Qualitative Risk Assessment: What is the risk of food or food contact materials being a source or transmission route of SARS-CoV-2 for UK consumers?

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Risk question

What is the risk of food, food contact materials, or food packaging being a source or transmission route of SARS-CoV-2 for UK consumers?

Summary

Overall risk estimate

We consider that the probability that UK consumers will receive potentially infectious exposures of SARS-CoV-2 via the consumption of food or the handling of food contact materials or packaging is **Very Low** ("very rare but cannot be excluded"). The uncertainty associated with this estimate is **High** partly as there are significant data gaps relating specifically to SARS-CoV-2; a number of assumptions in this document are therefore based on data relating to other coronaviruses (SARS-CoV and MERS-CoV).

The worldwide case fatality rate for the disease COVID-19 appears to be around 4% based on current reports, meaning the severity of detriment is considered **High** (Severe illness: causing life-threatening or substantial sequelae or illness of long duration); high-risk groups include people with weakened immune systems, older people, and those with certain long-term conditions like diabetes, cancer and chronic lung disease.
Uncertainty relating to severity of detriment is **Low**; significant volumes of data are now available although current case fatality estimates may be biased as a result of incomplete outcomes and the potential for severe cases to be overrepresented in early detections.

We note that the genome of SARS-CoV-2 suggests that it is most closely related to SARS-CoV, for which foodborne transmission was not implicated in any cases of infection. This assessment represents a conservative estimate of risk whilst acknowledging and reflecting current knowledge gaps.

Limitations of this assessment

This risk assessment does **not** currently consider:

- The risk associated with illegal importation activities. This is due to the lack of data on volumes of product illegally entering the UK as well as their processing and transportation.
- The occupational risk to food preparers or those frequently exposed to products of animal origin, for example slaughterhouse workers.
- Implications for integrity of the food chain, including reduced availability of food handlers, packers or distributors if they themselves become ill or reduced availability of approved disinfectants etc for cleaning of food manufacturing equipment and food preparation areas due to shortages.

Key uncertainties

Potential future developments which could significantly alter this assessment include:

- Any evidence or suspicion of transmission via food;
- Experimental studies suggesting that foodborne transmission could occur;
- Further data on the incidence of infection in the UK, particularly of the proportion of infections which are subclinical, for example significant changes to testing policy in the UK.
- Evidence that UK livestock or companion animals could become infected;
- New data significantly changing our assessment of the effects of storage or processing on the activity of virus in food, or survival of the SARS-CoV-2 virus on surfaces and the general environment.

Interpretation of probability categories used in this risk assessment

(Tables from ACMSF (ACM/1065) adapted from EFSA 2016 modified from OIE 2004).

Frequency category	Interpretation
Negligible	So rare that it does not merit to be considered
Very Low	Very rare but cannot be excluded
Low	Rare but does occur
Medium	Occurs regularly
High	Occurs very often
Very High	Events occur almost certainly

Severity category	Interpretation
Negligible	No effects, or so mild they do not merit to be considered
Low	Mild illness: not usually life-threatening, usually no sequelae, normally of short duration, symptoms are self-limiting (e.g. transient diarrhoea)
Medium	Moderate illness: incapacitating but not usually life-threatening, sequelae rare, moderate duration (e.g. diarrhoea requiring hospitalisation)
High	Severe illness: causing life-threatening or substantial sequelae or illness of long duration (e.g. chronic hepatitis)

Qualitative categories for expressing uncertainty in relation to qualitative risk estimates

Uncertainty category	Interpretation
Low	There are solid and complete data available; strong evidence is provided in multiple references; authors report similar conclusions
Medium	There are some but no complete data available; evidence is provided in small number of references; authors report conclusions that vary from one another
High	There are scarce or no data; evidence is not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusions that vary considerably between them

Background

On 31 December 2019, the National Health Commission of the People's Republic of China notified the World Health Organization (WHO) of a cluster of cases of pneumonia of unknown cause in Wuhan City, Hubei Province, China. Most early cases were associated with visiting Wuhan South China Seafood City market, which reportedly sold meat, poultry, seafood and live animals. On the 11th and 12th of January the WHO received further evidence from the National Health Commission identifying the cause of these infections as a novel coronavirus first isolated on the 7th of January. The novel coronavirus has been named SARS-CoV-2 and the disease caused by it has been named COVID-19.

Hazard Identification

The hazard is identified as SARS-CoV-2

SARS-CoV-2 is located in the subgenus *Sarbecovirus*, genus *Betacoronavirus*, family *Coronaviridae* and it is closely related to the only other virus in this subgenus, Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV). Beta-coronaviruses are enveloped viruses with a large (27-32kb), positive-sense single-strand RNA genome. Early phylogenetic studies of a number of SARS-CoV-2 genomes suggests that all originated from a single crossover event.

Based on cases reported by national authorities to WHO at 10:00 CET 25th March, there are currently 414,179 cases globally, with 81,848 cases confirmed in China (resulting in 3,287 deaths). There are 332,331 confirmed cases outside China, in 197 other countries and territories, with 15,153 deaths. The majority of cases outside China are no longer linked to travel to Wuhan, Hubei Province. Cases in some areas outside of China can be attributed to travel from infected regions, but local transmission is believed to be occurring in a number of areas. In Europe there are a reported 220,516 cases, with 69,176 cases and 6,820 deaths in Italy. As of the 25th March 2020, there are 9,529 cases in the UK and there have been 463 deaths.

Exposure assessment

There are two overarching pathways for potential foodborne exposure to SARS-CoV-2, which are:

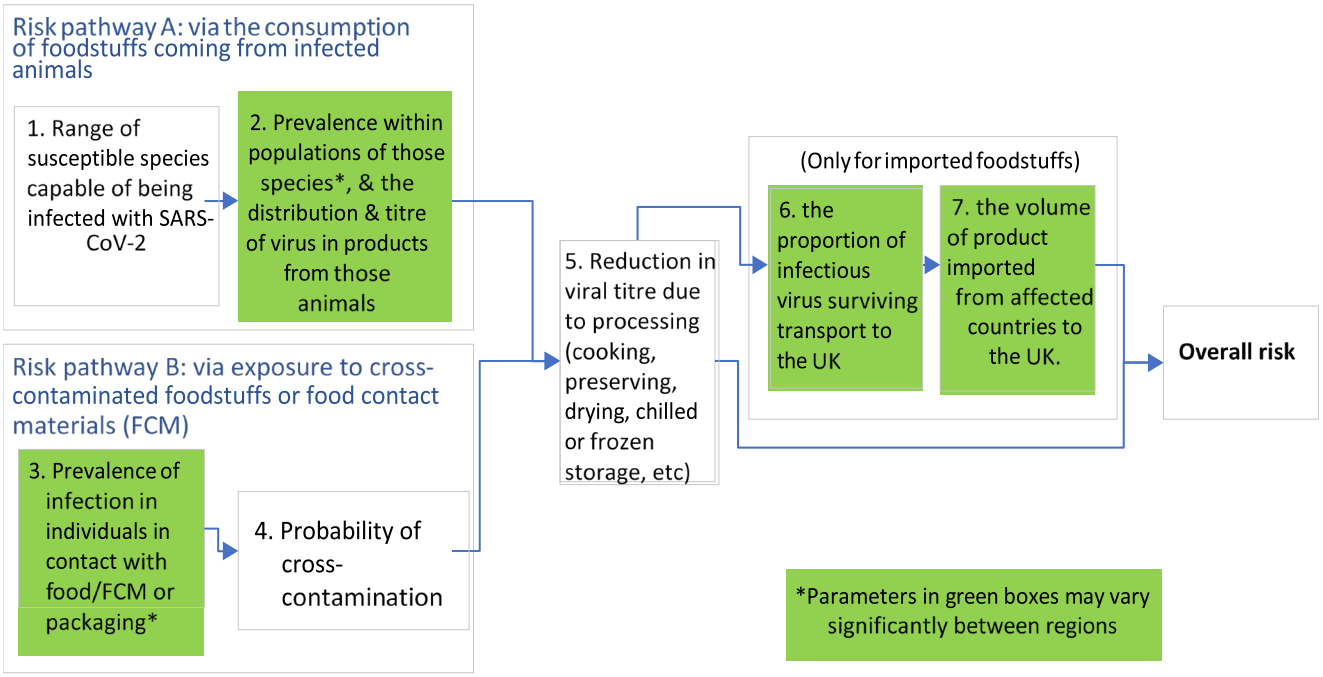
A. via the consumption of foodstuffs of animal origin (primarily meat, eggs, milk, dairy and blood products) from infected animals, or

B. via the consumption of foodstuffs cross-contaminated by one or more of the following: contaminated products of animal origin, foods of non-animal origin, food contact materials, preparation surfaces, or infected individuals involved in food preparation.

Each of these pathways could theoretically apply to food produced and prepared overseas and then imported into the UK, to food produced overseas and prepared in the UK, or to food both produced and prepared in the UK.

The seven key steps affecting the risk presented by foodstuffs consumed by UK consumers, and how they depend on the type of foodstuff and its origin, are illustrated in Figure 1 and then discussed in turn in the following sections.

Figure 1: key steps in the two pathways considered for potential foodborne exposure



1. Probability of susceptible animals being infected with SARS-CoV-2

The species responsible for the original human infections has not yet been identified, and the range of species capable of being infected with SARS-CoV-2 is not yet known (**uncertainty**). Beta coronaviruses mainly infect bats, but also infect other species, including rodents, lagomorphs (hares and rabbits), livestock species such as pigs, and coronaviruses exhibit frequent host-switching (Bolles et al. 2011). Some other coronaviruses infect mammalian livestock species (such as bovine coronavirus in cattle and porcine epidemic diarrhoea virus in pigs). SARS-CoV was capable of infecting palm civets, and MERS-CoV was capable of infecting dromedary camels (WHO 2019). The first known cases of SARS-CoV-2 were a cluster associated with the Wuhan South China Seafood City market, a "wet market" which sold meat, poultry, seafood and a large range of live animals. This market was closed on January 1st 2020. A list of the species sold live at the market is not currently available (**uncertainty**).

SARS-CoV-2 is a mammalian strain of coronavirus. Previous attempts using the closely-related SARS-CoV to experimentally infect poultry (chickens, turkeys, geese, ducks, and quail) have been unsuccessful (Swayne et al. 2004). We consider that the probability of consumer exposure via food products such as eggs and meat from infected avian hosts is therefore **Negligible** and not further considered.

Expert opinion received from CEFAS via Defra[1] suggests that fish and seafood are not susceptible and therefore represent a **Negligible** probability as they are not a potential

[1] "Aquatic *Nidovirales* briefing note: (with respect to *Coronavirus*)" authored by R. Paley, 18th Feb 2020.

host organism for known species of *Coronaviridae*. They are not further considered in part risk pathway A.

For other groups of mammals (either livestock or those traditionally viewed as wildlife species), in the absence of specific challenge information and ambiguity about the potential host range of the virus, the likelihood is considered to be between “Negligible” and “Very low”. This is summarised in the table below.

Table 1: Probability of certain animals being susceptible to infection with the virus

Category	Probability
Fish and seafood species	Negligible
Other species (including mammals)	Negligible to Very Low
Avian species (e.g. poultry)	Negligible

2. Prevalence of virus within populations of susceptible animals, and the distribution and titre of the virus in edible products obtained from those infected

Although SARS-CoV-2 was identified based on a cluster of cases apparently originating at a market selling food in Wuhan, no specific evidence implicating foodborne transmission of SARS-CoV-2 has been found. However, foodborne infection through poor hygiene and potentially involving contact with contaminated surfaces or water cannot be completely discounted. Infected animals bought live for consumption may provide a source of infection, particularly if poor hygiene practices are followed during slaughter, preparation and cooking.

No animal morbidity or mortality event has been reported in any species of animals in China or worldwide (WHO, 2020) and, with the exception of one dog owned by an infected person in Hong Kong, viral RNA has not been detected in animals despite active surveillance and efforts to determine the source of the outbreak by Chinese authorities or other countries currently experiencing the outbreak. WHO currently recommends that veterinarians should maintain a high level of vigilance and to report any unusual presentations seen in any animal species present in the markets to veterinary authorities.

All companies producing food within the UK and those exporting to the UK should be implementing food standards and hygiene protocols which include not permitting visibly sick animals to enter the food chain. Therefore, if disease is present in an animal population and results in clinical disease in that species, it is likely to be at a sufficiently low level to escape detection or be inapparent during the incubation period. Therefore, it is assumed that if animal populations are infected, that the prevalence is likely to be a low level, thereby reducing the probability that food products would be produced from an infected animal, although there is no active testing or surveillance to verify this. As the host range of the virus is currently not known, there is also currently no data on the proportion of infected animals likely to display clinical disease, or on the likely relationship between the development of clinical disease and infectiousness in infected animals, adding uncertainty to this assumption (**uncertainty**).

The distribution and titre of virus in the tissues of infected wild animals or livestock, is currently not known (**uncertainty**). The potential for the virus to remain infectious in the tissues of infected slaughtered animals is not known (**uncertainty**). For SARS, a disease caused by the closely-related SARS-CoV, research suggests that transmission was likely only for individuals sat close to or involved in the slaughter of infected animals rather than those consuming their meat (Wang et al. 2005), and meat is not known to be a dominant route for the transmission of other coronaviruses. Earlier in the outbreak WHO promoted precautionary generic recommendations to avoid the consumption of raw or undercooked animal products, as this carries a high risk of infection from a variety of pathogens that might cause disease in humans. However, this is not coronavirus-specific advice and has now been removed from WHO guidance.

The shedding of coronaviruses in the milk of infected wild animals and certain farmed or working animals is poorly understood (**uncertainty**). MERS-CoV RNA and antibodies to MERS-CoV are detectable in dromedary camel milk, although in quantities too low for virus isolation to be attempted (Reusken et al. 2014), and *E. coli* was not present at detectable levels, suggesting that faecal contamination was unlikely to be the source in this study. MERS-CoV persisted with a decreased viral titre in experimentally-spiked milk for several days at +4°C (van Doremalen et al. 2014). Current WHO recommendations are that pasteurisation is likely to inactivate MERS-CoV and it has been shown that heat treatment (30 minutes at 63°C) of camel milk containing MERS-CoV reduced levels of infectious virus below the threshold of detection (van Doremalen et al. 2014), although no data could be found on significantly higher temperatures but of shorter duration more closely emulating processes such as HTST pasteurisation (**uncertainty**).

The host organism(s) for SARS-CoV-2 has not yet been identified, however, there is some evidence of an association between the consumption of unpasteurized dromedary milk and cases of the related MERS-CoV. Therefore, with no further information at this time, the probability of food products being produced from an infected animal is **Very Low**, and the probability that there are sufficient infectious viral titres being present in the edible fraction of meat and dairy products derived is considered **Very Low**. Combining a Very Low and Very Low together, produces a **Negligible** probability for this step.

3. Prevalence of infection in human handlers producing commercial food (UK or in importing countries)

For certain commodities, multiple people can be involved in the food chain from farm to fork during harvesting, manufacturing, processing and serving which may result in cross-contamination to food if the human handlers are infected.

Coronaviruses are mainly transmitted by large respiratory droplets and direct or indirect contact with contaminated secretions. SARS-CoV-2 has been detected in saliva, blood, faeces, gastric duodenal and rectal epithelia and in urine (Xiao et al. 2020, Zhang et al. 2020), and viral shedding in blood and faeces has been identified from 30% of SARS-CoV-2 patients. Current data suggest that the proportion of clinical cases of SARS-CoV-2 presenting with diarrhoea could be as high as 10% (Wang et al. 2020), but this estimate is based on a small number of patients and may be revised as more data become available. Human- human transmission of SARS-CoV-2 has been confirmed as the main source of transmission, however the risk of infection via the faecal-oral route cannot be excluded. To date there are no further studies on viral shedding via other body fluids such as sweat

(**uncertainty**).

WHO advice to the public to reduce exposure to SARS-CoV-2, and a number of other pathogens, includes frequently cleaning hands using alcohol-based hand rub containing 60% or higher concentration of alcohol, or soap and water, avoid touching eyes, nose and mouth without rigorous and regular hand washing. Good food hygiene practices should always be followed, such as avoiding cross contamination of foods with body fluids from infected animals or humans, including foods potentially contaminated with animal saliva. Raw meat, blood products, milk or animal organs should be handled with care to avoid cross-contamination. Unprocessed fruit and vegetables should be handled hygienically and well washed before consumption or preparation.

The average incubation period (time from exposure to the onset of symptoms) for COVID-19 is 5.1 days, and 97.5% of those who develop symptoms will do so within 11.5 days, during which time workers may be asymptomatic but still shedding SARS-CoV-2. Workers who have visited high risk countries or have been in contact with COVID-19 cases are advised to self-isolate at home for 14 days. Based on current government advice, workers at UK food businesses presenting with clinical signs such as a raised temperature should be considered unfit to work. However, people may become infectious prior to the development of clinical signs, although the extent of this is not known (**uncertainty**).

In areas outside the UK, the likelihood that individuals infected with SARS-CoV-2 are involved specifically in food production for export is difficult to estimate **(uncertainty)** but is likely to be between **Negligible** and **Very low**. At the peak of infection in Wuhan, the human prevalence can be estimated from the population size in affected areas (Wuhan population = 11.08 million) and the number of infected humans (20,000 confirmed infected people in Wuhan, 4th February 2020), giving a detected prevalence of 0.2%. A recent paper suggested that the rate of low or asymptomatic transmission in China was 86% (Ruiyun et al., 2020) including potential false negatives. However, the estimate prevelance does not reflect the imposition of strict quarantine and self-isolation measures which would reduce the prevalence in the working population even further. The number of detected cases in the UK coupled with the surveillance and current government advice means that the likelihood of a food handler or others involved in the manufacturer of food being infectious can currently be considered to be **Very Low**. This may need to be re-assessed if the case numbers significantly increase.

4. Probability of cross-contamination (UK or in importing countries)

The probability of cross-contamination from infected human handlers to food will be dependent on the frequency of contact that is sufficient to transfer a significant amount of virus, the degree to which hygiene measures mitigate the transmission, and the subsequent survival of the virus on that food, food contact materials, or packaging.

Frequency of contact from infected food handlers and the degree to which hygienic food preparation methods mitigate this exposure

The persistence of coronaviruses on hands or cooking equipment are not well known (**uncertainty**); a summary of available evidence for different surfaces and materials is provided in Appendix 1. A different coronavirus inoculated onto iceberg lettuce could no longer be detected after 4 days at 4^{o}C and could not be recovered from inoculated strawberries (Yepiz-Gomez et al. 2013). The survival potential in wastewaters is unclear (Grundy et al. 2009).

The risk of cross contamination from affected food workers would be reduced by following recommended self-isolation for affected individuals or those who have recently travelled to high risk areas.

The risk of cross contamination to food, food contact materials, and packaging from infected workers before displaying symptoms should be **Very Low** if food hygiene and HACCP processes are followed (**uncertainty**), alongside the current recommendations for self-isolation after travelling to high risk areas.

However, assuming good food hygiene practices, HACCP and self-isolation policies are followed, it is our opinion that the probability of cross-contamination resulting in food products, food contact materials or packaging in the UK being contaminated with infectious virus during food production is **Negligible to Very Low.** The associated uncertainty is **High** (**uncertainty**) and this opinion may be reviewed as further information becomes available.

The survival of the virus on food packaging, food contact materials or food preparation surfaces

The main transmission route of SARS-CoV-2 in the UK is assumed to be direct human-human transmission via infectious droplets. A study on the survival of SARS-CoV-2 in aerosols found that SARS-CoV-2 remained viable throughout the 3 hour experiment, with a reduction of $10^{1.2}$ $TCID_{50}$ per litre of air in 3 hours at room temperature (21-23°C) (Van Doremalen et al. 2020), however these aerosolised particles do not represent the larger droplets produced for example from coughing, which would fall more rapidly onto a surface. The main route of SARS-CoV-2 transfer to food packaging, food contact materials and food preparation surfaces is assumed to be via cross contamination from infected workers. A table summarising the survival times of coronaviruses on surfaces can be found in Appendix 1. A review of the survival of SARS-CoV can be found in Otter et al. (2016). SARS-CoV and MERS-CoV seems to survive better than influenza virus on surfaces, and SARS-CoV and SARS-CoV-2 have similar survival times on most surfaces, although SARS-CoV-2 appears to be inactivated more slowly on cardboard than SARS-CoV (Van Doremalen et al. 2020). Human coronavirus 229E survived on plastics, ceramics, stainless steel and glass for 4-5 days (Warnes et al. 2015). Duan et al. (2003) showed that infectious SARS-CoV could be recovered from wood, paper, plastic and glass surfaces for 5 days.

Survival on paper and cardboard

SARS-CoV-2: No infectious SARS-CoV-2 could be recovered from inoculated cardboard at sampling points beyond 24 hours at 21-23°C and 40% relative humidity (Van Doremalen et al. 2020) .

The survival time of SARS-CoV dried onto paper was found to vary between five hours and two days, depending on the amount of SARS-CoV virus present (Lai et al. 2005).

Survival on plastic

Two manuscripts have reviewed the survival of SARS-CoV on plastic. One found that SARS-CoV could survive for 20 days dried onto the surface of plastic in media at 40%

relative humidity (Chan et al. 2011) and the other for over six days on the surface of plastic (Rabenau et al. 2005). Human coronavirus 229E survived 4-5 days on PVC and PTFE (Warnes et al. 2015). A study on survival of SARS-CoV-2 observed a reduction from $10^{3.7}$ to $10^{0.6}$ $TCID_{50}$ per mm^2 in 72 hours giving a half-life of SARS-CoV-2 on plastic of 6.8 hours (Van Doremalen et al. 2020).

Survival on other surfaces

A paper which looked at the survival of SARS-CoV, which is related to SARS-CoV-2, on wood board, glass, cloth and metal surfaces, found that SARS-CoV survived for >72 hours on all surfaces but with reduced infectivity (Duan et al. 2003).

A study on survival of SARS-CoV-2 on stainless steel found a reduction from $10^{3.7}$ to $10^{0.6}$ $TCID_{50}$ after 48hours giving a half-life of 5.6hours on stainless steel (Van Doremalen et al. 2020), whereas no viable SAR-CoV-2 could be detected on copper after 4 hours (Van Doremalen et al. 2020).

Other studies showed survival of human coronavirus 229E (HuCoV229E) and SARS-CoV-2 on copper and copper alloys for minutes, for several hours, respectively but these alloys are not widely used in the food industry at the present time (Warnes et al. 2015; Van Doremalen et al. 2020).

Disinfectants

A range of disinfectants were tested in their ability to reduce the viral titre of SARS-CoV. Their efficiency ranged from reducing the viral titre >1.68 log^{10} to >5.01 log^{10} (Rabenau et al. 2005). A paper summarising the survival of coronaviruses and the effectiveness of disinfectants can be found at (Kampf et al. 2020), the most effective disinfectant in reducing the viral titre of SARS-CoV in the papers summarised was either 85% or 95% ethanol.

In cases where the viral contamination occurs with organic matter, the organic matter protects the virus and reduces the effectivity of the disinfectants. For example, in the influenza studies from Otter et al. (2016), influenza survival times on bank notes increased from hours to 17 days in the presence of mucus.

Unlike bacteria, viruses are unable to replicate outside of the host cells. Therefore, if SARS-CoV-2 was present on a food preparation surface, food contact material or food packaging the virus could not replicate. As a worst case the viral tire would not reduce, however, the viral titre is reduced by desiccation and disinfectants.

5. Reduction in viral titre due to processing

A review of the available literature has found a number of publications that have investigated the impact of processing on the related SARS-CoV and other members of the *Coronaviridae* family:

No processing: viability studies on SARS-CoV show that it can survive for up to 96 hours in sputum and faeces, and 72 hours in urine with low level infectivity. Viral activity remained stable at 4°C, 20°C and 37°C in the environment (Duan et al. 2003).

Chilling: Species of *Coronaviridae* have been found to survive for periods of over two weeks in liquids at 4ºC with little inactivation of the virus (loss of ~0.5 $\log_{10}$ pfu; Lamarre and Talbot 1989), although this is likely to depend on the matrix of the sample.

Freezing: No significant reduction in titre was seen in *Coronaviridae* samples frozen to -70°C and thawed for 25 cycles (Lamarre and Talbot 1989).

Preserving: Some preservatives such as vinegar have been shown to reduce viral activity in *Coronaviridae* species (Rabenau et al. 2005) and similarly the canning process is highly likely based on heating experiments (see below) to destroy these viruses. However, without knowing the exact preservatives, processing steps and pH of each food in this group it is not possible to identify whether preserving would reduce viral activity (**uncertainty**).

Drying: desiccation reduces the viral activity of *Coronaviridae* species, with the rate of inactivation differing between species. SARS-CoV, which as stated above is the most closely related virus known to SARS CoV-2, is among the more resistant of the coronaviruses tested; infectious virus could still be recovered from samples initially containing 10^6-10^7 $TCID_{50}$ of SARS-CoV after nine days of drying at room temperature (21-25°C;Rabenau et al. 2005). As we do not know how long the food products will have been dried for, the amount of water left in the products, the product pH, or the timeframe from start of desiccation to the product being consumed it is not possible to accurately say whether the virus would be inactivated (**uncertainty**).

Heating: Limited data are available describing the effects of heating on SARS-CoV-2 (**uncertainty**). The reduction in titre of SARS-CoV due to heat is dependent on the level of protein present. In the absence of protein, heating at 56˚C for 30 minutes reduces viral titre by at least 5-6 $\log_{10}$ $TCID_{50}$/ml (i.e. to below the threshold of detection in the study), but the reduction was only ~2 $\log_{10}$ when protein (20% FCS) was present (Rabenau et al. 2005). Another paper found that heating to 56°C for 90 minutes, 67°C for 60 minutes and 75°C for 30 minutes reduced the infectivity of SARS-CoV by at least 6 $\log_{10}$ (initial dose 10^6 $TCID_{50}$, no detectable CPE after treatment) (Duan et al. 2003). A further study on SARS-CoV found a 4 $\log_{10}$ $TCID_{50}$ at 65ºC for 4 minutes or more, although some infectious virus remained (Darnell et al. 2004). This paper also found that SARS-CoV was inactivated by ultraviolet C light (UVC) at 254 nm for >5 mins and alkaline (pH > 12) or acidic (pH < 3) conditions (Darnell et al. 2004).

Because these studies were not specifically intended to inform food risk assessments, the heating regimes were not designed to represent typical cooking profiles. However, it is assumed that any virus present would be via cross-contamination and therefore only likely to be present on the surface of foods. Exposure to heat particularly temperatures used for cooking should be sufficient to inactivate any virus present.

A large proportion of ready to eat (RTE) products will undergo no further inactivation step. It is also not possible to define the protein content of products which may undergo further cooking. It is therefore not possible to reduce the probability of exposure to product groups as a consequence of post-production processing with confidence (**uncertainty**), although

RTE foods produced in accordance with good hygienic practice are unlikely to have been contaminated before consumption if sealed in packaging.

6. Proportion of infectious virus surviving transport to the UK (imported foods only)

The proportion of infectious virus on imported food, food packaging and FCM surviving transport to the UK is dependent on the product origin, method of transport, product type and packaging material. As described in section 5, different processing methods such as desiccation may reduce any potential viral load. However, this may also be dependent on shipping time, for example dried products shipped over a number of weeks would have time for any virus present to desiccate fully whereas fresh produce arriving by air would not. However, a higher proportion of virus is likely to remain infectious in products that are shipped frozen or chilled.

Total food import data collected by HMRC does not contain information on which products are ready to eat (and therefore would have no further inactivation step other than consumer/caterer storage and handling) or to be further processed or cooked. It is therefore not possible to reduce the likelihood of exposure by product type as a consequence of anticipated post-import processing with confidence (**uncertainty**).

7. Volume of product imported from affected countries to the UK

As there are coronavirus cases in 190 countries and territories to date it is not possible to collectively assess the food import from all infected countries. Taking into account the considerations listed above in sections 4,5 and 6 it may be possible to individually assess imports of interest from a particular country if the need arises. Particular uncertainties which may require reassessment include countries or regions with a high concentration of cases, if an animal host species is identified, or occurrences of reverse zoonosis are identified. Previous versions of this risk assessment focussed on imports from China (as the country of origin for SARS-CoV-2) but this is no longer relevant given the wider distribution of COVID-19 cases to date.

Risk pathway A: The estimated risk from infected animals

This pathway consists of steps 1, 2, and 5 above, as well as 6 and 7 for imported products, (Table 2). To summarise:

Step 1: the risk from infected eggs, poultry meat and fish and seafood is assumed to be **Negligible**; the likelihood that meat and blood products, milk and dairy products from other species (including mammals) may be susceptible to the virus is considered to be **Negligible to Very Low**.

Step 2: the probability that products consumed in the UK would be derived from infected animals with sufficient viral titres in edible fractions is considered to be **Negligible**.

Step 5: Some food processing methods would be expected to reduce the viral titre; however, due to the diverse range of products available both through international imports and domestic production, it is not possible to provide a generalised probability covering all products. Heating to 56ºC for 30 minutes is likely to inactivate the virus if present in food. Heating to temperatures above 65ºC for shorter periods is likely to significantly reduce the infectivity of any virus present, although with greater uncertainty.

Step 6 (imported route only): survival of virus present in products stored or transported under chilled or frozen conditions is likely to be variable but in some cases the virus may survive for a period of weeks.

Step 7 (imported route only): low volumes of meat and other food products of animal origin are imported from China (see Appendix 1); data for other affected areas is currently being incorporated. Data using historical trade volumes may not be representative of current trade patterns which vary between years or the full extent of imported foods (e.g. composite foods).

Overall, the combined likelihood of human exposure to the virus from infected animals (livestock or wildlife) from which meat or products of animal origin are derived is considered to be **Negligible**, with **High** uncertainty.

Risk pathway B: Cross-contaminated foodstuffs

Summarised in Table 2.

Large quantities of fruit and vegetables are imported to the UK from locations worldwide and in many cases with minimal processing. This risk pathway B estimates the probability of consumption of cross-contaminated foods and therefore must consider both for products of animal origin (POAO) and foods not of animal origin (FNAO).

This pathway consists of steps 3,4,5 for domestic food production and steps 3,4,5,6,7 for imported foods.

Step 3: The prevalence of infection in people involved in food harvesting, preparation and processing in the UK is currently considered to be **Very Low**; the prevalence of infection in those people involved in food production in other areas of the world is currently considered to be **Very Low**.

Step 4: On the assumption that good food hygiene practices are adhered to, the probability of cross contamination in either domestic or international production is **Negligible**. However, if good food hygiene practice is not followed the risk would be **Negligible** to **Very Low**.

Step 5: Some food processing methods would reduce the viral titre; however, due to large range of products available both through international import and domestic production, it is not possible to state a generalised probability for all products. Heating to 56^{o}C for 30 minutes is likely to inactivate any virus present in food therefore processes such as canning and UHT should be sufficient to inactivate the virus; heating to temperatures above 65^{o}C for shorter periods is likely to significantly reduce the infectivity of any virus present, although with greater uncertainty.

Step 6 (imported only): Virus present in products stored or transported under chilled or frozen conditions may survive for a period of weeks, and this was therefore considered unlikely to significantly alter the likelihood of exposure via such products.

Step 7 (imported only): the overall volume of food and FCM and food packaging imported into the UK is high, but will vary significantly by region of origin.

Overall the likelihood of exposure to SARS-CoV-2 via cross contamination from food products produced both domestically and internationally (imports) is **Negligible** to **Very Low**. Although the likelihood in some steps with pathway B is considered Negligible, due to the high volumes of food and FCM and food packaging produced both domestically and internationally a conservative estimate of **Negligible** to **Very Low** is assigned. Imports

defined in section B exclude illegal imports.

Potential for infection via ingesting virus

Food has not currently been identified as a source of infection and the genome of SARS-CoV-2 suggests that it is most closely related to SARS-CoV, for which foodborne transmission was also not implicated in any cases of infection. However, this route cannot be ruled out and we therefore make the conservative assumption that such transmission is possible (**uncertainty**). SARS-CoV-2 requires the presence of the Angiotensin-converting enzyme 2 (ACE2) receptor to infect a cell, which is present in various human tissues including oral and nasal mucosa, nasopharynx, stomach, small intestine, and colon (Hamming et al. 2004). As already stated, at body temperature the virus is likely to be inactivated rapidly at the pH occurring in large parts of the digestive system (Darnell et al. 2004) and therefore infection via the oral mucosa may present the most credible route of infection during ingestion of contaminated foodstuffs. Certain medications may theoretically affect this potential for infection; for example, individuals undergoing treatment involving proton pump inhibitor medication are likely to have reduced stomach acidity with potential consequences for viral inactivation during digestion.

Hazard Characterisation

Illness caused by coronavirus species vary and range from cold like symptoms to more severe illness in humans including gastroenteritis and respiratory tract diseases. SARS-CoV-2 has been associated with cases of viral pneumonia and respiratory tract disease (WHO 2020, Gov.uk 10th January 2020).

An analysis of the clinical presentation of 41 patients (median age of 49) with lab-confirmed COVID-19 in China published online on 24th January 2020 (Huang et al. 2020) suggests that common symptoms at onset of illness are fever (98%), cough (76%) and myalgia/fatigue (44%); less common were sputum production (28%), headache (8%), coughing blood (5%), and diarrhoea (3%). Laboured breathing developed in 55% of patients after a median time from onset of 8 days. 63% of patients had lymphopenia and all 41 patients had pneumonia with abnormal findings on chest CT.

Current evidence suggests that a high proportion of patients developing severe clinical disease had pre-existing health conditions, and this group is likely to represent most of the individuals at risk of severe disease.

Overall risk

Table 2. Summary of probabilities defined below.

Section	Question	Probability
1	Consumer exposure via food products such as eggs and meat from infected avian hosts	**Negligible**
	Consumer exposure via fish and seafood	**Negligible**
	Consumer exposure via other species (including mammals)	**Negligible** to **Very Low**
2	Consumer exposure via the prevalence of virus within populations of susceptible animals, and the distribution and titre of the virus in edible products obtained from those infected	**Negligible**
3	Consumer exposure via the prevalence of infection in human handlers producing commercial food (UK or in importing countries)	**Very Low**
4	Consumer exposure via the frequency of close contact of infected food handlers and the degree to which hygienic food preparation methods mitigate this exposure	**Negligible** to **Very Low**
5	Reduction in viral titre due to processing	Not assessed*
6	Proportion of infectious virus surviving transport to the UK (imported foods only)	Not assessed*
7	Volume of product imported from affected countries to the UK	Not assessed*
Overall probability	Pathway A (1,2,5,6,7)	**Negligible**
	Pathway B (3,4,5,6,7)	**Very Low**

*assumed not to reduce the risk as a worst case assumption

Our risk assessment below is formatted according to the extended two-dimensional representation of risk recommended by ACMSF in 2019.

We consider that the probability of exposure of UK consumers to SARS-CoV-2 via food produced in the UK is **Negligible to Very Low** (between “so rare that it does not merit to be considered” and “very rare but cannot be excluded”). The uncertainty associated with this estimate is **High** as there are still limited data relating specifically to SARS-CoV-2.

The worldwide case fatality rate for COVID-19 appears to be around 4% based on current reports, meaning the severity of detriment is considered **High** (Severe illness: causing life-threatening or substantial sequelae or illness of long duration), although as noted above severe disease has so far mostly occurred in individuals with pre-existing health conditions. Uncertainty relating to severity of detriment is **High** as data remain sparse.

We note that the genome of SARS-CoV-2 suggests that it is most closely related to SARS-CoV-1, for which foodborne transmission was not strongly associated in any cases of infection.

This is a rapidly moving outbreak and important uncertainties remain, specifically:

- The prevalence of the SARS-CoV-2 virus in humans.
- The proportion of any susceptible animals that are infected;
- Which animal species are capable of being infected with SARS-CoV-2;
- The titre and survival of any SARS-CoV-2 in edible fractions of products from infected animals;
- Whether food products (meat and blood products, milk and eggs) of infected animals are being illegally imported into the UK, and relevant volumes;
- The role of workers in the food industry particularly infected food handlers including asymptomatic ones in any transmission of SARS-CoV-2;
- The heat inactivation time and temperature combination to inactivate SARS-CoV-2 in foodstuffs;
- The survival of SARS-CoV-2 in water or waste-water;
- The potential for fresh produce from other endemic countries to be contaminated and volumes imported;

Limitations of this assessment

This risk assessment does **not** currently consider:

- The risk associated with illegal importation activities. This is due to the lack of data on volumes of product illegally entering the UK as well as their processing and transportation.
- The occupational risk to food preparers or those frequently exposed to products of animal origin, for example slaughterhouse workers.
- Implications for integrity of the food chain, including reduced availability of food handlers, packers or distributors if they themselves become ill or reduced availability of approved disinfectants etc for cleaning of food manufacturing equipment and food preparation areas due to shortages.

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Appendix 1

Summary of published studies on coronavirus survival on surfaces

Surface	Virus	Time	Conditions	Reference
PVC	HCoV 229E	5 days	21°C 30-40% Relative Humidity	Warnes et al 2015
PTFE (Teflon)		5 days		
Ceramic		5 days		
Glass		5 days		
Rubber (silicon)		3 days		
Stainless steel		5 days		
Brass (>70%Copper)		<40mins		
Nickel		<120mins		
Plastic plate	SARS-CoV	5 days	22-25°C 40-50% Relative Humidity	Chan et al 2011
Polystyrene plate	HCoV 229E	72 hours	21-25°C	Rabenau et al 2005
	SARS-CoV	9 days		
Paper	SARS-CoV	24 hours*	Room Temperature	Lai et al 2005
Plastic gown		2 days*		
Cotton gown		24 hours*		
Metal	SARS-CoV	5 days	Room Temperature	Duan et al 2003
Wood		4 days		
Paper		4-5 days		
Glass		4 days		
Copper	SARS-CoV-2	4 hours	21-23°C 40% Relative Humidity	Van Doremalen et al 2020
Cardboard		24 hours		
Stainless steel		48 hours		
Plastic		72 hours		

*Times varied by viral titre, these are the maximum survival times based on the highest initial viral titre.

Survival time is defined as the time after which the viral titre dropped below the detectable level (detectable level was variable depending on the experiment). For less precise end times this was due to the viral titre reaching the required log fold reduction before that time point was measured.