ANALYSIS OF REPORTED FOOD FRAUD IN THE GLOBAL BEEF SUPPLY CHAIN 2000-2020

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ARTICLE INFO

Received 7. 12. 2021
Revised 15. 2. 2022
Accepted 22. 2. 2022
Published xx.xx.20xx

Regular article

ABSTRACT

Relevant food notifications published under the Rapid Alert System for Food and Feed (RASFF) for 2000-2020 were selected and analyzed to determine their overall formula. Fraud-counterfeiting was categorized according to the type of fraud, its location in the food production chain, the reporting country, and the origin of the food. "Adulteration" was the most common type of fraud in the beef industry; it accounted for 70% of all documented reports. According to the classification of supply chain messages, 59% of all cases were attributed to secondary processing, of which 83% were cases of "adulteration". The most common counterfeiting practices included products manufactured-packaged in non-approved areas, without appropriate control or documentation, products with fraudulent health certificates, and substitution of meat types or the addition of veterinary medicines.

INTRODUCTION

Meat has high production costs (Wiedemair et al., 2018). It is an essential source of protein globally, and its consumption is related to the local diet, production method, and price offered to the consumer. In 2019, the largest beef consumers were Argentina, the USA, and Brazil, with consumption rates of 39.7 kg, 26.7 kg, and 24.6 kg per capita (Hati et al., 2021). Due to the high consumption and high economic value of meat and meat products, these foods are subject to adulteration. The most common form of adulteration of meat products is the addition of meat or materials with lower economic value and lower quality. This type of fraud is difficult to identify due to the homogenization and transformation of the components in the production process before the grinding, mixing, and cooking phases (Meza-Márquez, Gallardo-Velázquez, and Osorio-Revilla, 2010).

Meat and meat products are important vitamins or minerals and are in great demand worldwide. With such high demand, some meat processors or retailers will always replace expensive beef and mutton with cheaper alternatives to maximize profits (Vlachos, Arvanitoyannis, and Tserkezou, 2013). For example, in 2013, the equine meat scandal in Europe attracted global attention to meat counterfeiting (Abbots and Coles, 2013). Similar scams often occur in China, such as wholesale markets, rural fairs, or even some supermarkets (Zhang and Xue, 2016). These activities not only harm the fundamental interests of consumers but can also have serious public health consequences. Therefore, it is important to protect consumers from these adverse effects by developing reliable detection techniques that could make it easier for legal authorities to detect illegal food adulteration and help with Halal certification (Lo and Shaw, 2018). The fraudulent sale of horsemeat under the pretext of other meat, especially beef, is nothing new. In January 2013, after testing by the Irish Food Safety Authority as part of its regular proactive monitoring activities, a horse meat scandal took place. Horsemeat has been found in beef meat products sold in retail and catering establishments in the United Kingdom and Ireland. Testing revealed that beef products were adulterated with horse meat. Horse DNA was identified in 37% of beef burgers purchased at grocery stores such as Tesco, Dunnes, Lidl, and Aldi. All came from three meat plants in the UK and Ireland. In February 2013, the British company Findus and retailers such as Aldi and Tesco announced that they had found horse meat in their lasagna, spaghetti bolognese, burgers, and meatballs. A French supplier manufactured all products. Following these revelations, the European Union (EU) has launched a Europe-wide three-month random DNA sampling program for processed meat (Brooks et al., 2017).

MATERIAL AND METHODS

Data from 1 January 2000 to 31 December 2020 were exported from the RASFF online portal (URL 1) to an Excel file. We found the total number of fraud reports in the beef market and evaluated them based on criteria. RASFF search criteria included:

1) Product category: animal by-products, feed additives, feed and food-producing animals, meat and meat products (other than poultry),
2) danger category: counterfeiting/fraud, inadequate and insufficient controls, residues of veterinary medical products,
3) keywords: cattle, beef, bovine.

Once loaded, the messages were exported and recorded to meet the two selection criteria. The report had to include:

1) It concerns beef and beef products and
2) It is considered a food fraud report on the RASFF website.

The reports from the system were checked and ranked according to predetermined categories/criteria provided by the RASFF and included:

- A date
- Country of origin
- Subject/reason for the notification
- Country of notification
- Danger

Additional fraud-type columns have been added to the Excel spreadsheet to facilitate analysis. Spink and Moyer (2011) define the type of fraud in Table 1. In the absence of legal definitions of the types of food fraud, the reports were grouped based on the "type of fraud" described in detail by Spink and Moyer (2011). However, it should be noted that the reports sometimes overlapped with several types of fraud. For example, if the report contained counterfeiting, such as species substitution, it was assumed that the product was produced without control, which is also considered counterfeit. In these cases, the report was recorded once for each type of fraud listed.
Table 1 Types of food fraud by categorization Spink and Moyer (2011)

<table>
<thead>
<tr>
<th>Adulteration</th>
<th>The finished product is fraudulent. This category includes replacement, dilution, or unapproved enhancements.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Counterfeiting&quot;, &quot;fake&quot;, copy, falsification</td>
<td>All aspects of the fraudulent product and packaging are entirely replicated. This includes breaches of property copies of popular foods produced without the same food safety guarantees. This category applies to illegal production.</td>
</tr>
<tr>
<td>Diversion</td>
<td>Sale or distribution of legitimate products outside the intended markets, such as the black market.</td>
</tr>
<tr>
<td>Tampering, manipulation, forgery</td>
<td>Legitimate products and packaging are used fraudulently, such as intentional mislabeling and changes in expiration date.</td>
</tr>
<tr>
<td>&quot;Theft&quot;</td>
<td>A legitimate product is stolen and issued as legitimately made.</td>
</tr>
<tr>
<td>Over-run exceedance</td>
<td>A legitimate product is produced beyond production agreements. Insufficient production reporting.</td>
</tr>
<tr>
<td>&quot;Simulation&quot; imitation</td>
<td>An illegitimate product is designed to look like legitimate products, but it does not exactly copy them. These are fraudulent products of lower quality.</td>
</tr>
</tbody>
</table>

Selection criteria

After selecting and sorting the messages, the data were subjected to the following protocol:

- Reports that indicate "suspicion" or "attempted fraud" are excluded because it is not possible to infer whether or not fraud has taken place.
- The reports recorded must relate only to beef and beef products. Reports indicating "different meat products", "red meat products" (or variations thereof), or reports which do not indicate that the product was meat derived from bull, heifer, ox, cow, or calf were excluded. All categories of beef are included, i.e. fresh, frozen, dehydrated, canned beef, etc. Products listed as "containing beef" are only recorded if there was a fraud problem directly related to the beef in the product. For example, if hydrated beef noodles are reported as the report and the beef has been named as a confirmed illegal product, the report has been included in the analysis.
- Animal feed fraud was recorded when the feed was intended for cattle. It could have gotten into the human food chain when the cattle consumed it.
- Residue residues were only recorded if illegal veterinary drugs or growth promoters were found. Legal residues found above the maximum residue limit are not included as this may not be intentional and, therefore, not fraudulent.

Data analysis

Following the selection criteria to the data, an analysis of the included reports was performed to identify the risks to the beef supply chain and to identify vulnerable areas in the supply chain. The results present:

- The incidents of cases during the 20 years between 2000 and 2020 included:
  a. the country of origin of the fraud,
  b. fraud reports reported at country level,
  c. reporting trends by area and
  d. the number of reports by type of fraud.
- Fraud by type and area in the beef supply chain.

RESULTS AND DISCUSSION

A total of 274 food fraud reports were identified in the beef supply chain through the RASFF program. Within these 274 reports, only four of the seven types of fraud defined in Table 1 were identified, namely: Adulteration, counterfeiting, copying, diversion, tampering manipulation, forgery. No reports of "Theft" "Over-run" violations were identified in this data or "Simulation". Of the reported reports, 70% (n = 193) were categorized as "Adulteration" counterfeiting, 5% (n = 14) as "Counterfeiting" "fake", copy, 8% (n = 21) as "Diversion" and 21% (n = 58) and as "Tampering", manipulation, forgery. Most of the detected fraudulent reports in the beef supply chain can be attributed to counterfeiting. 70% (n = 193) reports were categorized into this group. Adulteration involves the addition of unknown substances to a product or the dilution of a product and may involve a wide range of contaminants. Of the reports categorized as "Adulteration", the falsification resulted from substitution or dilution. Illegal veterinary medicines and growth promoters caused other reports of counterfeiting. 8% (n = 21) of the identified frauds were categorized as "Diversion". These products shall be deemed to be those products that have been illegally imported or exported, as well as the illegal sale of products that relate to the placing on the market of the illegal product or where: the legitimate product is sold illegally through the informal market.

Tampering, manipulation, counterfeiting accounted for 21% (n = 58) of detected fraud. Reports in this category consisted of fraudulent health certificates, date changes, and expirations. 5% (n = 14) reports were categorized as "counterfeiting", "fake", copying, falsification. Counterfeiting is generally considered to be a trademark or patent infringement. Replication of a product or product packaging is a useful example of a trademark infringement. Spink and Moyer (2011) explained counterfeiting as "copies of popular foods that are not produced with the same food safety guarantees". For this inspection, counterfeit products shall mean beef products that have been unlawfully produced to imitate or copy. This includes products from unauthorized premises that indicate illegal production.

Country of origin and country of notification

Country of origin

The identified food fraud reports are believed to come from 37 countries. In 12 cases, the country of origin was unknown or not indicated. Figure 1 shows the trends in the first six countries from which the most reports come. These are the countries of Brazil, Poland, Italy, Argentina, Netherlands, and Uruguay. 68% (n = 187) of the reports came from these six countries.

![Figure 1 Chronology of fraud reports found in RASFF by country of origin](image-url)
Most reports came from Brazil (35%, n = 98). Of these, 81.6% (n = 80) were the result of adulteration, where 78.7% (n = 63) of the reports were for the presence of illicit or unauthorized substances and 13.7% (n = 11) were for levels of veterinary medicines. 8.7% (n = 7) diversion reports represented unauthorized or illegal imports/transit. 16.2% (n = 10) were included in the category of "tampering" manipulation, falsification, missing or falsified health certificate. Reports from Poland accounted for 11.6% (n = 23) of all reports. Most of these reports (90%, n = 29) were due to adulteration, of which 79% (n = 23) were due to adulteration of the species by the addition of horsemeat. Of the Polish reports, 6.2% (n = 2) were due to illegal sales, and one case involved a lack of veterinary checks for beef, which was probably unfit for human consumption. The total amount of fraud originating in Italy was 7.6% (n = 21). 85.7% of these frauds were classified as "adulteration" counterfeitering. Six (28%) cases were due to insufficient withdrawal periods for veterinary medicines. Poor hygienic conditions, organismic properties, or meat contamination accounted for 19% (n = 4). Counterfeiting by substituting or adding horsemeat occurred in four cases (19%). 4.3% (n = 12) of the reports came from the Netherlands, of which 58.3% (n = 7) were due to counterfeiting and 33.3% (n = 4) were classified as tampering, counterfeitering. Two cases (16.6%) concerned poor traceability and imports of thawed beef products. The presence of the Prohibited Substance accounted for 41.6% (n = 5) of all Dutch cases. One case was the result of bovine fat adulteration.

The number of cases originating in Argentina represented 4.7% (n = 13) of all reports. 31.5% (n = 8) belong to the category of "tampering", manipulation, forgery, of which 37.5% (n = 3) were caused by damage to the refrigeration chain and thus poor temperature control. Counterfeiting of a health certificate occurred in five (58.5%) cases. Three (23%) reports of poor beef status were reported. Uruguay is among the last countries with additional cases of the country of origin reporting. The number of reports from this country is 4% (n = 11). 63.6% (n = 7) of these reports were classified as tampering. One report (9%) represented illegal production in an illegal beef establishment. Poor temperature and cold chain damage occurred in eight reports (72.7%). In one case (9%) it was a forgery of a health certificate.

Country of notification

Fraud reports came from 26 countries. Figure 2 illustrates trends from the top 6 reporting countries in the beef supply chain between 2000 and 2020. These were the United Kingdom, Italy, Germany, Netherlands, Belgium, and Greece, which reported 61.5% (n = 169) of all identified frauds. Of these cases, 76.9% (n = 130) were classified as adulteration, 12.4% (n = 21) belonged to tampering, 11 (6.5%) of these reports are a “diversion” and 7 (4.1%) cases fall under the “counterfeiting” copy.

The United Kingdom reported the most fraud reports, 14.9% (n = 41) of all reported cases. The highest number of frauds in the UK was reported in 2011, representing 43.9% (18 reports) of all UK reports in the 20 years from 2000 to 2020. 100% (n = 18) of these reports in 2011 referred to reports originating in Brazil resulting from counterfeitering through the use of an illegal veterinary medicinal product and growth promoters. Overall, 14% (n = 6) of all frauds reported by the United Kingdom came from the United Kingdom. The highest number of notifications from Italy was in 2010 (33.3%, n = 12). Ten (83.3%) of the 12 reports in 2010 were caused by counterfeitering. The remaining 2 (16.6%) can be attributed to the black market. 75% of these 12 reported cases to come from Brazil; 10 reports were the result of counterfeitering through the use of an illegal veterinary drug and growth promoters, and two reports (16.6%) of species substitution (one was from Pakistan where sheep’s intestines were declared bovine and then illegally exported to Brazil). Reports from 2006 show two reports of illegal beef imports from the Philippines. All reports notified by Italy occurred between 2003 and 2020, with an average of 1 to 2 reports per year, except for 2004, 2008, 2014, 2017, when Italian notifications were not submitted. Of the reported reports, 36.1% (n = 13) come from Italy alone.

Germany is the third most reported fraudulent report by 10.2% (n = 28) of all reported. 28.6% (n = 8) of these reports were from Brazil due to falsification of the veterinary medicinal product, 14.3% (n = 4) were the result of falsification of certificates from Argentina, 17.1% (n = 5) were reported as a result of counterfeitering of meat species from Poland and 10.7% (n = 3) were reported from Germany. There was a significant increase in fraud reports from Germany in 2010 and 2013, where 7 and 6 notifications were recorded. The first notifications submitted by the Netherlands occurred in 2002, of which 50% (n = 3) were adulterated meat from the Netherlands. Of the 27 notifications submitted by the Netherlands, 25.9% (n = 7) were due to poor hygiene measures. In 2011 and 2012, there was an increase in notifications from the Netherlands, which represented 33.3% (n = 9) of Dutch notifications. The majority of notifications made by the Netherlands came from the Netherlands (37%/10 reports), the rest came from Argentina (18.6% /3 reports), Brazil, and Poland after (11.1%/3 reports). Two reports were made in 2012, where the country of origin was not reported.

The highest number of reports from Belgium was in 2010, 2011, and 2018. In 2011, this represented 31.6% (n = 6). All of these cases concerned counterfeitering with veterinary medicines and originated in Brazil. The year before, there were also several cases (4) from Brazil of the same intent. 26.3% (n = 5) of counterfeitering cases originated directly from Belgium. One case involved incorrect indication of the date of freezing, and another four reports mentioned falsification with drugs. Greece first reported fraud reports in 2009. 4 notifications concerned a false certificate originating in Brazil. The largest number of notifications in Greece was reported in 2013. 55.6% (n = 10) of all reported notifications were the result of meat substitution or replacement. In two cases in 2013, Greece was also the country of origin; Greece’s other countries were reported by France, Poland, Romania, and Italy.

Breakdown of food fraud by beef supply chain area

Of the 26 areas identified in the beef supply chain, 12 were involved in food fraud reports. The number of reports found by supply chain area and the types of reports in each area are summarized in Table 2. We have summarized our fraud reports into the four most common and key areas of the chain. Primary processing, secondary processing, and breeding are crucial in the supply chain, as they are the basis for all other areas in the supply chain. This is very important because any fraud that arises in any of the three main areas can easily be passed on to all the other stages of the beef supply chain.
Secondary processing messages

Secondary processing was the most vulnerable area in the beef supply chain, with approximately 52.5% (n = 144) of reports occurring in this area. The widest variety of frauds in this area was the "adulteration" of counterfeit, which accounts for 86% (n = 144) of the messages identified. Most of the adulteration in the secondary processing of 43.7% (n = 63) was caused by the use of illegal additives preservatives, which also included dyes (to hide the restoration) and bleaches (to remove meat stains). The other most common frauds were caused by species substitution (26.6% / n = 33). Various types of meat have been hidden in meat products such as meatballs, burgers, lasagna, and sausages in combination with horse chicken and pork. Water and fat replacement represented one record. 13% (n = 19) of the reports in the secondary processing were due to tampering manipulation. These reports included production without proper temperature control and falsification of health certificates.

Primary processing messages

30.6% (n = 84) of the identified messages occurred in the primary processing stage. These reports also included fraud involving Category 1 and Category 2 animal by-products and Category 3 animal by-products. Reports in this area were categorized as adulteration 78% (n = 66) and tampering, manipulation, forgery 20% (n = 17). In this processing, there were cases of adulteration where the beef was not suitable for human consumption, the meat was not sufficiently cooled to the required temperature, or cases with poor meat hygiene were found.

Breeding reports

In this sector, we included reports of illegal beef establishments, which accounted for 42% (n = 6) of the total 14 reports and cases where 35.7% (n = 5) of the veterinary drug protection periods were not met. One report was about veterinary checks that were not carried out properly for beef from Poland, which was probably unfit for human consumption.

Beef trade notifications

100% of reports (n = 21) concerning fraud in the agricultural trade phase were caused by illegal or unauthorized transit or import of beef and beef products. This included canned beef, burger, boneless meat, and frozen beef. We have included all these cases in the "Counterfeiting" category diversion.

Analysis by type of fraud

Reports on food fraud in the beef supply chain from 2000 to 2020 are shown in figure 3. The top line of the graph indicates the total number of fraud reports in the beef supply chain between 2000 and 2020. The first reports of fraud were recorded in 2001.

The largest share of reports (20.8% of total reports) was reported in 2013. Another critical year can be 2011, when 20.8% (n = 45) of cases were reported. 61.6% (n = 169) of fraud in the 20 years (2000 to 2020) occurred between 2009 and 2013. Between 2014 and 2020, 17.8% (n = 49) of the total frauds occurred. 20.4% (n = 56) of frauds were reported between 2001 and 2008, of which 21.4% (n = 12) of frauds occurred in 2006. As shown in figure 3, overall fraud reports vary from year to year. However, after 2013, frauds were lower than before the peak of reports reported in 2013, except in 2019, where 6.9% (n = 13) of frauds were reported. The most significant number of reports of adulteration occurred in 2013. 7 5.4% (n = 43) of these reports were caused by meat adulteration. In 2013, 20.8% of all counterfeit reports occurred during the 20 years. Most frauds in 2013 were caused by species substitution (75.4%). The remaining 25% (n = 14) resulted from the use of illegal veterinary drugs. The second highest reports of counterfeit reports occurred in 2011, representing 16.4% (n = 45) of all counterfeit reports between 2000 and 2020, with 77.6% (n = 35) being the result of the illegal use of veterinary medicines and growth promoters and 22.2% (n = 10) was due to poor hygiene or measured chilled temperature. Counterfeit reporting trends are volatile. Figure 3 shows dramatic peaks and lows. "Adulteration" counterfeiting is more mentioned and during the 20 years, it records more messages than in the case of "counterfeiting" copying. The first reports of counterfeit were reported in the RASFF in 2011, and between 2011 and 2020, reports of counterfeiting were reported every year.
In 2006, 4.4% (n = 12) of all reports occurred, with 66.6% (n = 8) being the result of illegal imports or exports. In 2019, 4.7% (n = 13) of frauds occurred due to improper handling of beef.

### Analysis of fraud by supply chain location

The cases were grouped into the four most common phrases. Primary processing, secondary processing, breeding, and trade had the highest number of identified fraud reports. These areas are shown by date in figure 4. The largest increase in reports was recorded in the secondary processing in 2013. In 2013, 14.6% (n = 40) of all reports occurred in the secondary processing. These reports account for 25% of all reports that occurred in secondary processing during the evaluated 20-year period. The number of frauds detected in secondary processing was lower after 2013. Between 2008 and 2012, 49.6% (n = 81) of frauds occurred in secondary processing, before 2013 and in 2000-2007, only 12.2% (n = 20) of reports were reported during secondary processing.

![Figure 4 Chronology of fraud reports found in RASFF by location in the supply chain](image-url)

Reports in primary processing were consistently lower than in secondary processing over 20 years. Most reports in primary processing occurred in 2013 (20.2%, n = 17). In 2011, there was also a larger increase in primary processing messages, representing 13% (n = 11) of all messages in this area. The first breeding reports occurred in 2002. Between 2010 and 2014, there were no fraud cases in this area. It was similar in 2008, 2017, and 2004. As we can see in figure 3 did not show a rapid increase over the 20 years, and reports of 1 to 2 were maintained over the years.

The highest number of reports concerning illegal imports/exports occurred in 2006, including 33.3% (n = 7) of all reports in this area. After 2016, no cases of "black market" were registered. It was also until 2003. Between 2000 and 2020, 21 reports of illegal or unauthorized transits were registered.

Tähkäpää et al. (2015) identified 44 reports concerning meat and meat products (other than poultry) out of 14 types of meat fraud and 29.5% of these fraud reports were caused by illegal or unauthorized trade/import/transit. In this review, the reports identified by Tähkäpää et al. (2015) would be categorized as "Diversions", which based on our analysis, accounted for only 8% of reports. The discrepancy in the RASFF reports may be the result of differences in the time frame examined and how the type of fraud was defined, or because Tähkäpää et al. (2015) examined a more comprehensive range of commodities (Kowalska et al., 2018). Tähkäpää et al. (2015) found that 9.1% of food fraud in meat was caused by "Adulteration", "Tampering". These reports would be classified in our report as "Adulteration" counterfeiting, which accounted for 70% of fraud in meat and meat products. This may also be a consequence of the 2013 "Horsemeat" scandal, which was not included in Tähkäpää et al. (2015) analysis.

As defined in our review, counterfeiting consists of processing/production at an unapproved site, without inspection or with fraudulent or missing documentation, including fraudulent or missing traceability documents, entry records, or health certificates (Lambin et al., 2018). It also involves adding unknown substances to the product or diluting it and may involve a wide range of contaminants. Counterfeiting was the biggest threat to the beef supply chain, as most reports were reported in this category. Production in non-approved premises also indicates that there are illegal supply chains outside the realm of the legitimate beef sector (Mahood et al., 2020). Counterfeit products threaten the food industry and public health because they are unlikely to undergo the required level of hygiene or quality control and, therefore, significantly increase the risk of a food safety outbreak (Moore et al., 2012). The beef sector is likely to suffer an economic downturn due to the immediate withdrawal costs. The longer-term impact of consumer distrust in the industry could also affect sales throughout the supply chain, involving both legitimate and non-legal actors.

According to the findings, secondary processing is the most vulnerable area for the beef sector. Many reports were identified in this sector (59%/163 reports). Secondary processing is an area where products from other companies and countries enter the beef supply chain, making it an area of vulnerability (Robson et al., 2021). Counterfeit reports are the most common. This means that these counterfeit reports do not occur within a legitimate beef sector that is well regulated by legislative requirements, third-party accreditations, and customer requirements. Unauthorized processors can damage the reputation of the whole supply chain and endanger public health, the consumer, and the beef industry (Webb et al., 2018). Other reports have been made available of veterinary drugs and the use of growth promoters. Residues of the veterinary medicinal product and growth promoters will persist in the current stages of the beef supply chain, which will pose a threat to public health. The health effects of a vehicle with veterinary drugs and growth promoters may vary depending on the substances. A major concern associated with the use of antimicrobials in animals is the development of antimicrobial resistance in humans, which makes it difficult to treat infections. Other effects include blood dyscrasias and cancer (Bolton, 2021). Due to the large number of substances that can be subsequently taken up, the relevant components are very problematic. As a result, there is the constant use of active veterinary drugs and substances to support the growth of fisheries for meat suppliers (Pighin, 2016).

The trend in the beef chain in food is that fraud is still occurring. As a result of regular and improved testing, detection, and awareness, more fraud is detected regularly. This is evidenced by the year 2013 when the highest level of reported fraud took place, which coincided with the "Horse" scandal. After 2013, fraud reports were consistently higher than before 2013, only in the 20 years from 1997 to 2017. I argued that the threat of food fraud began after the reduction of 'Horsemeat' because of increased testing (Robson et al., 2021). The first report of fraud was reported in 2001, but food fraud dates to Roman times, so fraud in the beef industry likely occurred long before 2001 (Schulze, 2021). In 2001, the EU implemented a bovine testing program in response to the bovine spongiform encephalopathy (BSE) crisis, and the resulting increase in testing could also explain the increase in fraud detection.

In 2011, there was an increase in counterfeiting of illegal veterinary drugs and growth promoters. This is in line with the fact that the World Health Organization (WHO) in 2011 selected antimicrobial resistance as the theme of World Health Day (Leung et al., 2011). This has raised public awareness, leading to overhauling and the use of antibiotics in production animals (Herrero et al., 2015). It could be confirmed that this awareness-raising has led to an increase in testing and thus to greater detection of the use of illegal veterinary medicines.

There may be differences in levels by country and fraud following relevant country reports due to differences in testing between countries, as well as differences depending on the type and frequency of authentication. These differences can be attributed to the amount of beef produced between countries and to the difference in the amount of beef imported/exported to/from the countries. Most of the reported cases of food fraud under the RASFF come from Brazil. However, Brazil has not
reported any reports of fraud. It may be the result of various controls and legislation on food fraud reporting (Robson et al., 2021). Due to the hidden nature of food fraud, the true frequency of its occurrence is unknown (Manning and Soond, 2016). Resources like RASFF or HorizonScan are needed to better understand trends and events in food fraud. However, it is unlikely that all cases of food fraud in the global beef supply chain will be caught in the RASFF (Ropodi et al., 2015).

CONCLUSION

Our analysis aimed to increase understanding of the different types of fraud in the beef supply chain. In addition, highlight the areas in the supply chain that are most prone to fraud. This information helps to understand better how to defend the supply chain and protect legitimate actors and consumers from fraud. Adulteration, counterfeiting, fake, copy, diversion tampering is the biggest threat to the beef supply chain in terms of the type of fraud. We further found that the most vulnerable area is secondary processing, followed by primary processing. These areas are considered key in the supply chain, as there is a risk that all subsequent areas of the beef supply chain will be affected by fraud.

However, an in-depth analysis of detection and prevention measures within the beef supply chain is urgently needed to achieve a broader understanding of vulnerabilities. Furthermore, the analysis of suspected fraud, which is discussed in the media and scientific sources, is important, as it is unlikely that all fraud reports can be detected by traditional means. Combined with an overview, these efforts will help to understand and enable the development of targeted detection and prevention methods in the beef supply chain.

Acknowledgements: This work was supported by the Slovak Research and Development Agency under Grant: the Contract no. APVV-19-0180.

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