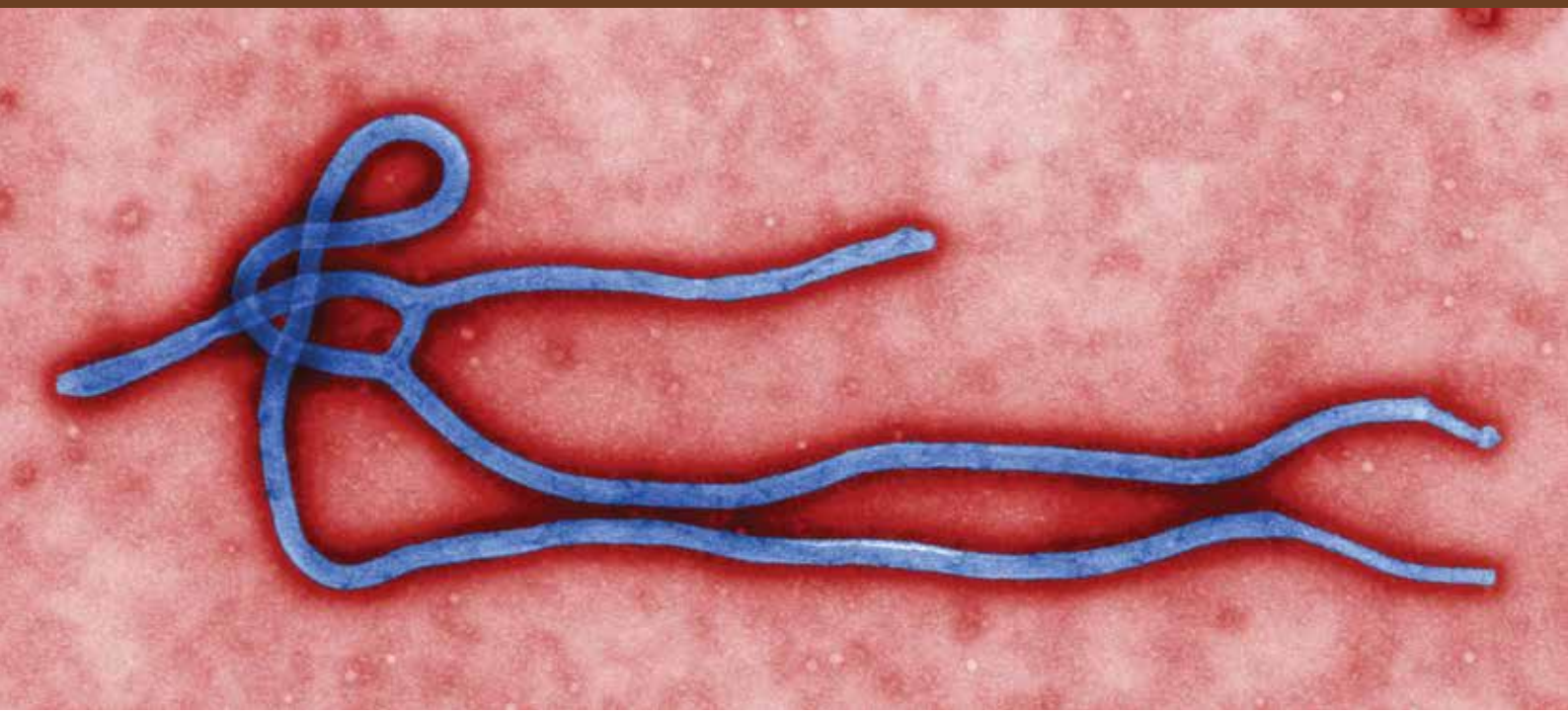
Food and Agriculture Organization of the United Nations

Addressing Zaire Ebola virus (EBV) outbreaks

Rapid qualitative exposure and release assessment



SUMMARY

The potential exposure and spread of EBOV

The outputs from this rapid qualitative exposure and release assessment are highlighted below:

1 The **likelihood** of spillover to **one human** from:
- » **one individual fruit bat,** such as *Hypsignathus spp., Epomops spp., Mops spp., Micropterus spp., Rousettus spp.* and *Myonycteris spp.,* **through handling and consumption** can be considered as **very low,**
- » **one individual from other wild mammalian species,** such as non-human primates like gorillas *(Gorilla gorilla)* and chimpanzees *(Pan troglodytes)* or non-primate species, like black-backed duikers *(Cephalophus dorsalis),* can be considered as **very low.**

Even if such spillovers can be **viewed as rare events,** their consequences are nonetheless disastrous. Human-to-human transmission of the virus can lead to important epidemics that are difficult to control, especially when people are engaging in risky practices (funeral or health care centres).

2 The **likelihood** of spillover to one human from **domestic mammalian species, such as:**
- » **dogs** can be considered **very low** to **low,**
- » **domestic pigs** as **very low.**

3 The likelihood of EBOV **being transmitted to humans through trade, handling or consumption of meat from wild animals** and leading to a new human outbreak in non-affected countries is considered **very low.**

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Following the ongoing outbreaks of Ebola virus disease (EVD) in several African countries reported since March 2014, the Food and Agriculture Organization of the United Nations (FAO) prepared a rapid qualitative exposure and release assessment in order to evaluate the role of meat from wild animals and related activities linked to Zaire Ebola virus (EBOV) in human populations. The likelihood for human exposure to EBOV through close contact with wild species, hunting, handling and consumption of meat from different wild species as well as the likelihood of introduction and onward transmission of EBOV in non-infected countries through the consumption and trade of wild animal meat are assessed in this document.

This rapid qualitative assessment is based upon information available up to 18 December 2014 and will be revised as circumstances change.

The reader should note that the **uncertainty in the assessment of the different levels of likelihood remains high** since there is a need for a better understanding of EBOV and related issues to provide a more precise assessment.

The background information used to conduct this rapid qualitative risk assessment can be found in the Annex at the end of this document.

1. MAIN RISK QUESTIONS ADDRESSED

- What is the likelihood for humans to be exposed to EBOV through close contact[1] with wild mammalian species in EBOV suitable areas of Africa[2]?
- What is the likelihood for humans to be exposed to EBOV through close contact with domestic mammalian species in areas of Africa where EBOV is present?
- What is the likelihood of EBOV spreading to an unaffected country through movement of meat from wild animals originating from EBOV suitable or affected African countries?

2. MAIN ASSESSMENT

QUESTION 1. What is the likelihood for humans to be exposed to EBOV through close contact with wild mammalian species in EBOV suitable areas of Africa?

Considering that:

- Fruit bats, particularly of the genera *Hypsignathus, Epomops, Mops, Micropterus, Rousettus and Myonycteris* (Olson *et al.,* 2012) are considered the likely natural host of EBOV in Africa; they can be infected and shed the virus without showing clinical signs of disease. These genera of bats, hunted by local populations for consumption, have been associated with spillovers of EBOV into rural settlements, while no other wild species were found to be affected by the virus. There is no evidence of other animals acting as naturally occurring reservoirs for EBOV.
- Other wild mammalian species, such as gorillas *(Gorilla gorilla),* chimpanzees *(Pan troglodytes)* and wild antelopes *(Cephalophus dorsalis)* showed high case fatality rates when exposed to EBOV and can be considered as wild sentinels of EBOV circulation in its forest environment. Human exposure and infection to EBOV through hunting, preparing and consuming such species was reported following close contact with blood and bodily fluids of infected animals and/or carcasses.
- EBOV spillover events from infected animals (infected fruit bats or other infected wild mammalian species) to humans may be seen as a rare event. Indeed, few EBOV outbreaks have been reported since the discovery of the virus in 1976 (Pigott *et al.,* 2014). Some authors suggest that isolated human cases may happen frequently in forested communities without being reported, as several epidemiological sero-surveys report high prevalence of Ebola virus antibodies in the absence of reported outbreaks in those communities (Muyembe-Tamfum *et al.,* 2012).

Therefore the likelihood for humans to **be exposed** to EBOV through close contact with:

- **Fruit bats,** especially of the genera *Hypsignathus, Epomops, Mops, Micropterus, Rousettus* and *Myonycteris* can be considered **high**[3] from infected animals and **nil** in uninfected ones. The fact that these species are suspected to harbour the virus without showing clinical signs makes it difficult to differentiate if they are infected or not. In addition, it is not known how often and for how long the natural infection of fruit bat populations occurs and how often they come into contact with humans while shedding the virus. It seems that even if exposure of humans to the virus may occur via close contact with infected fruit bats, this event could be regarded as **rare** and might not always lead to human EBOV outbreaks. The likelihood (taking into account the rarity of exposure) of EBOV **transmission** from one fruit bat to one human could therefore be considered as **very low;**
- **Other wild mammalian species,** such as non-human primates like gorillas *(G. gorilla)* and chimpanzees *(P.n troglodytes)* or non-primate species, like black-backed duikers *(C. dorsalis),* can be considered **high** when sick or dead EBOV infected animals of such species are handled or consumed. The exposure of humans to EBOV infected animals (sick or dead) might also be regarded as a **rare event.** As before, the likelihood of EBOV **transmission** from one wild mammalian species to one human could therefore be viewed as **very low.**

The reader should note that the **uncertainty in the assessment of the different levels of likelihood remains high,** since there is a need for a better understanding of EBOV.

It is important to remember that, aside from the first spillover event from an infected wild animal (clinically affected or not) to one single individual, the main exposure of humans to the virus during an epidemic is through close contact with bodily fluids from EBOV infected humans. Human-to-human transmission is likely to occur when engaging in risky practices (such as caring for an ill person or preparing the body of an Ebola patient for burial for instance), leading to high and potentially fatal consequences.

In the context of the EBOV epidemic in Western Africa (2014), genetic analyses conducted early in the outbreak suggest a single spill-over event, followed by human-to-human transmission (Gire *et al.,* 2014). More information would be needed to clarify if other spillover events have happened since then.

QUESTION 2. What is the likelihood for humans to be exposed to EBOV through close contact with domestic mammalian species in areas of Africa where EBOV is present?

Considering that:

- In past EBOV infected areas, no domestic animal has been found infected with EBOV or linked to EBOV exposure in human so far. It remains yet to be identified

[1] Close contact can be defined as any contact with carcasses, blood and bodily fluids of infected species.

[2] As defined in Pigott *et al.,* 2014.

[3] Levels of likelihood are defined as follow (from highest to lowest levels): **high** (highly likely to occur), **moderate** (potentially occurring), **low** (unlikely to occur), **very low** (very unlikely to occur) and **nil**.

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if domestic animals have a role in the epidemiological cycle. Dogs were shown to develop an immune reaction to EBOV (Allela *et al.,* 2005) in highly infected areas (i.e. during an ongoing human epidemic) but were never associated with virus isolation or viral shedding (Olson *et al.,* 2012). Their actual role in the transmission of the virus in highly infected areas has never been demonstrated and warrants investigation. It is, however, theoretically possible that dogs could act as passive carriers and serve as a source of virus for humans in highly infected areas, especially when feeding on infected corpses or contaminated materials.

- An experimental study showed that EBOV can be transmitted from infected domestic pigs to non-human primates (Weingartl *et al.,* 2012). Even if the minimal infectious dose for pigs via the oral-nasal route remains unknown, the study showed that shedding is primarily from the respiratory tract, and that infected pigs were able to infect other pigs and non-human primates via respiratory droplets without direct contact. Domestic pigs are susceptible under field conditions to Ebola Reston virus (REBOV), a strain that is avirulent for humans. No field data exists regarding their potential infection by EBOV.

Therefore the likelihood for humans to be exposed to EBOV through close contact with:

- **Dogs** can be considered **very low to low.** The likelihood of dogs spreading the virus mechanically after feeding on infected corpses or on bodily fluids in **highly infected areas** could be considered as **low.** In areas where deceased patients are appropriately buried and access by feral carnivores is prevented, this likelihood could be considered as very low. Nevertheless, their role as passive carriers should be further investigated;
- **Domestic pigs:** The results of the experimental study should be correlated with the epidemiological features of the disease in highly infected areas where symptomatic humans might not come in close enough contact with pigs to be able to transmit the virus. For domestic pigs, the likelihood of acting as biological carriers can therefore be considered **very low.**

QUESTION 3. **What is the likelihood of EBOV spreading to an unaffected country through the movement of meat from wild animals from EBOV suitable or affected African countries?**
Considering that:

- Meat from domestic and wild animals is regularly transported illegally from Africa to Europe or the United States of America in various forms. One study (Chaber *et al.,* 2010) estimated that 273 tonnes of meat from wild animals were imported every year into Paris Roissy-Charles de Gaulle (CGD) Airport in France on Air France carriers alone. Another study (Smith *et al.,* 2012) estimated an average of 25 000 tonnes of meat from wild animals to enter the United States annually.
- Studies showed that meat from wild animals is shipped in various forms (e.g. raw, transported raw in coolers, lightly smoked or well dried). The type of wild animals was also highly variable. Non-human primates were most often found, along with other wild non EBOV susceptible species, such as cane rats *(Thryonomys spp.).* No meat of bat origin was identified in the studies consulted for this assessment, even though some reports indicate that meat from bats has been shipped illegally to the United States.
- Meat from wild animals is usually shipped, sold and consumed well cooked or smoked. Even if the effect of cooking (inactivated after 30 minutes at 60 °C) and boiling on EBOV infectivity (inactivated after 5 minutes) is documented, no data is available regarding the viral survival of the virus in smoked meat products. Carcasses are considered to remain infective for 3 to 4 days after the animal's death.
- In the context of the 2014 Western Africa outbreaks, activities like hunting, trading and consuming meat from wild animals have been banned in infected countries (e.g. in Sierra Leone, Guinea and Liberia) and other West

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African countries to prevent wildlife-to-human spillover events. In Côte d'Ivoire for instance, a ban on meat from wild animals has been established and controls have been implemented in restaurants. Seized products of wildlife origin are destroyed. This ban has also affected commercial producers of farmed wild species, such as cane rats *(genus Thryonomys),* since it is not possible to differentiate their origin. Despite the ban on meat from wild animals, wildlife hunting is still ongoing in some western African countries.

Therefore:

- the likelihood of EBOV **being present in fresh meat from wild animals** (less than four days after the animal's death) is considered **low if originating from fruit bats and dead or sick wild animal species in the EBOV suitable areas of Africa,** including non-human primates and duikers described as being affected by the disease;
- the likelihood of humans being exposed to EBOV through transporting and preparing raw meat from **fruit bats, dead or sick wild animals in the EBOV suitable areas of Africa,** including non-human primates and duikers, is considered as **low;**
- the likelihood of the Ebola virus being found in thoroughly cooked meat from any wild species is considered **very low;**
- the likelihood of **meat from wild animals being shipped from infected countries** is considered low (if effective mitigation measures are in place limiting wildlife hunting and illegal trade for human consumption) to **moderate;**
- the likelihood of EBOV **being transmitted to humans through the trade, handling or consumption of meat from wild animals** and leading to a new human outbreak in non-affected countries is considered **very low.**

Wildlife hunting for consumption is common in the countries currently affected by the epidemic. The wild animal value chain, which involves a large range of stakeholders, is mainly informal and poorly regulated or documented. There is limited knowledge about the drivers of bush meat demand and marketing and its supply to urban centers. There is an urgent need for better understanding of value chains of wildlife products, of preparation and consumption practices as well as consumer preferences for meat from wild animals.

3. MITIGATION MEASURES AVAILABLE

The following risk mitigation measures should be considered to reduce the risk of EBOV transmission from wildlife to humans:

- In many areas of Africa, especially in currently affected Western African countries, meat from various wild species is a major source of protein, especially in rural areas. Therefore, a total ban on meat from wild animals might not be effective in those settings. Some studies have shown that bats and non-human primates represent an extremely small percentage of wild meat consumed in Central Africa.
- Communities should therefore be advised that:
  - » hunting, slaughtering, selling, preparing and consuming bush meat that originates from any species of bats should **be avoided at all times;**
  - » handling, slaughtering, selling, preparing and consuming bush meat that originates from wild mammalian species, such as gorillas *(G.gorilla),* chimpanzees *(P. troglodytes)* and wild antelopes *(Cephalophus spp.)* **found sick or dead should be avoided.** Since these species are protected, their hunting should be prohibited in any case.
- Continued monitoring and early warning of wildlife mortalities, using community engagement in rural areas aims to **prevent exposure of human populations to zoonotic pathogens from wild species,** such as EBOV and other viruses (Bisson *et al.,* 2014; Olson *et al.,* 2012). Early warning systems should be implemented to increase awareness of local populations with regards to safe procurement of meat in forested areas and inform the Ministries in charge of Health, Agriculture and Environment in a timely manner of unexpected wildlife mortalities. Community health officers should be well-versed in risk communication to address local populations. A total ban on meat from wild animals may be considered only during well-defined high-risk periods.
- Substitutes for meat from wild animals should be encouraged in order to provide alternate protein sources. Accredited commercial producers of some "wild" species, such as cane rats (genus *Thryonomys*), and producers of domestic animals (such as pig and poultry farms) can provide safer protein sources. Therefore, production and trade of meat originating from farmed wildlife should be promoted.

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ANNEX
BACKGROUND ON EBOLA VIRUS DISEASE

- On 22 March 2014, Guinean authorities reported an outbreak of EBOV to the World Health Organization (WHO).
- Since then, the EBOV outbreak rapidly spread within Guinea and to other countries, such as Sierra Leone, Liberia and Nigeria, leading to the biggest EBOV outbreak ever recorded in Africa, and in the world.
- Scientists investigating the source of the Guinean outbreak believe that this outbreak can be traced back to a 2-year-old boy in a village near Guéckédou, a remote forested area in southeastern Guinea, who died on 6 December 2013 a few days after he displayed fever, vomiting, and diarrhea. From there, the disease reportedly infected the child's mother, 3-year-old sister, and grandmother, before infecting a health care worker from Guéckédou. The team of epidemiologists traced the disease by reviewing hospital documentations and interviews with affected families, patients with suspected disease, and inhabitants of villages in which cases occurred[4]. Exposure to EBOV might have happened through close contact with fruit bats.
- Analysis of the viral sequence suggests that the virus involved in the Western African epidemics is a member of the Zaire lineage that has spread from Central Africa into Guinea and West Africa in recent decades (Dudas and Rambaut, 2014; Calvignac-Spencer *et al.,* 2014; Gire *et al.,* 2014).
- Serologic analyses of human blood samples collected between 2006 and 2008 suggest past human exposure to a virus of the Ebola genus in the West Africa region, although no outbreak had been previously observed (Schoepp *et al.,* 2014). This suggests that an Ebola virus has been circulating in the region for some time.
- On 25 August 2014, a new EBOV outbreak was reported to WHO by the Ministry of Health of the Democratic Republic of Congo. So far no epidemiological or genetic evidence suggests that this outbreak is related to the Western African outbreak. The outbreak has since been controlled by the country authorities.
- Ebola viruses affect a large range of mammalian species, from humans to wild and domestic animals. Fruit bats, particularly of the genera Hypsignathus monstrosus, Epomops franqueti and Myonycteris torquata, are considered likely natural hosts for Ebola virus in Africa (Leroy *et al.,* 2005; Hayman *et al.,* 2012; Pourrut *et al.,* 2005; Pourrut *et al.,* 2009). Ebolavirus-specific antibodies were detected in serum, and nucleotide sequences were found in the liver and spleen tissues of those three African fruit bat species (Leroy *et al.,* 2005; Pourrut *et al.,* 2005). Some experimental infections of bats showed that they could become infected without showing symptoms and shed the virus in their feces (Swanepoel *et al.,* 1996). Antibodies to EBOV have also been detected in additional bat species in Africa, including Micropteropus pusillus, Rousettus aegyptiacus and Mops condylurus (Pourrut *et al.,* 2009). Epidemiological case-studies also showed a strong spatial and temporal association between the annual bat migration and Ebola outbreaks and further suggested that human exposure to bat blood could lead to EBOV outbreaks in human populations (Leroy *et al.,* 2009). The geographical distribution of the three bat species of the genera Hypsignathus monstrosus, Epomops franqueti and Myonycteris torquata has been one of the main risk factors taken into account while assessing a first evidenced-based indicator of locations with potential for future zoonotic transmission of EBOV (Pigott et al. 2014). Despite this, no Ebola virus has been isolated from any free-ranging bat (Muyembe-Tamfum *et al.,* 2012).
- Other wild mammalian species can be infected by EBOV, such as wild non-human primates like gorillas (Gorilla gorilla), chimpanzees (Pan troglodytes) (Bermejo *et al.,* 2006, Formenty *et al.,* 1999; Rouquet *et al.,* 2005) and non-primate species like black-backed duikers (Cephalophus dorsalis) (Rouquet *et al.,* 2005; Leroy *et al.,* 2004) and other small wild mammals like rodents (Swanepeol *et al.,* 1996). Their role as reservoirs has been disregarded as most of these species show high case fatality rates (Lahm *et al.,* 2007) when their respective populations are exposed to EBOV.
- One experimental study showed that EBOV can be transmitted from infected pigs to non-human primates (Weingartl *et al.,* 2012). Even if the minimal infectious dose for pigs via the oral-nasal route remains unknown, the study showed that older infected pigs were more likely to present respiratory symptoms (respiratory distress, coughing) than younger ones (thus remaining asymptomatic). The study also showed that shedding is primarily through the respiratory tract (via droplets of different sizes) and that infected pigs were able to infect other pigs and non-human primates without direct contact. Pigs were also found susceptible under field conditions to Ebola Reston in the Philippines (Miranda *et al.,* 2011).
- The virus is first introduced to human populations from wild animals through close contact with blood, secretions, organs and other bodily fluids of infected wild mammalian species. In outbreaks for which information is available, the human index cases have invariably had direct contact with gorillas, chimpanzees, antelopes or bats (Muyembe-Tamfum *et al.,* 2012). Large outbreaks among wild animals are believed to amplify human outbreaks by increasing the number of index transmission events (Rouquet *et al.,* 2005). People likely to be exposed to the virus in its natural environment (Pigott *et al.,* 2014) and likely to cause an outbreak in a limited population are bush meat hunters and people in contact with likely infected animal products. When the Ebola virus is introduced into a village, the outbreak seems to end spontaneously with a limited generation of cases (Muyembe-Tamfum *et al.,* 2012).
- The increase in Ebola outbreaks since 1994 is frequently associated with drastic changes in forest ecosystems in tropical Africa, which may have promoted direct or indirect contact between humans and infected wild animals (Muyembe-Tamfum *et al.,* 2012). The precise factors that result in Ebola virus outbreaks remain unknown, but require a better understanding of the complex linkages between ecological and socioeconomic factors in a constantly evolving interface between humans, animals and their ecosystems.
- The circulation of multiple lineages of EBOV in some past outbreaks suggests repeated exposure of humans and susceptible wild animals to the virus' natural hosts (Leroy *et al.,* 2002; Rouquet *et al.,* 2005; Lahm *et al.,* 2007).
- After a first spillover event, the virus continues to spread from human to human through both direct transmission (contact with blood, secretions, organs and other bodily

[4] http://www.nejm.org/doi/full/10.1056/NEJMoa1404505

fluids of infected people, in health care settings or during burial ceremonies) and indirect transmission (contact with fomites contaminated with such fluids).

- A systematic survey of custom seizure of bush meat in Charles de Gaulle airport (France) estimated that around five tonnes of meat from wild animals per week is smuggled in personal luggage (Chaber *et al.,* 2010). Meat from wild animals was not only imported for personal consumption but was part of a lucrative organized trade, with high prices indicating luxury status. Half of the travellers were found to carry mainly fish (446 kg in the time of the study) and livestock and bush meat (131 and 188kg respectively). Bush meat was being carried by a smaller number of travellers in bigger containers, mainly from the Central African Republic, Cameroon, and Côte d'Ivoire and fewer from Ivory Coast. Fish and smaller quantities of livestock meat were carried in iceboxes, but bush meat and larger livestock, such as entire sheep and calves, were wrapped in plastic and placed in casual holds. Travellers reported slaughtering the livestock just before boarding and, consistent with this, most livestock meat was fresh. Bush meat arrived dressed and often smoked. About half of the travellers carrying foodstuff presented sanitary certificates apparently issued by the veterinary authorities from their country of origin. These papers listed the foodstuff carried, such as bush meat or miscellaneous, and certified that they were fit for human consumption, but were in fact not legally valid.
- An average of 25 million kilogrammes of non-live wildlife products is believed to enter the United States each year. A pilot project to establish a surveillance methodology for zoonotic agents in confiscated wildlife products in several American airports (Smith *et al.,* 2012) identified parts originating from non-human primates, such as chimpanzees (Pan troglodytes). Specimens were found to vary in condition, including items that were fresh, transported raw in coolers, lightly smoked or well dried. Most specimens contained moist inner tissue. Pathogens such as retroviruses (simian foamy virus) and/or herpesviruses were isolated from these samples.
- EBOV is sensitive to heat and is inactivated by heating meat products 30 minutes at 60°C or boiling for 5 minutes. There is no data on the effect of the survival of the virus in smoked meat products. According to some authors, animal carcasses are only infective for 3 to 4 days after the animal dies (Leroy and Rollin, unpublished data). One study reports that the virus can still be detected in muscle tissue of gorillas 5 to 8 days post mortem and in chimpanzees 3 to 10 days post mortem (Rouquet *et al.,* 2005).

CONSULTED EXPERTS

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The Emergency Prevention System (EMPRES) is an FAO programme, founded in 1994, with the goal of enhancing world food security, fighting transboundary animal and plant pests and diseases and reducing the adverse impact of food safety threats. EMPRES-Animal Health is the component dealing with the prevention and control of transboundary animal diseases (TADs).

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This summary of the preliminary risk assessment is based on the information available to date and will be reviewed as new findings emerge from field investigations, laboratory testing and epidemiological studies at both the animal and human levels.

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