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Methods to Prevent Marketing and Distribution of Physically Contaminated Food Products

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Abstract:

Purpose: *In this publication, we analyzed the data of physical contaminants in food. It was indicated, what kind of physical hazards exist in food and presented changes occurring as physical hazards over the analyzed period.*
Approach/Methodology/Design: *The publication used a critical literature review and presents data compiled from notifications reported to the RASFF (Rapid Alert System for Food and Feed) system.*
Findings: *From 2015 to 2019, the number of physical threats reported to the RASFF system ranged from 3,0 % to 5,6 %, which is on average 4,4 % of all notifications in the analysed period. It is important, because any potential threat may affect not only health, but also the lives of consumers.*
Practical Implications: *In terms of identifying and counteracting physical hazards to food products, the final, but extremely important part of this publication is the presentation of devices used to detect and prevent the presence of physical contaminants in the final product offered to consumers.*
Originality/Value: *In the article it was indicated that despite the enormous technological advances, the risks related to the possible occurrence of physical contamination existing in food are still unavoidable.*

Keywords: *Food safety, physical hazards, RASFF, Contaminants detection.*

JEL classification: *I11, I12, R41, R42.*

Paper Type: *Research article.*

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1. Introduction

Coupled with problems of economic and social nature related to insufficient food distribution and management, and consequently hunger and malnutrition, threats have emerged that directly affect the quality of food. To respond to the new challenges, the concept of food security has been extended to include issues related to food safety. The world of science, in close cooperation with the economic environment, has defined the existing threats present in food and proposed solutions to detect them and, above all, to prevent product contamination during production. Quality and food safety management systems and standards have been developed to regulate the conditions of production necessary to produce food of the required quality and safety, and tools such as the Rapid Alert System for Food and Feed (RASFF), which aims to provide early notification of food safety risks.

Physical hazards are present in food products at all stages of the food chain, from production to storage and transport of food. The primary cause of physical hazards is failure to comply with production and hygiene procedures. Some contaminants occur naturally in the raw material, which is why it is crucial that pretreatment is carried out properly. Defective cleaning and sorting equipment, lack of maintenance and control of its operation may be responsible for the migration of contaminants into the subsequent stages of the production process. Furthermore, workers themselves can be a source of contamination. Seen from this perspective, the sources of contamination may include lack of training, failure to observe basic rules of personal hygiene and failure to wear personal protective clothing (Ciecierska and Sobocińska, 2013). Despite the available contamination detection systems and hygiene and quality standards, production facilities still show inadequate hygiene conditions of production halls and insufficient safety measures to protect food from hazards. The problem described above is of great relevance, which is definitely confirmed by the number of notifications submitted to the RASFF system.

The aim of this publication is to present the problem of food safety with a focus on physical contaminants found in food based on an analysis of data on their occurrence as retrieved from the RASFF system, as well as to present an overview of the machinery and equipment used in the food industry to detect physical hazards.

2. Food Safety and Food Security

Food security mainly refers to ensuring sufficient food supplies at adequate prices and improving the efficiency of agricultural production (Michalczyk, 2019). There are three main pillars of food security, adequacy, access, and disposability. Adequacy is understood as food free of harmful substances and free of disease, availability means its unlimited supply, and finally, disposability denotes having enough food to make it available to all people at a given place and time (Leśkiewicz, 2012; Kwasek, 2012).

Food safety is complementary to food security. Compared to food security, food safety involves an aspect of quality, which assumes that food is healthy and nutritious, and that it meets norms and standards. Following these assumptions makes it possible to control and minimize the risk of food quality deterioration throughout the entire food chain, starting from production, through processing, distribution, and trade. Therefore, one may venture to assert that food safety has an interdisciplinary character, giving equal attention not only to the food chain, but also to the agricultural sector, plant cultivation, care for the natural environment, and animal welfare. It pays equal attention to chemical, physical and microbiological contamination of food, i.e., non-food and toxic components entering food during the production and processing process. Thus, food safety means concern for health-promoting and nutritious resources. Failure to ensure it has similar consequences as the failure to ensure physical and economic availability of food (i.e., food security) - malnutrition, hunger and, in extreme cases, death (Michalczyk, 2019).

Hazards in food safety can be defined as any factors whose presence in food can potentially affect the health and life of the consumer. A distinction is made between chemical hazards, such as toxins produced during the production process, biological hazards, such as pathogenic bacteria, and physical hazards, such as metal fragments or minor stones (Lawley, Curtis, and Davis, 2008). In the following part of the publication, due to the subject matter undertaken, attention is primarily given to physical hazards, with information and issues related to other hazards reduced to a necessary minimum.

3. Hazards in Food

Biological hazards:

Biological hazards, comprising a very large group of bacteria, molds, yeasts, insects and pathogens, are assumed to pose the greatest risk to consumer health. For example, some microorganisms found in food, such as Clostridium botulinum, Salmonella and E. coli, have the capacity to cause large disease outbreaks in a short period of time. Only a small number of food products at the production, storage and distribution stages are not susceptible to biological hazards. Biological contamination may also involve larger organisms, such as rodents and insects. However, they only very rarely pose a direct threat to health safety.

Chemical hazards:

Chemical contamination of food represents a small proportion of immediate threats to food security, particularly in developed countries. A more serious issue posing a direct threat to public health is the continuous exposure to small doses of residues of chemical compounds present in food products that are part of the daily diet. This can lead to chronic conditions and even cancer. Chemical contaminants may penetrate food at any stage in the production process. For instance, plant protection products such as herbicides or insecticides can accumulate in plants already at the primary production stage (i.e., during cultivation). Some raw materials may contain natural toxins, lubricants and detergents, which are potential sources of contamination during the processing of the raw material (Lawley, Curtis, and Davis, 2008). Of particular concern are mycotoxins, amongst which the best known are aflatoxin, ochratoxin A, fumonisin, and patulin. Mycotoxins are natural toxins harmful to humans and animals, produced by fungi under specific conditions as a secondary metabolite in response to competition from other fungi and bacteria. Although only a few of them can be found in food (in connection with the cultivation of crops such as cereals, maize or apples), they nevertheless have the potential to damage human and animal cells (Government of Canada, 2014).

Physical hazards;
A physical hazard is most commonly connoted as a foreign body whose presence in a food product is desired neither by the consumer nor by those who control product quality at the production, processing, and distribution stages. Unwanted physical bodies can be divided into two groups: organic and inorganic. The first group refers to all foreign bodies connected with the natural environment, humans, and animals, nails, teeth, bones, fish bones, stones, insects, hair, rodent droppings, leaves, sticks. The second group includes contaminants of inanimate matter such as: fragments of glass, plastics, metals, sand, peeling paint, stones (Ciecierska and Sobocińska, 2013).

A special category of food contaminants in the presented breakdown are physical contaminants of animal origin. These contaminants are characterised as parts of the animal which are generally not fit for consumption, e.g., skin, bones, gristle or feces. This is where, in addition to the quality aspect, the consumer aspect comes into play. Specifically, the presence of animal tissue or material that resembles animal tissue may be undesirable for consumers following a vegan or a vegetarian diet. Similarly, for those following a meat-based diet, any meat material that is edible but as a result of a technological process deviates in appearance from fresh meat is undesirable (Campden BRI, 2015). In such cases, the foreign body, i.e., animal tissue, does not pose a direct health risk to consumers, but may be a source of dissatisfaction and complaints.

According to other sources, physical contaminants can be classified by ways in which contaminants enter food. Such classification includes (Ciecierska and Sobocińska, 2013):

- contaminants present in raw materials (bones, fruit stones);
- contaminants which get into the product during the technological process (metal elements, plastic elements);
- contaminants deliberately introduced into the product;
- contaminants that get into the product along with the raw material (leaves, sticks, sand);
- contaminants due to non-compliance with the Good Manufacturing Practice (chunks of glass, plaster, paint);

- contaminants due to the failure to observe hygiene principles and use protective clothing by employees (jewelry, buttons, hair).

Implementation of production management systems, such as the HACCP system, Good Hygiene Practice or Good Manufacturing Practice, significantly reduces the risk of metal particles entering the products, while proper selection and operation of metal detectors, by detecting and eliminating contaminants, increases product safety. Sources of ferromagnetic contamination include the following (Panasiewicz, 2018):

- tools used to repair, adjust and maintain machines on production lines (screwdrivers and other tools, copper wire, metal filings from metal pipe repairs, machine parts, welding slag);
- personal belongings and objects belonging to employees operating machines and servicing production lines (buttons, coins, jewelry, pens, hair clips, paper clips, thumb tacks, pins);
- ferromagnetic contamination during technological processes (fragments of broken screens, filings and shavings of metal parts resulting from friction of mating machine parts);
- contaminated agricultural raw materials (fishhooks, parts of tractors and agricultural machines in vegetables, wire in the bulk of grain, lead shots in game meat, wire from sieves used for cleaning and sorting loose raw materials).

All food safety standards and procedures are designed to protect food against hazards and also to eliminate them from food. Protection is more effective when the hazards occurring in food are well understood and safety procedures are based on scientific knowledge. While this is particularly important for biological and chemical hazards, it is less important for physical hazards whose potential negative impact on public health is lower (Lawley, Curtis, and Davis, 2008).

The presence of foreign bodies in food can cause physical damage to the human body, e.g. fractures of teeth, lacerations of the mouth, the esophagus or the digestive tract (Sitarz and Janczar-Smuga, 2012). In addition to serious injuries, physical hazards may also exhibit toxic effects.

Unconscious ingestion of most foreign bodies does not require treatment, however, more serious cases may occur requiring endoscopic or surgical treatment. Most often foreign bodies block the esophagus, less often they pass into the stomach, intestines or even the colon. The passage of a foreign body from the stomach to the intestine does not guarantee that it does not get lodged in the rectum. Small objects pass through the digestive system and are excreted without complications. However, larger and sharp-edged objects (e.g., bones, fish bones) are dangerous, as are small, blunt-edged objects whose ingestion causes a sensation of pressure in the esophagus and difficulty swallowing. The sensation persists even after the passage of the foreign body into the stomach.

Furthermore, the swallowed object may cause pain even if the person is able to swallow normally. In extreme cases, a blocked esophagus leads to esophageal dysphagia manifested by whooping, choking, and the vomiting reflex. A foreign body that blocks the stomach, small intestine and large intestine may cause cramps, bloating, abdominal pain, nausea and vomiting. Far more serious consequences occur when a foreign body punctures the esophagus. In this case, food contents may leak into the thoracic cavity, resulting in the life-threatening condition of inflammation of the mediastinum. One of the most dangerous complications caused by ingestion of sharp objects is gastrointestinal perforation. This leads to food, digestive juices or intestinal contents entering the abdominal cavity. This condition is called peritonitis and poses an immediate threat to human life (Malik, 2021).

It should be noted that ingestion of certain objects can cause toxic effects. For example, ingestion of small and potentially harmless button cell batteries, as a result of the electrolyte they contain, can cause chemical burns and mucosal damage (Lurka, 2019).

4. Detection of Physical Contaminants in the Food Industry

The probability of the risk of contamination of food products with metals and other foreign bodies in food production and processing plants is very high. The risk exists both in food processing and in the packaging of the finished product. Increased automation on production lines also impacts the potential risk of product contamination. The drive to improve production efficiency coupled with fewer staff increases the risk of metal contamination from worn-out machine parts, e.g., wire mesh screens (Ketchin, n.d.). By using detectors, the risk of contamination of raw materials, semi-finished and finished products with ferromagnets and other foreign bodies is reduced to a minimum. At the same time, the deployment of detectors protects production machines from damage caused by physical hazards during technological processes, thus guaranteeing their safe operation. Detection of various foreign bodies by means of appropriate detectors is considered by many producers of food products as one of the most important components of the quality control system, being at the same time an important element of establishing and complying with the principles of ISO 9001 and HACCP procedures. With that approach, products and raw materials can be adequately protected against contamination, at the same time reducing the risk of recalls.

Taking into account the types of contaminants, especially their physical properties, two main types of detectors are used to detect their presence at any stage of the production process - metal detectors and X-ray detectors.

Metal detectors;

The detection of ferromagnets, regardless of the category of food products, plays an important role in ensuring the health safety of food. There are simple devices which separate metals from food, such as sieves, magnets, filters, as well as more advanced ones based on modern technologies, i.e., detectors or systems which detect and remove ferromagnetic contaminants. The general principle of metal detectors is to detect changes in the electromagnetic field caused by nearby contaminants such as conductive and magnetic materials. Electromagnetic field of different frequency ranges is applied. The product to be tested should be as neutral as possible to the applied electromagnetic field, while the contaminants should react strongly with the applied field, so that they can be easily detected and separated from the product or raw material. When a contaminant is detected, the product or the raw material containing the metal is automatically discarded outside the production line by the detector's ejector. In most cases, the contaminated products are immediately dumped by the ejector into a lockable bin which is located next to the detector. Metal contamination is additionally indicated by an acoustic signal or a flashing light.

The most commonly used metal detection system is composed of four interacting parts: the transport system, the detector head or coil, the control panel and the automatic ejection system, and other components essential for an effective operation of metal detecting machines.

A conveyor system is used to move products through an inspection area. It is characterized by different designs, it can be belt conveyors, non-metallic tubes mounted vertically or horizontally to transport raw materials or products in bulk or liquid form, or plastic chutes with a detector mounted at an appropriate angle. The next detector element comes in two types. The first category of detectors are those that use a sensor head with balanced coils. They detect all types of metal contaminants, e.g. ferrous, non-ferrous, stainless steel, that can potentially be found in fresh and frozen products. The food to be inspected can be packaged (including metallized foil) or unpackaged. The second category of detectors are those that use magnets permanently embedded in the detector head. Like the first type of detectors, they detect ferrous metals, magnetic metals and stainless steel in fresh and frozen foods (including those wrapped in aluminum foil).

Manufacturers offer heads of all sizes, usually rectangular or round, adapting them accordingly to the product under inspection. They are mounted vertically, horizontally or at any other desired angle. Another part of the detectors is the control panel, which takes care of the electronic control of the machine, most often located on the detector head. Depending on the type of food under inspection, metal detection machines also employ systems that automatically remove contaminated products from the production line. The following types of discarding units can be distinguished: ejecting, ratchet or blow-out. Other components of metal detection systems include: containers for collecting and storing contaminated products, which are often located at the side of the conveyor, guards between the detector and the discarding unit, and emergency detectors to be used in case of failure of the main detector. Furthermore, there are devices on the machines to alert the operator of rejects, and sound or light signals to indicate when the reject bin is full, for example.

Currently available systems enable the detection of contaminants with a diameter of less than 1 mm, even in packaged or frozen products. The metal detection process should be performed at every stage of production and should include raw materials, semi-finished products, as well as products. Furthermore, each production batch and each individual product within it should be subject to metal detection. Metal detection machines or systems should be placed at or as close as possible to the end of the production line used for packaging. They are designed to detect primarily particles of iron, aluminum, copper, various bronze alloys, lead, and zinc. These particles, such as pieces of machinery, filings and other miscellaneous metal parts, may find their way into raw materials, semi-finished, and finished products, thus contaminating them (Panasiewicz, 2018).

The detectors used in the food sector vary depending on the industry in which they are used and the products they are used to inspect. Depending on the purpose and the design used, the devices can be divided into the following categories:

- magnetic drum separators;
  they are built of a stationary magnetic part that is encased with a layer of stainless steel. The stainless steel rotates around the magnet and removes impurities beyond the regular path of the raw material, the latter not changing its trajectory. Furthermore, this design allows the particles to rotate, which facilitates the separation of contaminants from the product. The drum is usually placed in a housing. It can be used to detect both dry and wet material, while for non-volatile materials it does not need to be fitted in a housing. As a standard it is equipped with a ferrite magnet and a stronger neodymium magnet (Matykiewicz.com, n.d. [a]);
- gravity flow metal detectors;
  gravity flow metal detectors inspect powdery and granular products such as flour, milk powder, nuts, dried fruit, etc. The products transported through the production line fall freely into the small opening of the detector head, which ensures very high inspection efficiency. When contamination is detected, a fully automatic rejection unit is activated. It alters the flow path of the raw material to separate the contaminated portion from the stream (Mettler-Toledo, n.d. [a]);
- conveyor belt metal detectors;
  the conveyor belt is integrated with a tunnel metal detector. The product passes through the opening of the detector head, which makes it possible to assess whether it is contaminated. Automatic rejecting units such as a blow-out station, lifting/lowering flaps, pushing arms, etc. are often installed on conveyor belts (Mettler-Toledo, n.d. [b]). The sensitivity of this type of detector depends on the height of the detection gate - the higher it is, i.e. the greater the clearance, the greater the contamination must be in order to be detected by the detector. For this reason, these devices are very sensitive to external interference (Matykiewicz.com, n.d. [b]);

- pipeline metal detectors;
  are designed for controlling pumped liquids, pastes, suspensions, and highly viscous fluids as well as vacuum-packed products. These products can be inspected by virtue of a short section of a pipeline with a non-metallic pipe passing through the metal detector. Pipeline metal detectors can also reject contaminated products; when contamination is detected, a valve opens which diverts the contaminated liquid. Alternatively, the pump may be switched off and the contamination removed manually (Mettler-Toledo, n.d. [c]);
- rotational magnetic separators;
  are intended for the removal of metals from powders and granulates. They are designed for viscous products and products with poor flow properties (e.g. dried milk and cocoa powder). The magnets are connected in longitudinal rods and are insulated from the product by thin-walled stainless steel. The magnetic rods rotate slowly, which ensures a smooth flow of the liquid and appropriate contact of the magnets with the product. The rods can be cleaned once they have been removed from the casing (Matykiewicz.com, n.d. [c]).

X-ray detectors:
X-radiation (X-ray) is electromagnetic radiation with a wavelength of approx. 0.0001 nm to approx. 10 nm. The general principle of operation of X-ray detectors is based on the difference in density between the product under inspection and the contaminant present in it. When X-rays penetrate through the inspected product or raw material, they lose some of their energy, whereas they lose even more energy when penetrating contaminants. After passing through the food under inspection, the radiation reaches the sensor where the electrical signal is transformed into an image. Foreign bodies are visible as a darker shade of grey, which helps to identify contaminants (SMIT-tech Smart Industrial Technologies, n.d. [a]).

The X-ray inspection system consists of three components: a generator, a detector and an image processor. In addition, it always includes mechanical systems and transport systems. Depending on the customer's needs, the detector can be adapted to the intended purpose. The generator is, in other words, an X-ray tube which consists of a glass body, a heated cathode, a copper anode, and a tungsten disc. All these components are enclosed in a vacuum in a ceramic or glass housing. Since heat is generated during the process of X-ray generation, the X-ray tube is additionally encased in an outer casing filled with a coolant (e.g., oil). An ionizing radiation (X-ray) detector contains an element called a scintillator - a component that makes up the detection area for Roentgen radiation. Its task is to convert invisible X-rays into light visible to the human eye.

This area contains the X-ray tube, usually mounted at the top of the system, although it can also be located at either side. The beam coming out of the X-ray tube travels downwards, passes through the product under inspection and the conveyor belt directly to the detector. The beam coming out of the X-ray tube is about 2 mm wide and widens downwards. The detector and scintillator thus cover the entire width of the conveyor belt. It is worth noting that the more X-ray quanta fall on the scintillator, the brighter it glows. Thus, the initial power of the scintillator is directly proportional to the incident X-ray radiation. For the X-ray detector to work effectively, image processing software is required.

After the detector captures the radiation passing through the entire product, the computer creates a grey-scale image of it. The image is then checked for the presence of foreign bodies in the product under inspection by applying appropriate algorithms. If the computer detects a foreign body, the product is automatically rejected. To ensure proper image quality, the X-ray inspection system automatically adjusts the detector scanning speed to the conveyor belt speed. X-ray systems produce a grey-scale image of products that corresponds to their density. Therefore, detection of contamination is possible when there is a significant contrast between the contaminant and the product under analysis (Ries, 2017).

The following factors influence the sensitivity and consequently the effectiveness of X-ray systems:

- product structure, thickness and cross-section: X-ray systems are best able to detect products that are thin, lightweight and have a homogeneous structure. The packaging should be invisible to the detection system and of simple construction. The X-ray tube and the detector should be positioned in such a way that the X-ray beam passes through as large a cross-section of the product as possible;
- spatial orientation of foreign bodies: it is very difficult to detect foreign bodies that lie perpendicular to the X-ray beam. The most favorable situation occurs if the foreign body lies cross-sectionally to the beam path, as it absorbs the most radiation then (Minebea Intec, n.d.);
- line speed: it should be adjusted to the product under inspection. However, at high technological line speeds, the detection rate may deteriorate;
- software: using software that includes many types of algorithms makes it possible to detect a greater number, more types and shapes of contaminants (Ries, 2017).

The X-ray inspection systems used in the food industry all follow the same operating principle, but differ in the individual design of their components to suit the product to be inspected. Listed below are selected examples of X-ray systems for food inspection:

- X-ray system for the inspection of packaged and bulk products;
  the system was developed to detect contaminants such as metals, glass, stones, but it is also suitable for detecting sharp and dense objects. It monitors such parameters as overfilling, insufficient filling of the packaging

with the product, whether the product is damaged, misshaped or whether it is in the right packaging. It is used in the inspection of packaged products and food products transported in bulk, e.g. seeds, fruit, nuts, vegetables. It has an automatic rejection system for the removal of contaminated products. It also has a module for modifying the width of the conveyor belt to enable optimization of product flow and detection sensitivity (SMIT-tech Smart Industrial Technologies, n.d. [b],[c]).;

- pipeline X-ray inspection system;
  an inspection system designed for pumped products such as poultry, meat, pulps, sauces. In addition to metal detection, it detects many other contaminants: bones, stainless steel, ceramics, glass, and dense plastics. It also enables product integrity checks, product counting, and the detection of missing items (Loma Systems, n.d.);
- dual-beam X-ray system;
  it has two X-ray tubes that can generate two beams of radiation. This facilitates more accurate detection of contaminants in inspected products. The system is primarily suitable for detecting glass in vertical glass containers. It can identify contamination also at the bottom and on the walls of the container. In addition, it detects thin, flat shards and fragments of glass (SMIT-TECH Smart Industrial Technologies, n.d. [d]).

It should be noted that X-ray detectors can also be used for purposes other than foreign body detection. The software used in the equipment enables e.g., weighing, counting products, checking filling levels, as well as checking the shape, dimensions, volume, and identifying empty spaces and defects in products.

5. Analysis of RASSF Reports on Physical Contaminants in Food

Materials and methods:
The Rapid Alert System for Food and Feed (RASFF) is in effect within the European Union. It was established in 2002 in accordance with the provisions of Regulation (EC) No 178/2002 of the European Parliament and of the Council concerning food law. Article 50 of the said act defines the principles of operation of the Rapid Alert System network and indicates when member states are under the obligation to submit notifications to the RASFF. It also requires member states to report on actions implemented or measures taken following notifications received (Ludwicki and Kostka, 2008).

This publication presents data compiled from notifications reported to the RASFF system, which are available from the RASFF online portal (RASFF Portal - European Commission, 2020). They cover the period from 1 January 2015 to 31 December 2019. Physical hazards are included in the system in the category "foreign bodies", which, in addition to metals, plastics, and glass, also includes hazards such as insects, dead animals, needles, wood, rubber, and other contaminants posing a direct threat to human health.

Description of RASFF system:
The RASFF system was introduced to provide early and rapid notification to European Union member states of food safety risks and non-compliant products that could be dangerous to consumers. It includes categories for food and animal feed and covers materials intended to come into contact with food. It is a compulsory system for the Community countries. It forms a network of National Contact Points with the central facility in the EU Central Contact Point. Notifications transmitted by the RASFF system can take the form of alert notifications, information notifications, border rejections, and communications. Alert notifications are issued for products that are on the market and pose a serious risk to consumer health. Where this is the case, immediate action should be taken to recall the dangerous product from the market.

Information notifications are given for products that do not present an immediate risk to consumers. Member states are not requested to take immediate action because the dangerous product is not on the market. In most cases, information notifications concern products that have been held and rejected at border controls. The purpose of these notifications is to prevent products that have been found suspect at borders from being marketed in EU countries (Ćwiek-Ludwicka, Stelmach, and Półtorak, 2007). In 2011, the European Commission introduced two sub-types of information notifications: follow-up notification issued when the contaminated product is on sale in a country other than a member state, and information notification for attention issued when the product is on sale only in the notifying country, has not yet been authorized for sale or is not on sale at the time the risk is reported in an EU country.

Border rejections are issued when food products, food contact materials or feed are refused entry into the territory of the member states of the European Union due to environmental and human or animal health risks identified during border controls (Majewski and Dziubdziela, 2018). Communications posted by the European Commission through the RASFF system provide information on products (food, feed, food contact materials) that do not qualify as alert or information notifications. However, they are of considerable importance from the point of view of food safety and control authorities.

Alert and information notifications are published by the European Commission on a weekly basis. The following data on hazards are given in the alerts:

- country notifying of the risk;
- reason for alert: type of product, extent of non-compliance, country of origin of the product;
- type of control: border control, market control, manufacturer’s own control, consumer notification;
- information about the potential marketing of the product in the European Union and measures taken by the notifying country.

Once a year, the European Commission publishes an annual report on RASFF notifications, which includes information on (Ćwiek-Ludwicka, Stelmach and Półtorak, 2007):

- the number of notifications registered, indicating the types of products for which notifications have been made;
- the notifying country;
- risk category;
- product country of origin;
- the sources of the reported information, e.g., consumer notifications, producer notifications, inspections.

Analysis of RASFF notifications for the years 2015-2019:
In the years 2015-2019, a total of 17251 notifications were submitted to the RASFF, with 716 notifications falling into the category of "foreign bodies". Table 1 shows the number of notifications by year for the analyzed period. One can notice that the number of reported physical hazards ranged between 110 and 173, representing between 3.0% and 5.6% (4.4% on average) of all notifications reported in the years under analysis, with an upward trend.

Table 1. *Number of notifications to the RASFF system by year in the analyzed period*

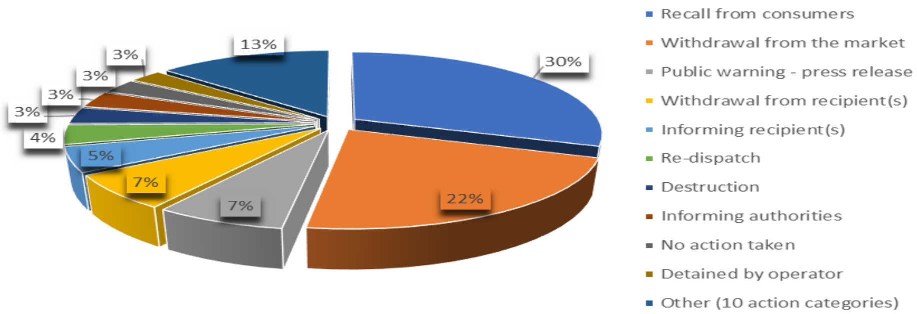
Year	**Number of submitted notifications**
2015	110
2016	134
2017	131
2018	168
2019	173
Total	716

Source: *Compiled by the authors based on RASFF data for 2015-2019.*

The highest number of notifications came from Germany with 157 notifications, the lowest from Cyprus with only 1 notification. Denmark, Italy, the Netherlands, and Great Britain were the countries with the highest number of notifications following Germany, with 80, 72, 65, and 64 notifications, respectively. Other member states reported fewer than 50 notifications over a period of 5 years. Most notifications, 56 %, were classified as alert notifications, 22 % as information notifications for follow-up. 12% and 10% were classified as information notifications for attention and border rejection. In 59 % of the cases the risk was decided to be serious, in 29 % it was determined to be negligible, whereas in 12 % of the notifications no decision was made about the risk.

The main source of notifications concerning physical hazards in food (52.7% on average) were complaints from consumers. The other sources of notifications were as follows, own inspections of production establishments - 28.6%, border control seizure - 8.8%, official control in the market - 8.4%, customs seizure - 1.4% and food poisoning - 0.1%. Figure 1 shows which actions were taken in relation to the risks identified.

Figure 1. *Actions taken regarding the products upon the identification of hazards*

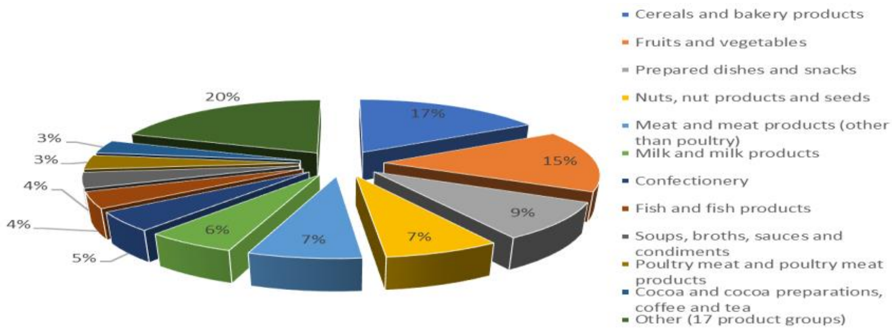


Source: *Compiled by the authors based on RASFF data for 2015-2019*

30% of products found to have physical hazards were recalled or recovered from consumers and 22% were withdrawn from the market. The remaining 16 action categories account for 44% of the total. The percentage contribution of these categories to the total categories ranges from 0.1% to 7%. In a descending order, these are: informing the recipient(s), returning the goods to the supplier, destroying the product, informing the authorities, no action taken, detention by the operator, withheld product import authorization, informing the sender, physical/chemical action, seizure approved by the authorities, returning the goods to the sender or destruction, confiscation, securing by the Customs Services, product stocks had been exhausted, used for purposes other than food/feed, requesting removal of the online offer. For 4% of the hazards, there was no data on the decisions taken.

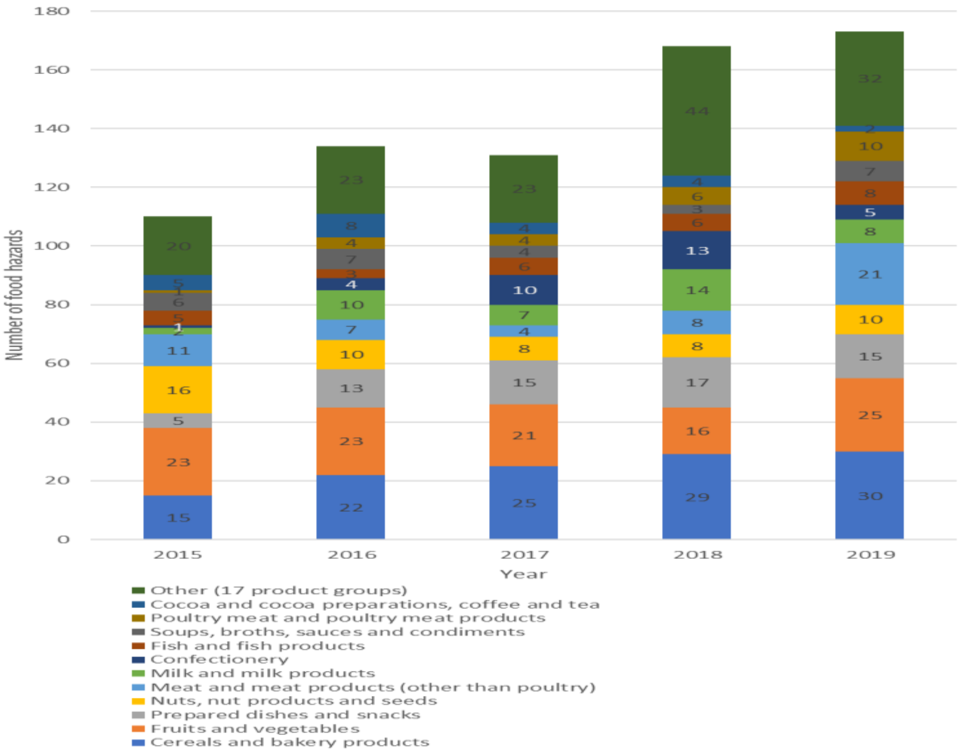
Figure 2 presents the percentage share of different food categories in the total number of notifications, while Figure 3 shows the total number of notifications to the RASFF system by food category in the years under analysis. The food groups in which contamination was most prevalent included: cereals and bakery products (17%), fruit and vegetables (15%), pre-cooked meals and snacks (9%), nuts and nut and seed products (7%), meat and meat products - other than poultry (7%). Further categories presented in the chart accounted for a much smaller share of the total number of hazards (between 3% and 6%). The category "other (17 product groups)", consists of such categories as herbs and spices, ice cream and desserts, soft drinks and alcoholic beverages, fats and oils, eggs and dairy products, among others. That category includes the food groups for which the fewest notifications of hazards were reported: fats and oils (0.1 percent), eggs and dairy products (0.1 percent), clams and related products (0.1 percent), and snails (0.1 percent).

Figure 2. *Average percentage share of food groups in the total number of notifications in 2015-2019*



Source: *Compiled by the authors based on RASFF data for 2015-2019*

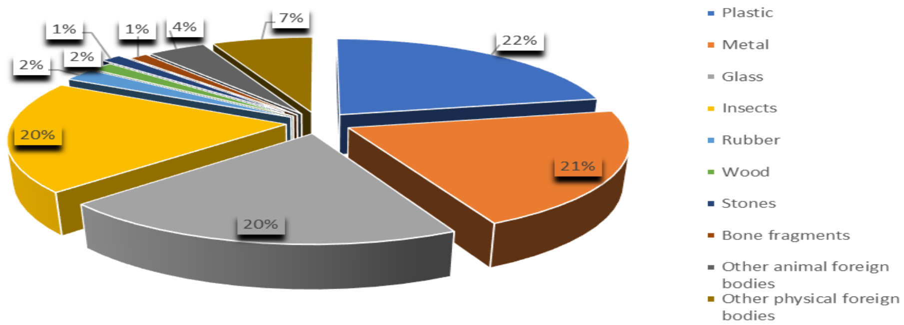
Figure 3. *Total number of RASFF notifications by food category in 2015-2019*



Source: *Compiled by the authors based on RASFF data for 2015-2019*

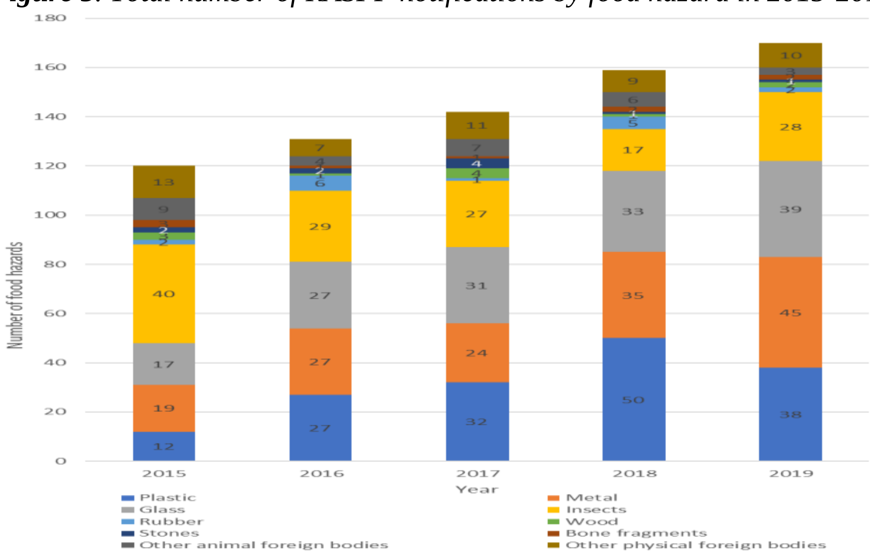
Figure 4 presents the percentage share of each contaminant in the total number of notifications, while Figure 5 depicts the total number of RASFF notifications by food hazard in the years analyzed. Plastics, at 22%, account for the largest number of hazards received by RASFF in 2015-2019, followed by metals (21%), very hazardous glass and insects (20% each). The category of insects includes dead insects, live insects as well as larvae. Contaminants such as rubber, wood, stones or bone fragments account for only 1-2 % of all reported hazards. The last two categories, namely "Other animal foreign bodies" and "Other physical foreign bodies" comprise hazards that occurred very rarely. More than once only 1 notification was submitted in the entire analyzed period. The category "Other animal foreign bodies" includes, for example: dead mice, scorpions and frogs, rodent droppings, animal skin with fur, whereas the category "Other physical foreign bodies" includes: sharp foreign objects, needles, pieces of fiber, porcelain, fragments of packaging.

Figure 4. *Average percentage contribution of each type of contaminant to the total number of notifications in 2015-2019*



Source: *Compiled by the authors based on RASFF data for 2015-2019*

Figure 5*. Total number of RASFF notifications by food hazard in 2015-2019*



Source: *Compiled by the authors based on RASFF data for 2015-2019.*

6. Summary

Food safety assures that food supplies are healthy and free from any contaminants and microorganisms. It is therefore crucial that the quality aspect of food be developed and that the health and nutritional value of food be improved. The Rapid Alert System for Food and Feed provides invaluable support in early detection of hazards within the EU. The analysis of data retrieved from RASFF has shown that out of 29 categories of hazards, foreign bodies represented on average 4.4% of all hazards reported in the period in question. In as many as 59% of the cases, the hazards were determined to be serious and likely to adversely affect consumer health, and a vast majority of contaminated products had to be withdrawn from the market.

More than half of the RASFF notifications originated from consumer complaints, which, at the same time, represented the share of hazards that had not been detected during the production and supply chain. The most frequently reported contaminants to RASFF were plastics, metals, glass, and insects. While insects thrive in food once the manufacturing process is complete, it is worrying to see such a high proportion of glass, metal, and plastic contamination that goes undetected during the production process. It is therefore worthwhile for manufacturers and distributors to take a closer look at this issue and to respond more effectively to any contamination occurring early in the food chain.

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