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OCCURRENCE AND ASSESSMENT OF PHYSICAL CONTAMINANTS BASED ON FOOD RECALLS IN CANADA

***Mohd Taufiq Mohd KHAIRI[1], Sallehuddin IBRAHIM[1], Mohd Amri Md YUNUS[1], Mahdi FARAMARZI[1], Jaysuman PUSPPANATHAN[2], Azwad ABID[1]**

[1]School of Electrical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor, Malaysia.
[2]Sport Innovation and Technology Centre (SITC), Institute of Human Centred Engineering (IHCE), School of Biomedical Engineering & Health Sciences, Faculty of Engineering, Universiti Teknologi Malaysia, Johor, Malaysia.
taufiq_khairi@yahoo.com
*corresponding author
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Abstract: *This paper investigates the association between types of food products, physical contaminants and year using food recalls dataset obtained from the Canadian Food Inspection Agency (CFIA) between 2014 and 2019. In the period of studies, a total of 269 foods under the category of physical hazards were recalled. Chi-square per cell test was used to deeply analyse the contingency table of the investigated topic categories. The results show that there is no association between the year and the number of food recalls by food products and year by physical contaminants type. However, the results indicated that there is an association between the food products and physical contaminants type. In particular, there were significant numbers of insects being found in grain and fruits/vegetables products with 15 and 53 cases, respectively. Plastic and bone fragments were significantly found in dairy and meat, poultry and seafood products, respectively with 9 and 15 cases. Glass was significantly found in wine and beverage (6 cases) and other food product (9 cases). Plastic material was highly detected in candy and confectionery product with 9 cases. The sources of the physical contaminants have been analysed, together with the precautionary measures that must be taken. Findings from this study provide the food industry with essential information. An understanding and analysis of physical hazards is critical for companies in order to restructure their food safety policies and technologies.*

Keywords: *Physical contaminants, food recall, food safety, foreign bodies*

1. Introduction

Food contaminated by hazardous agents may endanger the consumer's safety. Among the classifications of hazards there are chemical, biological and physical ones [1]. Chemical hazards include water, pesticides and food additives. Viruses (*Hepatitis A* and *Rotavirus*), parasites (e.g. *Trichinella spiralis* and *Cryptosporidium parvum*) and harmful bacteria (*Bacillus cereus* and *Salmonella*) are biological hazards [2]. On the other hand, physical hazard in food may refer to a foreign body that existed in a food product [3,4]. Objects such as metal fragments, glass, plastic pieces, stones, insects and wood debris are among frequent type of objects that have been found in food [5,6]. The existence of a foreign body may harm the consumer if it is accidentally being consumed. It can cause choking and internal injuries especially in the abdomen and intestines when it is ingested. As a consequent, surgery needs to be carried out to remove the foreign body [7]. A foreign body might accidentally enter food at any stage of the food chain such as processing,

packaging and distribution of food. Food and Drugs Administration (FDA) has regulated that the unwanted object in food that has a length of 7 mm to 25 mm is considered as a foreign body [8].

The food industry makes numerous efforts to avoid unwanted foreign objects in food. Several technologies and techniques have been applied to detect foreign bodies such as a metal detector, magnet, X-ray, ultrasound, near-infrared, terahertz and surface penetrating radar [9–11]. Although these methods are available, there are still cases of food recalls by food agencies. Some manufacturers do not use these technologies due to cost constrain. In addition, the weaknesses of each technique have restricted their applications and abilities to detect all types of foreign bodies. Recall notifications have to be made when the foods are believed to be contaminated and may harm the consumers. The food recalls were usually conducted by the food manufacturer or distributor. It also can be requested by government authorities or agencies around the world. The food recalls statistics is annually published based on the data collected from reports or complaints from a variety of sources such as manufacturers, retailers, government agencies and consumers. Several authors used the database in their research primarily for analysis of microbial and chemical hazard [12–15].

Although there have been numerous studies conducted on high-risk pathogenic threats such as *Salmonella*, *E. coli*, and *Listeria*, to our knowledge still there is a lack of research in food recalls focusing on physical hazards which are equally important to address. Food recalls analysis in food industry was performed in recent studies by Potter et al. [16] and Page [17] where the results revealed that the number of recalls regarding the physical hazard is less frequent than biological and chemical hazards. Therefore, the study and analysis on physical hazard is important, rendering possible the use as references for manufacturers to implement the Hazard Analysis and Critical Control Point (HACCP) program in order to predict the causes and implement preventive measures related to type of particular physical hazards and a particular type of food. Food recalls can cause significant economic losses in food industry and consumers also could lose their confidence in that product [18–20]. In this sense, the aim of this study is to provide a descriptive statistics of food recalls cases based on physical contamination occurring in Canada from the year 2014 to 2019.

2. Matherials and methods

2.1 Sampling

The data were collected from the Canadian Food Inspection Agency (CFIA) website (http://www.inspection.gc.ca). The website showed that the food that had been recalled was due to biological, chemical and physical hazards. All notifications that were recorded in the website under the physical hazard category were extracted for the period from January 1, 2014 to December 31, 2019. Within the records, the year, the food product category and type of foreign bodies were classified and tabulated in tables. All the degree classes of health risk which are class I, class II and class III are considered in the sampling data.

2.2 Statistical analysis

The association between the year and the number of food recalls by product category and types of foreign bodies were evaluated using the global chi-square test and chi-

square per cell test [21]. The tests had been used in previous food safety studies for dairy foods [22] and moldy foods [23]. In this study, the test has been carried out to determine whether there are statistically significant differences between different types of food products, different types of foreign objects and year. The statistical processing was performed using XLSTAT 2019.2 software (Adinsoft, Paris, France) and the statistical level significance was set at $\alpha = 0.05$.

3. Results and discussion

In the period of 2014 - 2019, a total of 269 foods from CFIA under the category of physical hazard were recalled where the distribution by year is shown in Figure 1. The data show that the year 2016 has the highest number of food recalls with 58 cases. The trend of graph also revealed that the number of recalls have increased from the year 2014 to 2016 before it fell consecutively in 2017 and 2018. In 2019, the recalls number increased with 43 cases.

The total of food recalls has been sorted into food categories as shown in the Figure 2. The statistic shows that the fruit and vegetable products have the highest number of recall notifications with 82 cases, followed by meat, poultry and seafood products (50 cases), other food products (35 cases), grain and cereals (29 cases) as well as candy and confectionary (20 cases). Other food products comprise foods such as soup, sauce, vinegar and baby food.

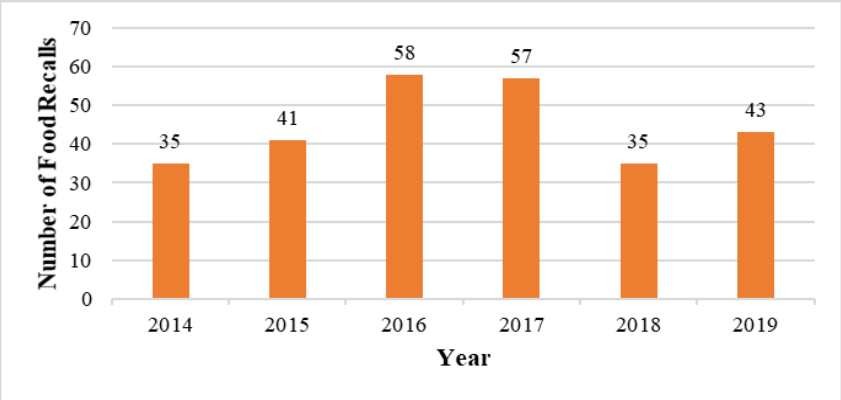

Fig. 1: Number of foods recalls due to physical hazards from the year 2014 to 2019

Table 1 and Table 2 show the quantitative data from 2014 to 2019 for types of food products and types of foreign bodies, respectively. As computed with global chi-square test, there was no association between the year and the type of food product (observed $\chi^2 = 47.909$; critical $\chi^2 = 72.153$; $p = 0.707$) as well as types of foreign bodies (observed $\chi^2 = 56.453$; critical $\chi^2 = 72.153$; $p = 0.383$). The results show that the p-value for both tables are greater than the significance level $\alpha = 0.05$.

In Table 1, the chi-square test per cell shows similar citations for all types of food products except nut and bakery products throughout the years of study. A lower citation was observed in 2015 for breads/bakery products. In 2018 and 2019, lower citation was demonstrated for nut. High citations were revealed for breads and bakery with 7 cases in 2019. Overall, there was no significant difference in citations for all food products except for nut and breads/bakery products.

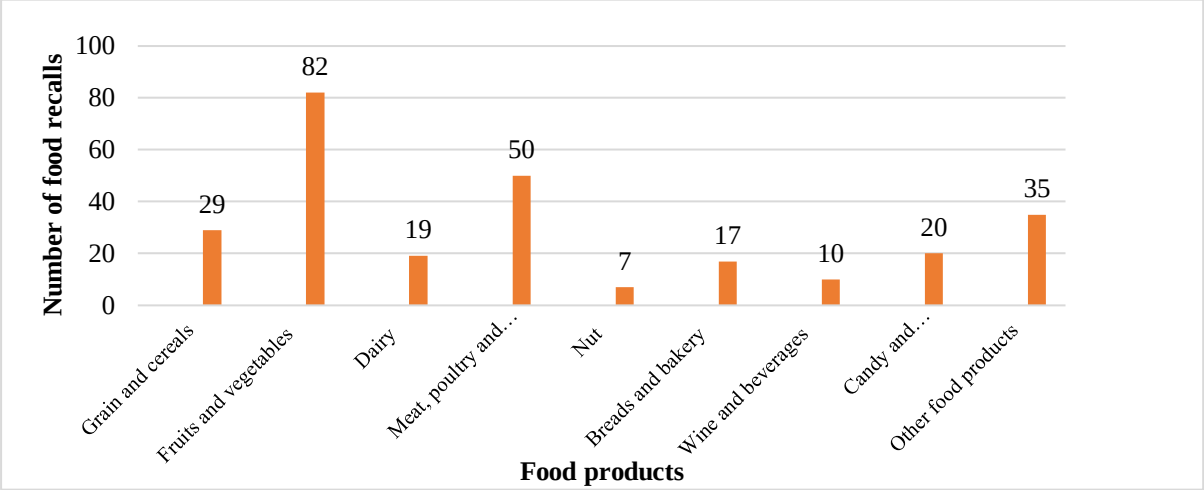

Fig. 2: Number of foods recalls due to physical hazards for different food products

The results of chi-square test per cell for the types of foreign bodies from 2014 to 2019 are shown in Table 2. Metal item indicated that it was the most significantly cited in 2014 and has a lower frequency of citation in 2015. It can also be observed that the item plastic did not reveal any significant differences of citations during the period of study. Glass and insects are noticeably less cited in 2017 and 2015, respectively. Fewer citations are also observed for bone in 2018 and rubber items in 2014 and 2019. Wood item indicated that it was significantly less cited in 2017 and 2018, while stone item shows the same results in 2014, 2016 and 2017. Finally, there was no significant difference in citations for unknown object throughout the years of study. Overall, food recalls caused by insects had shown the highest notification in 5 years with 81 cases, followed by metal (56 cases), plastic (50 cases), unknown object (25 cases) and glass (22 cases). The unknown object is considered as a solid object whose material cannot be identified.

Table 1

Distribution of foreign bodies based on product type from the year 2014 to 2019

Product type	**Years**						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Grain and cereals	2	7	10	3	3	4	29
Fruit and vegetables	13	8	18	20	14	9	82
Dairy	1	5	2	7	3	3	19
Meat, poultry and seafood	9	11	6	10	5	9	50
Nut	1	1	1	2	0(-)*	0(-)*	7
Breads and bakery	2	0(-)*	5	2	1	7(+)*	17
Wine and beverages	1	2	2	2	2	1	10
Candy and confectionery	1	3	2	7	3	2	20
Other food products	5	4	12	4	4	8	35
Total	35	41	58	57	35	43	269

* The effect of the chi-square per cell. (+) or (-) indicates that the observed value is higher or lower than the expected theoretical value. Significance level, $\alpha < 0.05$.

Table 2

Distribution of types of foreign bodies from the year 2014 to 2019

Foreign bodies	Years						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Metal	13(+)*	4(-)*	14	7	8	10	56
Plastic	8	11	8	14	4	5	50
Glass	3	4	5	1(-)*	5	4	22
Insects	6	7(-)*	20	23	13	12	81
Bone	1	3	2	5	0(-)*	6	17
Rubber	0(-)*	3	2	1	1	0(-)*	7
Wood	1	2	2	0(-)*	0(-)*	1	6
Stone	0(-)*	1	0(-)*	0(-)*	1	3	5
Unknown	3	6	5	6	3	2	25
Total	35	41	58	57	35	43	269

* The effect of the chi-square per cell. (+) or (-) indicates that the observed value is higher or lower than the expected theoretical value. Significance level, $\alpha < 0.05$

In Table 3, a global chi-square test revealed that there is an association between food products and types of foreign bodies (observed $\chi^2 = 190.512$; critical $\chi^2 = 103.010$; $p < 0.0001$). As computed, the p-value is lower than the significance level $\alpha = 0.05$. The results of chi-square per cell test for product and foreign body types are demonstrated in Table 3. The statistics revealed that grain and cereal products have low citation for wood item with no recall notification. Concerning fruits and vegetables, it is observed that insects are significantly more cited, and the other items show fewer citations except rubber and the unknown object. Dairy product presented a higher frequency of citation for plastic item and fewer citations for insects, bone, rubber, wood and stone. The citations for meat, poultry and seafood product are significantly higher for bone and significantly lower for glass, insects and stone. There is no recall notification regarding nut product for metal, glass, bone, rubber, wood, stone and unknown objects. For breads and bakery products, lower citations are observed for bone, rubber, wood, stone and unknown objects. Wine and beverages are markedly significantly higher for glass item and there are no complaints regarding plastic, bone, rubber, wood and stone. Candy and confectionery show low citation for glass, insects, bone and stone items. Finally, other food products exhibited a higher frequency of citations for glass items and fewer citations for bone and rubber items.

The correlation between food products and the types of foreign bodies is interesting to analyse. Overall, insect items have the most recall notifications among food products, followed by metal and plastic items with 69, 46 and 45 cases, respectively. All types of foreign bodies have been reported in the period of studies except for wood in grain and cereals products. Insects such as ant, flies and larvae show the most recalls in the fruit and vegetable products with 47 cases. This is not surprising because insects are usually attracted to this kind of products. Sometimes, there are hidden or trapped in the product which is difficult to detect. Visual inspection systems such as

conventional X-ray has difficulty in detecting insects because it cannot distinguish the difference between the density of the product and insects [24]. Terahertz and near-infrared techniques could be utilized to detect insects as reported in [25–27]. This kind of contamination has to be prevented and removed since it may bring along pathogens and germs.

Table 3

Distribution of physical hazards incidence according to product and foreign bodies types

Product Types	Foreign bodies									
	Metal	**Plastic**	**Glass**	**Insects**	**Bone**	**Rubber**	**Wood**	**Stone**	**Unknown**	**Total**
Grain and cereals	6	2	2	10	2	1	0(-)*	1	1	25
Fruits and vegetables	7(-)*	5(-)*	2(-)*	47(+)*	0(-)*	3	0(-)*	0(-)*	9	73
Dairy	5	8(+)*	1	1(-)*	0(-)*	0(-)*	0(-)*	0(-)*	3	18
Meat, poultry and seafood	13	10	0(-)*	1(-)*	9(+)*	2	2	0(-)*	4	41
Nut	0(-)*	3	0(-)*	2	0(-)*	0(-)*	0(-)*	0(-)*	0(-)*	5
Breads and bakery	3	5	1	1	0(-)*	0(-)*	0(-)*	0(-)*	0(-)*	10
Wine and beverages	1	0(-)*	5(+)*	1	0(-)*	0(-)*	0(-)*	0(-)*	2	9
Candy and confectionery	6	7	0(-)*	0(-)*	0(-)*	1	1	0(-)*	1	16
Other food products	5	5	7(+)*	6	0(-)*	0(-)*	2	1	3	29
Total	46	45	18	69	11	7	5	2	23	226

* The effect of the chi-square per cell. (+) or (-) indicates that the observed value is higher or lower than the expected theoretical value. Significance level, $\alpha < 0.05$.

For dairy products, plastic is the most frequent foreign body that leads to recall notifications with 8 cases, followed by metal with 5 cases. Plastic fragments may exist through packing debris, equipment and pallets. Several techniques that can be used to detect plastic materials are the filtering method [28], ultrasound [29] and hyperspectral imaging [30]. The conventional X-ray may not be appropriate to utilize since X-ray has a limitation in detecting low-density materials like insects and plastic. However, Li et al. [24] and Einarsdóttir et al. [31] have proposed a solution on this issue by introducing the polycapillary X-ray lens and grating-based multimodal X-ray imaging.

Metal has been mostly found in meat, poultry and seafood products which subsequently lead to recall warning. The existence of metal might be due to fragments from chopping tools and machine equipment parts [32]. Bone had been observably getting more citations in this type of food product where the source might come from the raw materials itself such as bones in fish or meat. It may due to the imperfect separation process between fish/meat and bone. Metal and bone items could be distinguished using visual inspection such as Near-infrared (NIR) spectroscopy [33] and hyperspectral imaging (HSI) technique [34]. The presence of metal also can be prevented by utilizing low cost techniques such as metal or magnet detection system [35]. The food recalls for nut and bakery products is mostly due to plastic debris with 3 and 5

cases have been reported, respectively. Whereas, broken glass was frequently found in wine and beverages as well as other food products. It may be due to broken containers and jars that are used to fill up the product [36]. Imaging techniques such as thermal imaging [37], ultrasound [38] and terahertz [39] are suitable to be applied for monitoring this kind of products since it is non-invasive and suitable be use in the production line. With regard to candy and confectionery product, plastic and metal materials had contributed to the food recall with 7 and 6 cases, respectively. These items probably originated from the packaging material and machinery parts.

Early detection and removal of foreign bodies are important to maintain good manufacturing practice. Preventive measures for the presence of foreign bodies can be divided into three main categories stages; plant/raw material, processing and final product. Pest control implementation can prevent pesticides from attacking the raw materials [40]. The use of technology such as sieving and filtration system to detect foreign bodies can be applied in food plant and food processing environment. Periodic training should be given to employees in handling the process of food production and monitor by supervisors [41]. Employees must be always reminded to practice good personal hygiene such as keep hand's clean, short fingernails, avoid wearing jewellery and wearing clean clothes. Food products are usually packed and located in the final production line. Therefore, visual inspection technologies such as X-ray, hyperspectral and ultrasound imaging systems are best suited to be utilized to ensure food is completely free from foreign materials [42]. The imaging systems have several advantages such as non-invasive and non-destructive, able to operate in real-time and provide high imaging resolution. However, not all companies especially in small scale industry are afforded to utilize it due to the high cost [43].

4. Conclusion

The findings show that food recalls due to the incidence of physical contaminants is relatively small compared to biological and chemical contaminants; still, it should not be neglected. Food recall is a vital action to ensure that all the affected products are removed from the market as soon as possible. Detection techniques especially visual inspection play important role in ensuring the highest safety and quality level regardless of the food product type. Authorities need to make periodic inspections to ensure that the manufacturers comply with the Good Manufacturing Practice (GMP) and Standard Operating Procedure (SOP) for handling food. The food adulteration due to foreign bodies can be avoided with the cooperation and endeavour of all the parties involved.

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