	Incorrect labeling (31%)	Chemical contamination (14%)	Undeclared ingredient (11%)
Herbs and spices	**3**	*(2, 5)*	Salmonella (37%)	Incorrect labeling (26%)	Undeclared ingredient (12%)
Non-alcoholic beverages	**3**	*(2, 6)*	Bacterial Contamination (20%)	Chemical contamination (11%)	E. Coli (11%)
Composite mixed	**2**	*(2, 3)*	Food fraud (17%)	Listeria (15%)	Incorrect labeling (15%)
Bakery	**2**	*(2, 3)*	Undeclared ingredients (30%)	Incorrect labeling (26%)	Manufacturing defect (17%)
Pet food	**2**	*(3, 0)*	Salmonella (66%)	Melamine (17%)	Manufacturing defect (7%)
Fats and oils	**1**	*(0, 6)*	Unauthorized colour Sudan 4 (93%)	Manufacturing defect (3%)	Bacterial contamination (3%)
Baby food	**1**	*(1, 3)*	Incorrect labeling (21%)	Plastic contamination (17%)	Spoilage (14%)
Cereals and other crops	**1**	*(1, 3)*	Insect/pest contamination (37%)	Undeclared ingredient (22%)	Unauthorized GM[2] (11%)
Animal feed	**1**	*(1, 0)*	Bacterial Contamination (28)	Other veterinary drug contaminations (22%)	Melamine (17%)
Alcoholic beverages	**1**	*(0, 3)*	Food Fraud (47%)	Glass contamination (33%)	Incorrect labelling[1] (7%)
Food supplements	**1**	*(0, 1)*	Incorrect labeling (29%)	Undeclared ingredient (21%)	Defective product (14%)
Eggs and egg products	**1**	*(1, 1)*	Salmonella (46%)	Metal contamination (15%)	Listeria[4] (8%)
Cocoa, coffee and tea	**1**	*(1, 0)*	Undeclared ingredients (33%)	Glass contamination (17%)	Incorrect labelling[3] (17%)
Food contact materials	**0**	*(0, 0)*	Migration of Lead (33%)	Migration of primary aromatic amines (33%)	Dioxins (33%)
Honey	**0**	*(0, 0)*	Chloramphenicol (50%)	Food fraud (50%)	n.a.

n= 2,053

[a] Percent of all recalls within the dataset that originate within each sub-industry; [b] Percent of all recalls within the USA that originate within each sub-industry; [c] Percent of all recalls within the UK and the Republic of Ireland that originate within each sub-industry; [d] Percent of all recalls within the sub-industry (inc. USA, UK & ROI); *1* = Manufacturing defects and chemical contaminations are also the third most frequent type of recall in this sub-industry; *2* = Incorrect labelling is also the third most frequent type of recall in this sub-industry; *3* = Melamine is also the third most frequent type of recall in this sub-industry; *4* = Allergens, incorrect labelling, undeclared ingredient, and glass contamination are also the third most frequent type of recall in this sub-industry; *5* = Allergens are also the third most frequent type of recall in this sub-industry

Table 2. Frequency of operational product recalls (2004 to 2010)

Operational Categories:	Total N *(USA, UK & ROI)*		Total % *(USA, UK & ROI)*	
Incorrect Labelling:	**416**	***(349, 67)***	**37**	***(43, 21)***
Undeclared Ingredient:	**280**	***(259, 21)***	**25**	***(32, 7)***
Production Contamination:	**198**	***(67, 131)***	**17**	***(8, 41)***
Metal Contamination	58	*(27, 31)*	5	*(3, 10)*
Glass Contamination	52	*(14, 38)*	5	*(2, 12)*
Plastic Contamination	50	*(21, 29)*	4	*(3, 9)*
Insect/Pest Contamination	23	*(2, 21)*	2	*(0, 7)*
Rubber Contamination	10	*(1, 9)*	1	*(0, 3)*
Poison	5	*(2, 3)*	0	*(0, 1)*
Production Defect:	**96**	***(67, 29)***	**8**	***(8, 9)***
Manufacturing Defect	88	*(65, 23)*	8	*(8, 7)*
Defective Product	5	*(2, 3)*	0	*(0, 1)*
Bad or Insufficient Controls	2	*(0, 2)*	0	*(0, 1)*
Defective Ingredient	1	*(0, 1)*	0	*(0, 0)*
Food Fraud:	**38**	***(27, 11)***	**3**	***(3, 3)***
Packaging Defect:	**32**	***(8, 24)***	**3**	***(1, 7)***
Packing Defect:	**22**	***(6, 16)***	**2**	***(1, 5)***
Foreign Bodies:	**22**	***(9, 13)***	**2**	***(1, 4)***
Spoilage:	**19**	***(5, 14)***	**2**	***(1, 4)***
Incorrect Ingredient Level:	**16**	***(12, 4)***	**1**	***(1, 1)***
High Ingredient Level	10	*(7, 3)*	1	*(1, 1)*
Low Ingredient Level	6	*(5, 1)*	1	*(1, 0)*
Unauthorized Ingredient:	**11**	***(6, 5)***	**1**	***(1, 2)***
Unauthorised placing on the market	6	*(6, 0)*	1	*(1, 0)*
Unauthorised Genetic Modification	5	*(0, 5)*	0	*(0, 2)*
Suffocation Risk:	**10**	***(2, 8)***	**1**	***(0, 2)***
No Information	**2**	***(2, 0)***	**0**	***(0, 0)***
TOTAL (Operational Recalls)	**1132**	***(811, 321)***	**100**	***(100, 100)***

Note: Operational hazards not associated with any product recalls, include Carbon Monoxide Treatment and Animal Constituents.

Table 3. Frequency of biological product recalls (2004 to 2010)

Biological Categories	Total N (USA, UK & ROI)		Total % (USA, UK & ROI)	
Bacteria:	**713**	***(618, 95)***	**96**	***(99, 79)***
Listeria Monocytogenes	249	*(233, 16)*	34	*(37, 13)*
Salmonella	275	*(217, 58)*	37	*(35, 48)*
Escherichia Coli (E-Coli)	111	*(103, 8)*	15	*(17, 7)*
Bacterial Contamination	77	*(65, 12)*	10	*(10, 10)*
Too high count of Faecal Coliforms	1	*(0, 1)*	0	*(0, 1)*
Biotoxins:	**14**	***(3, 11)***	**2**	***(0, 9)***
Aflatoxins	13	*(3, 10)*	2	*(0, 8)*
Fumonisins	1	*(0, 1)*	0	*(0, 1)*
Moulds:	**12**	***(0, 12)***	**2**	***(0, 10)***
Biological Contamination:	**2**	***(0, 2)***	**0**	***(0, 2)***
Disease Contamination:	**1**	***(1, 0)***	**0**	***(0, 0)***
TOTAL (Biological Recalls)	**742**	***(622, 120)***	**100**	***(100, 100)***

Note: Biological hazards not associated with any product recalls include: *(i) Bacteria:* Campylobacter Spp., Vibrio, Too high count of Enterobacteriaceae, and Too high count of Aerobic Mesophiles; *(ii) Biotoxins:* Deoxynivalenol, Ochratoxin A, Patulin, Marine Biotoxins, and Zearalenone; *(iii) Viruses:* Calicivirus, Hepatitis A Virus, and Norovirus; *(iv) Other biological hazards:* Mites, Parasites, BSE, and Foot and Mouth Disease.

Table 4. Frequency of chemical product recalls (2004 to 2010)

Chemical Categories	Total N *(USA, UK & ROI)*		Total % *(USA, UK & ROI)*	
Dyes:	**67**	***(0, 67)***	**34**	***(0, 63)***
Unauthorised Colour Sudan 1	31	*(0, 31)*	16	*(0, 29)*
Unauthorised Colour Sudan 4	30	*(0, 30)*	15	*(0, 28)*
Unauthorised Colour Para Red	6	*(0, 6)*	3	*(0, 6)*
Allergens:	**43**	***(43, 0)***	**22**	***(48, 0)***
Allergen	40	*(40, 0)*	20	*(44, 0)*
Histamine	3	*(3, 0)*	2	(3, 0)
Melamine:	**29**	***(22, 7)***	**15**	***(24, 7)***
Chemical Contamination	**18**	***(10, 8)***	**9**	***(11, 8)***
Drugs:	**17**	***(9, 8)***	**9**	***(10, 8)***
Other Veterinary Drug Contaminations	10	*(8, 2)*	5	*(9, 2)*
Drug Contamination	5	*(1, 4)*	3	*(1, 4)*
Drug residues	1	*(0, 1)*	1	*(0, 1)*
Chloramphenicol	1	*(0, 1)*	1	*(0, 1)*
Dioxins:	**8**	***(3, 5)***	**4**	***(3, 5)***
Irradiation / Radioactivity:	**4**	***(0, 4)***	**2**	***(0, 4)***
Food Additives:	**3**	***(0, 3)***	**2**	***(0, 3)***
Too high content of E 210 - Benzoic Acid	3	*(0, 3)*	2	*(0, 3)*
3-Monochlor-1,2-Propanediol (3-MCPD):	**2**	***(0, 2)***	**1**	***(0, 2)***
Pesticides:	**2**	***(2, 0)***	**1**	***(2, 0)***
Pesticide residues in general	1	*(1, 0)*	1	*(1, 0)*
Other Pesticide Contaminations	1	*(1, 0)*	1	*(1, 0)*
Heavy Metals:	**1**	***(1, 0)***	**1**	***(1, 0)***
Migration of Lead	1	*(1, 0)*	1	*(1, 0)*
Food Contact Substances:	**1**	***(0, 1)***	**1**	***(0, 1)***
Migration of Primary Aromatic Amines	1	*(0, 1)*	1	*(0, 1)*
High Content of Iodine:	**1**	***(0, 1)***	**1**	***(0, 1)***
TOTAL (Chemical Recalls)	**196**	***(90, 106)***	**100**	***(100, 100)***

Note: Chemicals not associated with any product recalls include: *(i) Allergens:* Too high content of sulphites, and Undeclared sulphite; *(ii) Drugs:* Furazolidone, Leucomalachite Green, Malachite Green, Nitrofurazone, Nitrofuran Metabolite SEM, AOZ, AMOZ, Sulphonamides, and Streptomycin; *(iii) Food Additives:* E 452 - Polyphosphates, Unauthorised Food Additives (other), Too high content of Colour Additives, and Unauthorised use of Colour Additives; *(iv) Pesticides:* Amitraz, Carbendazim, Chlormequat, Dimethoate, Omethoate, Methamidophos, Methomyl, Monocrotophos, Oxamyl, and Unauthorised Isofenphos-Methyl; *(v) Heavy Metals:* Arsenic, Cadmium, Mercury, Migration of Chromium, Migration of Cadmium, and Migration of Nickel; *(vi) Food Contact Substances:* 4,4-Diaminodiphenylmethane, Migration of Formaldehyde, ITX isopropyl-

thioxanthone, Phthalates, and too high level of total migration; *(vii) Other chemical hazards:* Caffeine / Taurine, Disinfectant, Ethanol, Feed Additive, Glycol Ether, Herbs, Microbial Toxin, Mineral, Narcotic, Natural Toxin, Nitrate/Nitrite, Peroxide, Pollutant, and Polycyclic Aromatic Hydrocarbons.