SCIENTIFIC REPORT

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An update on the risk of transmission of Ebola virus via the food chain – Part 2

European Food Safety Authority (EFSA)

Abstract

'Top-down' (e.g. surveillance-based) and 'bottom-up' approaches (e.g. using the standard microbial risk assessment paradigm) were combined to assess the risk of foodborne transmission of Ebola virus to persons in Europe arising from the consumption of raw food other than bushmeat imported from African countries where human outbreaks due to Zaïre Ebola virus (ZEBOV) have occurred. Using the 'top-down' approach, it was concluded that food other than bushmeat has never been identified as associated with human ZEBOV cases in any of the reported outbreaks. There is no evidence for foodborne transmission of ZEBOV to persons in the European Union (EU). The 'bottom-up' approach revealed that the necessary sequence of events in the risk pathway involves many hurdles: 1) the raw food to be exported has to be contaminated with ZEBOV at the point of origin; 2) the imported food needs to contain viable virus when it arrives in the EU; 3) the person has to be exposed to the virus; and 4) the person needs to get infected following exposure. Each of these steps is necessary in order for a case of disease to occur and none have been documented to happen in practice. Due to lack of data and knowledge, which results in very high uncertainty, it is not possible to quantify the risk of foodborne transmission of ZEBOV derived from the consumption of these imported foods, or in fact whether or not this mode of transmission could occur at all. The overall conclusions of both approaches are consistent and suggest that the risk of foodborne transmission of ZEBOV via food other than bushmeat imported into the EU remains a theoretical possibility only and has never been demonstrated in practice. However, the uncertainty in the combined assessment is considered high given the lack of data.

Keywords: Zaïre Ebola virus, ZEBOV, food, vegetables, fruits, survival, foodborne transmission

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Correspondence: biohaz@efsa.europa.eu

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Summary

Following a request from the European Commission, EFSA was asked to provide scientific and technical assistance on the risk of foodborne transmission of Ebola virus to persons in the European Union (EU) arising from the consumption of raw foods imported from African countries where human outbreaks due to Zaïre Ebola virus (ZEBOV) have occurred. The assessment had to cover food in general and in particular plants/fruits/vegetables and the products thereof. It did not consider illegally imported bushmeat, as this assessment was already performed.

Outbreaks of ZEBOV have been reported from 1976 to 11 March 2015 in nine African countries: Democratic Republic of Congo, Republic of Congo, Gabon, Guinea, Liberia, Mali, Nigeria, Sierra Leone and Senegal. A broad range of foods are imported into the EU from these nine African countries. Volumes of imports are highest for the category 'coffee, tea, cocoa, spices, and manufactures thereof' followed by 'vegetables and fruit' and then 'fish, crustaceans, molluscs and aquatic invertebrates, and preparations thereof'.

In this assessment, 'top-down' (e.g. surveillance-based) and 'bottom-up' (e.g. using the standard microbial risk assessment paradigm, where the agent is followed through the food chain to produce a prediction of risk to human health relative to other agents and/or foods) approaches were combined. Using the 'top-down' approach, it was concluded that food other than bushmeat has never been identified as associated with human ZEBOV cases in any of the reported outbreaks. There is no evidence for foodborne transmission of ZEBOV to persons in the EU.

Using the 'bottom-up' approach, it was concluded that the necessary sequence of events in the risk pathway involves many hurdles: 1) the raw food to be exported has to be contaminated with ZEBOV at the point of origin; 2) the imported food needs to contain viable virus when it arrives in the EU; 3) the person has to be exposed to the virus through the handling and preparation (both carried out by consumers or staff handling the food in kitchens immediately prior to consumption) as well as consumption of contaminated food; and 4) the person needs to get infected following exposure. Each of these steps is necessary in order for a case of disease to occur and none have been documented to happen in practice. Due to lack of data and knowledge, which results in very high uncertainty, it is not possible to quantify the risk of foodborne transmission of ZEBOV derived from the consumption of these imported foods, or in fact whether or not this mode of transmission could occur at all.

The overall conclusions of both 'top-down' and 'bottom-up' approaches are consistent and suggest that the risk of foodborne transmission of ZEBOV via food other than bushmeat imported into the EU remains a theoretical possibility only and has never been demonstrated in practice. However, the uncertainty in the combined assessment is considered high given the lack of data.

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1. Introduction

1.1. Background and Terms of Reference as provided by the European Commission

In April 2014 the European Commission requested the European Centre for Disease Prevention and Control (ECDC) to assess 'What is the risk of transmission of Ebola virus through contact with bushmeat irregularly transported by passengers coming from areas affected by Ebola virus disease. Has such a transmission mode been documented in the past?'

The ECDC consulted the European Food Safety Authority (EFSA) on the food safety aspects and identified a low risk in bushmeat but with high uncertainties.

Import into the European Union (EU) of any fresh meat from Western African countries is not authorised. Member States and EFTA countries have been alerted to increase vigilance on personal passengers' luggage.

Ebola virus (EBOV) is thought to circulate in wild animals in sub-Saharan Africa. It has been found in fruit bats, chimpanzees, gorillas and duikers. Human infections have been linked to direct contact with such animals. The World Health Organization (WHO) recognises that people in some parts of the affected countries rely on bushmeat for their livelihood and do not avoid eating meat from animals found dead in the 'bush'. Import of non-human primates is not harmonised (national rules apply) but they can only be introduced into approved bodies, centres and institutes in the EU. From the EU TRACES system, it appears that no imports have taken place from the affected countries.

The websites of WHO and ECDC mention that initial cases of Ebola were contracted by handling infected animals or carcasses, secondary cases occur by direct contact with the body fluids of an ill person, either through unsafe case management or unsafe burial practices.

Terms of Reference as provided by the European Commission

In view of the above I request EFSA to provide a technical assistance, in the framework of Article 31 of Regulation (EC) No 178/2002 in order to:

1. Review the risk linked to transmission of EBOV via bushmeat. This was considered low, although with a high level of uncertainties. Would new scientific information/evidence lead to conclude an increased risk of EBOV via bushmeat as a source of contamination or is the earlier assessment still valid?

2. What is the persistence/transmissibility of EBOV through meat or animal products?

3. WHO recommended for risk reduction, amongst others, 'to reducing the risk of wildlife-to-human transmission from contact with infected fruit bats or monkeys/apes and the consumption of their raw meat. Animals should be handled with gloves and other appropriate protective clothing. Animal products (blood and meat) should be thoroughly cooked before consumption.'

   Is meat from these species able to transmit/carry the EBOV? Are there other species potentially dangerous?

   Are there any data available on physical (especially heating) or chemical treatments that would inactivate the EBOV in products of animal origin and especially in meat?

4. In the event of possible future outbreaks, what would be the drivers for occasional spillover event, including ecological factors?

Following the receipt of EFSA's first Scientific Report on the Terms of Reference (ToR) one, two and three (EFSA, 2014b), I would like you to expand the mandate to the risk of transmission of Ebola through food in general, and in particular via the imports of plants/fruits/vegetables and the products thereof.

The Commission requested that EFSA provides the technical assistance by the end of March 2015.

Clarification provided by the European Commission

The European Commission agreed with EFSA's proposal to restrict the assessment to raw foods that are imported from African countries where human outbreaks due to Zaïre Ebola virus (ZEBOV) have occurred. The ToRs were therefore revised to:

'Assess the risk of foodborne transmission of Ebola virus to persons in Europe arising from the consumption of raw foods imported from African countries where human outbreaks due to ZEBOV have occurred.'

It is understood that the assessment will cover food in general and in particular raw foods such as plants/fruits/vegetables and the products thereof. It will not consider illegally imported bushmeat, as this was the focus of the first Scientific Report (EFSA, 2014b).

2. Data and Methodology

There are two different approaches to estimating the risk associated with pathogens in food, as discussed in EFSA Panel on Biological Hazards (BIOHAZ), 2012. In the surveillance-based, or 'top-down', approach, the level of risk associated with specific foods, hazards, or their combinations is based on information gathered from epidemiological systems such as disease reporting and outbreak databases. The top-down approach is directly related to observed human disease, but good surveillance information may not always be available, and it may be difficult to attribute cases of illness to specific sources of exposure. The 'bottom-up' approach adheres roughly to the standard microbial risk assessment paradigm and follows the agent through the food chain to produce a prediction of risk to human health relative to other agents and/or foods. This approach can integrate diverse and detailed information about the occurrence and dynamics of pathogens in food chains, and may provide a basis for selecting intervention measures. Data requirements for the bottom-up approach are high and expert opinion is frequently used to address missing data. A combined strategy using both top-down and bottom-up approaches may provide the best evidence for decision making, and this combined approach was adopted in the current Scientific Report. Within the bottom-up approach and specifically for this assessment, elements of the import risk assessment framework described in Chapter 2.1 Terrestrial Animal Health Code of the World Organisation for Animal Health (OIE) (OIE (World Organization for Animal Health), 2014) were combined with the CODEX food safety risk assessment (CODEX, 2007). These steps are: 1) Entry assessment (until the imported food arrives in the EU), 2) Exposure assessment, 3) Hazard characterisation, and 4) Risk characterisation.

The assessment in this report is based on the available information in the scientific literature or relevant websites. As in the previous Scientific Report (EFSA, 2014b), this assessment will only consider ZEBOV. In addition, only legal importation of (raw) food from those African countries where human outbreaks of ZEBOV infection have been reported was considered. The list of these countries was compiled using data published by the World Health Organization (WHO). The Eurostat Comext database was used to identify those food items that are legally imported into the EU from these countries.

To identify reported foodborne outbreaks or sporadic cases of ZEBOV infection worldwide, and to assess the occurrence of ZEBOV in food, a literature search in Web of Science database was undertaken. The search terms used cover all the relevant specific food items identified via the Eurostat Comext database as having been legally imported into the EU28 (the current 28 Member States in the EU, see Section 3.2) from January 2009 to November 2014 from the African countries where human outbreaks of ZEBOV infection have been reported (see Section 3.1). No time or language restrictions were applied for the literature search, which was conducted on 14 January 2015. The resulting search string was used: (Filov* OR Ebola OR ZEBOV OR EBOV) AND (food* OR meat* OR dairy OR poultry OR bird* OR egg* OR fish* OR crustacean* OR mollusc* OR cereal* OR vegetable* OR fruit* OR plant* OR coffee OR tea* OR cocoa OR spice* OR sugar* OR honey* OR salmon* OR tuna OR bonito OR skipjack OR herring* OR sardin* OR mackerel OR hake OR cod OR flour OR shrimp* OR prawn* OR cuttlefish OR octopus OR squid OR caviar OR wheat OR spelt OR rice OR barley OR maize OR oat* OR sorghum OR millet OR meslin OR malt OR potato* OR chick pea* OR bean* OR lentil* OR shallot* OR leek* OR tomato* OR onion* OR garlic OR cabbage* OR lettuce OR carrot* OR cucumber* OR leguminous OR mushroom* OR brassica* OR chicory OR turnip* OR gherkin* OR endive* OR beetroot* OR truffle* OR cassava OR arrowroot OR celeriac OR fungi OR

manioc OR salep OR radish*OR artichoke* OR tapioca OR sago OR nut* OR orange* OR lemon* OR citrus OR banana* OR lime* OR raisin* OR coconut* OR cashew OR almond* OR walnut* OR pistachio* OR melon* OR pineapple* OR date* OR avocado* OR juice* OR watermelon* OR papaya* OR papaw* OR guava* OR must OR mango* OR grape OR mangost* OR molasses OR syrup OR chocolate OR mate OR pepper* OR mace OR badian OR nutmeg OR fennel OR cardamon* OR coriander OR vanilla OR clove* OR nutmeg OR anise OR ginger OR cumin OR caraway). A total of 766 references were retrieved and screened for evidence of foodborne transmission of ZEBOV or its occurrence in food. A subset of 43 references were considered potentially relevant and reviewed in detail.

To identify information from the scientific literature on survival of ZEBOV in the environment, including on food, a separate search was conducted in Web of Science database. The search terms used were: (Filov* OR Ebola OR ZEBOV OR EBOV) AND (persisten* OR surviv* OR inactiv* OR viability OR viable) and no time or language restrictions were applied for the literature search. Using these terms, 465 unique references were identified and screened for relevance. A subset of 19 references were considered potentially relevant and reviewed in detail.

In addition, given the need for information on the presence of the virus in faeces in relation to environmental contamination, a different literature search was conducted with the following search terms: (Filov* OR Ebola OR ZEBOV OR EBOV) AND (faecal OR fecal OR faece* OR fece*), without time or language limitations. A total of 23 unique references were identified and screened for relevance, with four articles considered potentially relevant and reviewed in detail.

3. Assessment

This assessment follows on from a previous EFSA Scientific Report that addressed the risk of transmission of Ebola virus to persons in Europe via the handling and preparation (both carried out by consumers or staff handling the food in kitchens immediately prior to consumption) as well as consumption of illegally imported bushmeat from Africa[1] (EFSA, 2014b). Readers are therefore referred to this report for general background information on Ebola viruses.

Ebola viruses are considered to be highly transmissible to and among humans by direct contact with infected blood and other bodily fluids/secretions (e.g. stool, saliva, sweat, semen, breast milk), tissues, organs from dead or living infected persons, although quantitative information on rates and levels of shedding by these different potential sources of infection is sparse (ECDC, 2014). The principal mode of transmission in outbreaks is person-to-person transmission through direct contact with a symptomatic or dead Ebola virus disease (EVD) case. Transmission via inanimate objects contaminated with infected body fluids (fomite transmission) is also possible (Colebunders and Borchert, 2000). Airborne transmission has not been documented (WHO, 2014c).

The current outbreak in West Africa, first reported to the WHO on 22 March 2014 (impacting mainly Guinea, Liberia and Sierra Leone) was caused by ZEBOV. Between December 2013 and 11 March 2015, 24 282 human cases of EVD, including 9 976 deaths have been reported by the WHO (WHO, 2015).

3.1. African countries where human outbreaks due to ZEBOV have occurred

Human outbreaks of ZEBOV reported from 1976 to 11 March 2015 in Africa have been summarised by the WHO (2014a, 2015). Table 1 summarises this information and illustrates the number of outbreaks, total number of cases and deaths due to ZEBOV in African countries.

Human outbreaks due to ZEBOV have been reported in nine countries: Democratic Republic of Congo, Republic of Congo, Gabon, Guinea, Liberia, Mali, Nigeria, Sierra Leone and Senegal.

[1] Bushmeat was defined as 'meat taken from any animal native to African forests, including species that may be endangered or not usually eaten outside Africa'. Source: http://www.collinsdictionary.com/dictionary/english/bushmeat

Table 1: Summary of human outbreaks of Zaïre Ebola virus (ZEBOV) infection in African countries from 1976 to 11 March 2015 (WHO, 2014a, 2015)

Country	Number of outbreaks	Total number of cases	Total number of deaths
Past outbreaks			
Democratic Republic of Congo	5	930	736
Republic of Congo	4	249	211
Gabon[(a)]	4	208	150
Current outbreak			
Guinea	1	3 285	2 170
Liberia		9 343	4 162
Mali		8	6
Nigeria		20	8
Senegal		1	0
Sierra Leone		11 619	3 629

(a): A case of ZEBOV was confirmed in South Africa in 1996, but it was linked to the outbreak in Gabon the same year.

3.2. Food exported into the EU from countries where human outbreaks due to ZEBOV have been reported

Upon entry into the EU, animals, products of animal origin, germinal products, animal by-products and certain composite products, are required to undergo systematic import controls (documentary, identity and physical checks) at Border Inspection Posts. Checks are intended to verify compliance with the import conditions established by EU rules for these commodities and in particular: the provenance of the animals or products from an eligible third country, from an approved establishment, and the appropriate health certificates accompanying the imported products. Where one of these three conditions is not laid down in EU legislation for specific animals or products of animal origin, the applicable EU import conditions may be supplemented by national requirements. As none of the nine countries listed above fulfil these conditions, meat, meat products and meat preparations, milk and milk products, and eggs and egg products from these countries cannot be legally imported into the EU.

With regard to food of non-animal origin, all nine countries mentioned in Section 3.1 are allowed to export fruits and vegetables into the EU. The only exception is potatoes, the import of which is prohibited. There are no further plant health restrictions regarding the origin of fruits and vegetables or establishments/places of production in the countries of origin. Upon entry into the EU, some fruits and vegetables specified in Council Directive 2000/29/EC, Annex V.B, part I point 3 and part II point 6a are required to undergo systematic phytosanitary (plant health) import controls (documentary, identity and physical checks). Documentary check, at least, has to take place at a border Point of Entry (Border Inspection Post). Identity and physical checks may, under certain conditions, take place at the point of destination but, nevertheless, in such cases the checks have to take place prior to formal release by Customs. Checks are intended to verify compliance with the plant health import requirements established by EU rules for the specified commodities.

The volumes and types of food which have been legally imported into the EU from the nine African countries where human outbreaks with ZEBOV have ever been reported (see Section 3.1) were extracted from the Eurostat Comext database (http://epp.eurostat.ec.europa.eu/newxtweb/). Personal imports of food as part of the personal luggage allowance of visitors to these countries were not considered in this assessment given the relatively minor quantities involved compared to the volumes arriving into the EU via commercial trade.

Table 2 summarises the aggregated import statistics for five relevant food categories (according to the Standard International Trade Classification (SITC) food commodity categorisation) into the EU28 from January 2009 to November 2014, extracted on 12 March 2015. Import data are shown per exporting country and as the sums of volumes of imported foods from all relevant African countries. Data show that a broad range of foods are imported into the EU from those nine African countries. Volumes of imports are highest for the categories 'coffee, tea, cocoa, spices, and manufactures thereof' followed by 'vegetables and fruit' and then 'fish, crustaceans, molluscs and aquatic invertebrates, and preparations thereof'. For the latter two categories, most imports seem to originate

from Senegal. As an example, in the category, 'vegetables and fruit', tomatoes and leguminous vegetables (fresh or chilled) and melons and papayas (fresh), avocados, guavas, mangoes (fresh or dried) are imported. It should be noted that information provided through this source may be incomplete and have limitations due to lack of reporting harmonisation.

Table 2: Food belonging to categories that can be legally imported into the European Union from African countries where human outbreaks of Zaïre Ebola virus (ZEBOV) infection have been reported from 1976-present. Aggregated volumes from January 2009 to November 2014 are presented in metric tons. Data extracted from Eurostat Comext database on 12 March 2015 (http://epp.eurostat.ec.europa.eu/newxtweb/).

Exporting country	Food category[(a)] (metric tons)					
	03 – Fish (not marine mammals), crustaceans, molluscs and aquatic invertebrates, and preparations thereof	**04 – Cereals and cereal preparations**	**05 – Vegetables and fruit**	**06 – Sugars, sugar preparations and honey**	**07 – Coffee, tea, cocoa, spices, and manufactures thereof**	**TOTAL (sum of imported food categories 03 to 07)**
Democratic Republic of Congo	24.9	55.0	7 586	nt	33 520	41 187
Republic of Congo	4.3	20.0	786.5	0	41 312	42 123
Gabon	170.7	0.0	20.2	0	1 000	1 191
Guinea	N/A [(b)]	170.3	4 729	0.1	81 315	86 215
Liberia	N/A [(c)]	36.3	51.0	0	47 774	47 862
Mali	N/A [(c)]	1 031	31 894	34.7	109.4	33 070
Nigeria	24 519	495.5	55 504	188.6	1 204 022	1 284 729
Senegal	232 143	2 054	320 578	27.2	632.7	555 435
Sierra Leone	N/A [(c)]	0	1 036	16 932	88 933	106 901
Total	**256 862**	**3 863**	**422 185**	**17 182**	**1 498 620**	**2 198 712**

N/A: Not applicable; nt: no trade reported.
(a): Volumes are presented for the European Union considering the current 28 Member States (EU28). Food commodity categories according to Standard International Trade Classification (SITC). All subcategories imports that can legally be imported into the EU under the category code 'food and live animals' (code 0) have been included except for the subcategory 'Miscellaneous edible products and preparations' (code 09) because the food items classified under it were considered not relevant (e.g. margarine, shortening, edible products and preparations)
(b): This country does not have authorised establishments to export products from this category to the EU
(c): These countries are not approved to export products from this category to the EU

3.3. Assessment of the risk of transmission of ZEBOV via food other than bushmeat

As described in Section 2, in this assessment of the risk of transmission of ZEBOV via food other than bushmeat, a combined strategy using both 'top-down' and 'bottom-up' approaches was applied to provide the best evidence for decision making.

3.3.1. Top-down assessment: evidence of foodborne cases of ZEBOV infection in humans

There is no evidence that any persons in the EU (including the 12 cases of EVD evacuated to the EU from Africa during the current Ebola outbreak (ECDC, 2015) and the single case acquired in Spain) have been infected with ZEBOV from consuming foods. In previous Ebola outbreaks in Africa, practices prior to consumption (such as hunting, butchering, and preparation) rather than

consumption of the (bush) meat *per se*, were identified as key risk factors for people that became infected (Pourrut et al., 2005).

Even though there is no evidence of foods other than bushmeat being involved in transmission of ZEBOV to humans, Nkoghe et al. hypothesized that the high prevalence of ZEBOV-specific IgG in humans inhabiting forest areas in Gabon could be attributed to exposure to the virus while gathering or consuming fruits contaminated by bat saliva (Nkoghe et al., 2011b). ZEBOV (or EBOV) antibodies have been observed in disease-free individuals, even in areas where no outbreaks have been documented, more frequently than antibodies to other haemorrhagic viruses (Johnson et al., 1983; Mathiot et al., 1989). Different explanations for these observations have been proposed, including the circulation of less or avirulent strains (Mathiot et al., 1989; Petit et al., 1996), asymptomatic carriage (Rowe et al., 1999; Leroy et al., 2000) and the lack of specificity of serological tests, in particular the immunofluorescence tests used for these studies (Petit et al., 1996).

None of the references retrieved provided any useful information to support the possibility of foodborne transmission of ZEBOV, nor about its occurrence in any food other than bushmeat. It can therefore be concluded that food other than bushmeat has never been identified as associated with human ZEBOV cases in any of the reported outbreaks.

3.3.2. Bottom-up assessment of the risk of transmission of ZEBOV via food other than bushmeat

Food other than bushmeat has never been identified as associated with human ZEBOV cases in any of the reported outbreaks, but ingestion of contaminated food cannot be ruled out as a possible route of exposure in natural infections (Feldmann and Geisbert, 2011). It is possible for ZEBOV to contaminate food that could be exported to the EU, although this has never been observed.

To assess the potential risk of transmission of ZEBOV via food other than bushmeat, the risk pathway used in the previous Scientific Report (EFSA, 2014b) was modified. The main changes relate to the entry assessment, as food can theoretically be contaminated in several ways (Figure 1).

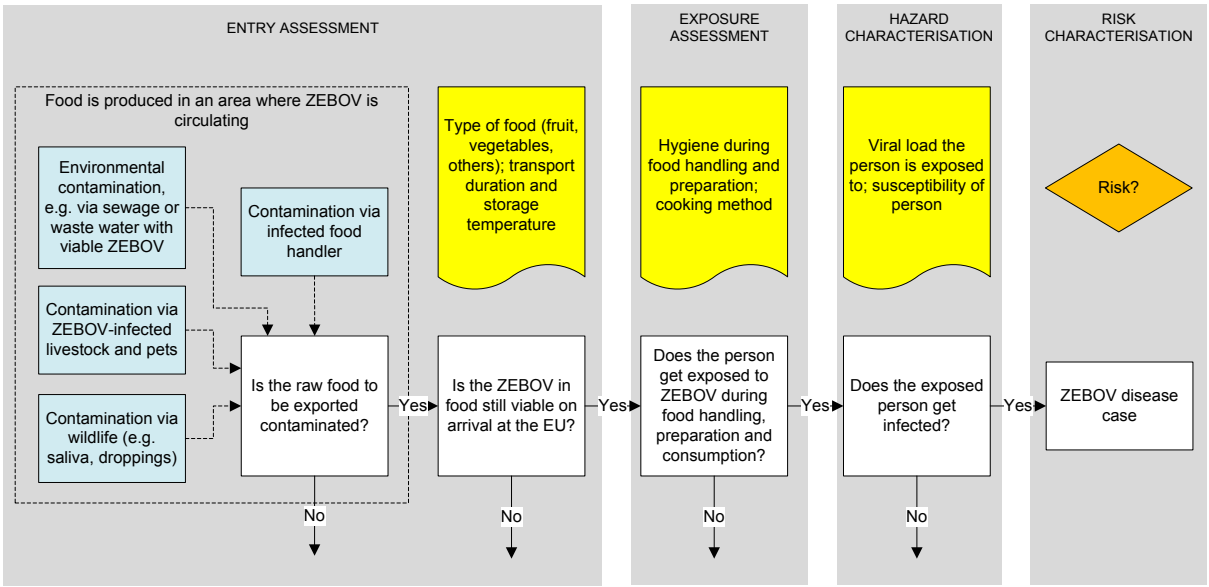

Figure 1: Risk pathway for ZEBOV to reach persons in the EU via food other than bushmeat

This diagram summarises the series of steps that are necessary for a single case of EVD to occur in the EU due to food other than bushmeat contaminated with ZEBOV. The necessary sequence of events involves many hurdles: 1) the raw food to be exported has to be contaminated with ZEBOV at the point of origin; 2) the imported food needs to contain viable virus when it arrives in the EU; 3) the person has to be exposed to the virus; and 4) the person needs to get infected following exposure. The different steps in this pathway are described below. It has to be noted that all the steps are necessary; if the answer to one of the questions in any of the steps is 'no', then the probability of the case of EVD occurring is zero. In addition, it is important to stress that, since foods other than

bushmeat have never been identified as associated with transmission of ZEBOV (as indicated in Section 3.3.1), this is a purely hypothetical exercise.

Entry assessment

Sources of contamination of food with ZEBOV at the point of origin

Food produced in one of the nine African countries in areas where ZEBOV is circulating (either in wildlife or the human population, or both) could be contaminated in a number of ways. The various ways considered in this assessment are contamination via infected wildlife, via infected livestock and pets, via the environment and via infected food handlers, as described below.

(a) Contamination of food via infected wildlife

Fruit and vegetables can become contaminated with ZEBOV through the droppings or saliva of wildlife, which may serve as virus reservoirs, such as fruit bats or non-human primates. For this to happen, infected animals would need to frequent areas where food, most likely fruits or vegetables, are produced. Although the presence of ZEBOV in faeces of infected bats has been demonstrated in experimental studies (Swanepoel et al., 1996), the role of contaminated faeces in the transmission of filoviruses is not clear (Paweska et al., 2012). Saliva is mentioned in the literature as a potential route of transmission (Gonzalez et al., 2007; Nkoghe et al., 2011a; Olival and Hayman, 2014; Plowright et al., 2015), but no definitive proof of food being contaminated with ZEBOV was provided. The virus might rapidly be inactivated by salivary enzymes or other factors in the oral cavity that are unfavourable to virus persistence and replication. This was suggested in the study by Bausch et al. (2007) where only one saliva specimen from humans was culture-positive for EBOV, in contrast to the eight specimens that were found positive by RT-PCR. Another study has shown that EBOV can be detected by RT-PCR up to ten days post-mortem in the oral cavity of cynomolgus macaques, viable virus was detected up to seven days post-mortem (Prescott et al., 2015).

(b) Contamination of food via infected livestock and pets

Although there are no reports of livestock becoming infected with ZEBOV other than in laboratory settings, the possibility of farm animals becoming infected following contact with infected wildlife or infected humans exists. There is evidence that pigs are susceptible to ZEBOV (Kobinger et al., 2011). As included in two recent reports (EFSA, 2014a; FAO, 2015), there is no evidence of dogs or cats becoming sick with EVD or of being able to spread EBOV to people or animals, including in areas in Africa where EBOV is present. There is high uncertainty about viraemia, virus shedding or clinical signs in pets, and about pets acting as fomites.

In addition, meat from livestock could also contain the virus, as hypothesised by Bausch (2011), although this has never been observed to date. This potential pathway should not lead to an increased risk given that imports of meat or meat products from countries where ZEBOV outbreaks have occurred into the EU are not allowed.

(c) Contamination of food via the environment

Considering that ZEBOV causes a systemic infection in humans affecting most organ systems, virus can be present in most secretions and excretions. ZEBOV is shed in a wide variety of body fluids during the acute period of illness (Ksiazek et al., 1999; Towner et al., 2004), including saliva, breast milk, stool, and tears (Bausch et al., 2007). ZEBOV could therefore be present in sewage or waste water from e.g. buildings such as hospitals, or areas with a high prevalence of human cases of EVD. These contaminated sewage or waste water could be used for irrigation, leading to fruits and vegetables being contaminated with the virus. The waste water can also contaminate water used for fish farming which could potentially result in contaminated fish or shellfish. There is very little information, however, on the role of sewage or waste water in the epidemiology of EVD.

Public Health England (2014) considers that if the virus enters the sewage system in the hospital setting it will be diluted and would likely be degraded by a combination of factors such as disinfectants present in the hospital waste, pH, osmolality, temperature and the effects of fermentation processes. Its advice was that the risk of survival and transmission of the virus in sewage is negligible. Similarly, in the United States, wastewater processing systems are designed to inactivate pathogens such as ZEBOV (CDC, 2014). It is unclear if these assessments can be generalised to the situation in areas

affected by the current EVD outbreak. WHO (2014b) state that 'The characteristics of the Ebola virus suggest that it is likely to be relatively fragile in the environment in comparison with the enteric viruses that commonly cause diarrhoeal disease. To date, there is no evidence for transmission of Ebola viruses via drinking-water contaminated by faeces or urine. The virus is unlikely to survive for extended periods outside of the body. Higher temperatures (room temperature or above) are likely to increase the speed at which the virus dies-off in the environment'. This document also provides detailed instructions for waste management in health care facilities and communities, although it is not known if these are applied consistently in areas affected by the current outbreak.

(d) Contamination via infected food handler

It could be possible for a symptomatic infected food handler to contaminate food with ZEBOV, which could then be exported. The risk for transmission would depend on the phase of human disease in the infected food handler. Transmission is considered negligible before the onset of symptoms (Bannister, 2010), but viral loads in blood and secretions rapidly increase during the course of illness, with the highest levels of virus shedding observed late in the course of illness of severely ill patients (Dowell et al., 1999), although there is variation in the amount of virus shed by sick people. Given the severity of the disease, it is unlikely that persons with clinical signs of EVD would still be manipulating food.

Occurrence and survival of ZEBOV in food

No information is available on the potential for ZEBOV to internalise within, or survive on, foods. Two studies (Piercy et al., 2010; Sagripanti et al., 2010) have been performed in which the survival of ZEBOV was followed when dried on solid surfaces. These studies show that rapid inactivation occurred under the experimental conditions used, at room temperature. At lower temperatures (4 °C), survival is better, but nevertheless a 4 $\log_{10}$ reduction was obtained after 14 days. Studies assessing the effect of ultraviolet radiation support the view that ZEBOV is relatively easy to be inactivated by sunlight. Lytle et al. (2005), indicated that Filoviridae are among the most UV-sensitive viruses. Viral particles in dried surfaces are more resistant than those suspended in liquid, as they are better shielded from UV radiation by other virions, proteins, and additional components of the medium (Sagripanti and Lytle, 2011).

In addition, in the course of an experimental study, several weed and crop plants were inoculated with ZEBOV to simulate mechanical transmission by rubbing, but no infectivity could be recovered from the plant tissues (Swanepoel et al., 1996).

Thus, the occurrence and survival of ZEBOV on food after storage will depend on where the virus is located (on the surface or internalised), the initial viral load and the storage conditions. For the latter, the factors to consider are: the temperature and time (with longer survival at lower temperatures), relative humidity and direct exposure to sunlight (ultraviolet radiation). In addition, the manipulation of the food prior to export (e.g. peeling, rinsing) could also influence the survival of the virus in the food.

In conclusion, there are no data in the literature about the different ways in which food other than bushmeat can get contaminated with ZEBOV, nor is there evidence on the occurrence of ZEBOV in any of the foods considered in this assessment or that contaminated foods could be imported into the EU.

Exposure assessment

As indicated in the previous EFSA Scientific Report (EFSA, 2014b), this step relates to the survival of ZEBOV on contaminated food during storage in the EU and the exposure (probability and numbers of ingested infectious virus) of persons in the EU to ZEBOV during handling and preparation (both carried out by consumers or staff handling the food in kitchens immediately prior to consumption), as well as consumption, of contaminated food.

Whether the virus survives in contaminated food or not will depend on how and for how long the food is transported and stored, how the food is handled and the method of food preparation, with complete inactivation expected in thoroughly cooked food and variable degrees of virus survival for those products consumed without further cooking (e.g. fresh leafy greens). Certain practices, such as drying/dehydrating, washing or peeling fruits and vegetables, could also reduce the degree of exposure to ZEBOV. In addition, the risk of cross-contamination might need to be considered.

Hazard characterisation

In this step, the probability of a person to get infected following preparation, handling and consumption of a meal containing contaminated food is assessed. From epidemiological observations, it is clear that ZEBOV generally uses mucosal sites as portals of entry to initiate the infection in humans. Experimental inoculation studies with ZEBOV were carried out in rhesus monkeys, used as appropriate surrogate for the infection in humans (Jaax et al., 1996). Monkeys were either inoculated intramuscularly (one positive control), via eye droplets (four animals) or orally (four animals, applying the virus by gently swabbing the oropharynx) using a dose of $10^{5.2}$ log virus per ml. All the intramuscularly and eye droplet inoculated monkeys developed a typical haemorrhagic disease and died. Three of the four 'orally' inoculated animals also developed typical disease signs and died while one remained uninfected (no virus isolation, no antibodies). In the orally inoculated animals, oro-pharyngeal tissues appeared to represent a prominent early target organ and, most likely, a portal of infection. The digestive tract itself became involved in later stages of the pathogenesis.

Upon ingestion and arrival in the digestive tract, ZEBOV is expected to be inactivated by the acid pH in the stomach as it is an acid labile virus (Mitchell and McCormick, 1984). However, it is known that the stomach pH may vary dependent on the presence or absence of food uptake. Also, food could be protective for acid inactivation of the virus.

When ZEBOV-contaminated raw food is ingested by humans, there is a possibility that the infection is initiated through contact of the virus with oro-pharyngeal tissues, depending on the amount of infectious virus taken up. However, other routes of infection (parenteral, eye droplets…) appear to represent more sensitive portals of virus entry than the oral route.

The conclusions reached in the previous report (EFSA, 2014b) are also valid in this case, as they are independent of the food that is being considered: 'Based on non-human primate studies, agents causing viral haemorrhagic fevers are believed to be highly infectious. The probability of infection will depend on the exposure route, e.g. ingestion, skin contact, mucosal surfaces etc. The public health consequences of a human case of ZEBOV linked to transmission via consumption of contaminated food occurring in Europe would be very serious given the high lethality and potential for secondary transmission'.

Risk characterisation

The outcome of this step would be the probability for at least a single human case of ZEBOV infection in Europe due to transmission via contaminated food other than bushmeat imported from African countries where cases of ZEBOV infection have been confirmed. The remit of the assessment was restricted to the risk of transmission of ZEBOV to persons in the EU arising from the handling and preparation (both carried out by consumers or staff handling the food in kitchens immediately prior to consumption) as well as consumption of contaminated food imported from African countries where cases of ZEBOV infection have been confirmed. Due to lack of data and knowledge, which results in very high uncertainty, it is not possible to estimate the risk of foodborne transmission of ZEBOV derived from the consumption of these imported foods, or in fact if this mode of transmission could occur at all. There is therefore no evidence to support this pathway of infection.

The necessary sequence of events (see the risk pathway) involves many hurdles: 1) the raw food to be exported has to be contaminated with ZEBOV at the point of origin; 2) the imported food needs to contain viable virus when it arrives in the EU; 3) the person has to be exposed to the virus, and 4) the person needs to get infected following exposure. Each of these steps is necessary in order for a case of disease to occur and none have been documented to happen in practice.

If the risk of foodborne transmission were confirmed in the future, the risk of acquiring a ZEBOV infection in the EU via imported contaminated food would be considered higher if:

- the food had been produced in conditions that would increase the likelihood of contamination (e.g. fruit collected from areas inhabited by infected wildlife),
- the contaminated food was consumed raw, without being washed or peeled in the case of vegetables and fruit,
- transport had a short duration and the transport storage temperature was lower, and

- favourable storage times and temperatures for viral survival were used at the household.

3.3.3. Combining the evidence from top-down and bottom-up assessments of the risk of transmission of ZEBOV via food other than bushmeat

The conclusions of both top-down and bottom-up approaches are consistent and suggest that the risk of foodborne transmission of ZEBOV via food other than bushmeat imported into the EU remains a theoretical possibility only and has never been demonstrated in practice. However, the uncertainty in the combined assessment is considered high given the lack of data.

4. Conclusions

Assess the risk of foodborne transmission of Ebola virus to persons in Europe arising from the consumption of raw foods imported from African countries where human outbreaks due to ZEBOV have occurred.

- In this assessment, 'top-down' (e.g. surveillance-based approach) and 'bottom-up' approaches (e.g. using the standard microbial risk assessment paradigm, where the agent is followed through the food chain to produce a prediction of risk to human health relative to other agents and/or foods) were combined.

- Using the 'top-down' approach, it was concluded that food other than bushmeat has never been identified as associated with human ZEBOV cases in any of the reported outbreaks. There is no evidence for foodborne transmission of ZEBOV to persons in the EU.

- Using the 'bottom-up' approach, it was concluded that:

  - the necessary sequence of events involves many hurdles: 1) the raw food to be exported has to be contaminated with ZEBOV at the point of origin; 2) the imported food needs to contain viable virus when it arrives in the EU; 3) the person has to be exposed to the virus through the handling and preparation (both carried out by consumers or staff handling the food in kitchens immediately prior to consumption) as well as consumption of contaminated food; and 4) the person needs to get infected following exposure. Each of these steps is necessary in order for a case of disease to occur and none have been documented to occur in practice.
  - Due to lack of data and knowledge, which results in very high uncertainty, it is not possible to quantify the risk of foodborne transmission of ZEBOV derived from the consumption of these imported foods, or in fact whether or not this mode of transmission could occur at all.

- The conclusions of both 'top-down' and 'bottom-up' approaches are consistent and suggest that the risk of foodborne transmission of ZEBOV via food other than bushmeat imported into the EU remains a theoretical possibility only and has never been demonstrated in practice. However, the uncertainty in the assessment is considered high given the lack of data.

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